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ABSTRACTS

NATIONAL OILSEEDS CONFERENCE

EDIBLE OIL SECURITY FOR ATMANIRBHAR BHARAT

6-8 February, 2026

ICAR-Indian Agricultural Research Institute, New Delhi



ORGANIZED BY

Society for Rapeseed-Mustard Research

Bharatpur, Rajasthan

IN COLLABORATION WITH

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Hyderabad

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CONTENT

Title and Author(s)	Page
Theme I : Research for Resilient Crop Breeding	**[1-85]**
Induction and genetic confirmation of a glossy leaf mutant in *Brassica rapa* (Pant sweta) via combined mutagenesis *Madhubala Kurmanchali and Usha Pant*	1
Evaluation of early maturing advanced breeding lines of Indian mustard (*Brassica junc*ea L. Czern & Coss) for heat stress tolerance *Bhagirath Ram, RS Jat, Prashant Yadav, MS Sujith Kumar, Reema Rani, HK Sharma, Arun Kumar, LK Meena, Vinod Kumar, BL Meena and VV Singh*	1
Developments in Indian mustard for salinity tolerance *Vijayata Singh and Jogendra Singh*	2
Identification of QTLs conferring aluminium toxicity tolerance in *Brassica carinata* derived *Brassica juncea* introgression lines *Shrusti Goud, Omkar Maharudra Limbalkar[1], Kanaka KK*	3
Effect of female-to-male planting ratios on seed yield in ogura CMS-based hybrid seed production of Indian mustard *Neeraj Kumar, Ram Avtar, Nisha Kumari, Rakesh Punia, Uma Kansal, Dalip Kumar, Mahavir Bishnoi and Rajbir Singh Khedwal*	4
Population structure and cluster analysis of Indian mustard genotypes *Mahavir, Ram Avtar, Rajbir Singh Khedwal, Nisha Kumari, Neeraj Kumar, Dalip Kumar and Rakesh Punia*	4
Molecular genetic diversity of Indian mustard using SSR markers *Aakash, Ram Avtar, Rajbir Singh Khedwal, Nisha Kumari and Neeraj Kumar*	5
Genotypic variation in oil quality and nutraceutical traits in Ethiopian mustard (*Brassica carinata*) *MS Sujith Kumar, Ibandalin Mawlong, Reema Rani and VV Singh*	5
Line × Tester analysis for morphological and physiological traits in Indian mustard [*Brassica juncea* (L.) Czern and Coss.] *VV Singh, Balbeer, HK Sharma, Bhagirath Ram, I Mawlong and ML Meena*	6
Identification of functional DGAT2 variants for seed oil enhancement in *Brassica juncea* (L.) Czern. through an integrated multi-omic analysis *Akhil, Sandeep Kaur Dhaliwal, Simarjeet Kaur Sra, Sanjula Sharma, Javed Akhatar, SS Banga, Chhaya Atri*	6
Development and validation of a KASP marker for Ogura fertility restorer in *Brassica juncea* (L.) Czern. & Coss. and *Brassica napus* L. *Sandeep Kaur Dhaliwal, Chhaya Atri, Dhakshi Taneja, Surinder S Banga*	7
Evaluation of promising strains of Indian mustard for yield and attributing traits *AK Dehinwal, Atman Poonia and Ankit Kumar*	8
In-silico and expression analysis of an H-isoform oleosin gene in Indian mustard *Ibandalin Mawlong, MS Sujith Kumar, Reema Rani, HS Meena and VV Singh*	8
Development of STS and InDel based molecular markers for *Sinapis arvensis* L. *Harshdeep Kaur, Mehak Gupta, Tanisha Bansal, Karthick B, Sivakumar, Gurdeep Kaur and Gurpreet Kaur*	9
Genetic variability and multivariate analysis in Indian mustard [*Brassica juncea* (L.) Czerns & Coss] germplasm *ADSS Ajay Nikhil, Rakesh Choudhary, Anshuman Singh, Shubha Trivedi, Kshitij Gupta and Vijay Kumar Yadav*	10
Development of a white rust–resistant Indian mustard (*Brassica juncea* L. Czern & Coss.) strain DRMRIJ 12-44 *KH Singh, Guman Singh Anil Kulheri, HS Meena, BL Meena and VV Singh*	10
Phenotypic and genomic insights into phosphorus use efficiency and resilience in Indian mustard (*Brassica juncea* L. Czern & Coss) *Priyanka Upadhyaya, Mehak Gupta, Simarjeet Kaur Sra, Gurdeep Cheema, Virender K Sardana, Javed Akhatar and Gurpreet Kaur*	11

Title and Author(s)	Page
Pre-breeding for climate-ready trait introgression in Indian mustard [*Brassica juncea* (L.) Czern & Coss.] *Nitin Doda, Manohar Ram and Karan Sachdeva*	12
Multivariate diversity analysis for Sclerotinia stem rot in diverse genotype set of Indian mustard (*Brassica juncea* L.) *Shambhavi Kumari, Rajesh Kumar, Abhishek Kumar and Shilpa Bharti*	13
MTSI based selection of high yielding and stable genotypes in yellow sarson *Preeti Lohani, Kajal Mehra, Ayushi Singh, Garima Aggarwal, Aakriti Singh, Usha Pant and AS Jeena*	13
Genetic insights into yield improvement of Indian mustard [*Brassica juncea* (l.) czern & coss.] through association studies *Karan Sachdeva, PKP Meena, Manohar Ram and Sharmila Kumari*	14
Preliminary varietal screening of *Brassica* spp. against mustard aphid, *Lipaphis erysimi* (kalt.) *Jatin Kumar Singh and Mohammad Sarfraz Khan*	15
Oilseed crops in India: status, challenges, technological advances, and future prospects *Shivani Singh and Sharad Kumar Jaiswal*	16
Phenotypic and molecular characterization of diversity fixed foundation set for phosphorus use efficiency in Indian mustard (*Brassica juncea* L. Czern & Coss) *Priyanka Upadhyay, Mehak Gupta, Simarjeet Kaur Sra, Gurdeep Cheema, Virender K Sardan, Javed Akhatar and Gurpreet Kaur*	16
Harnessing early sowing as a selection strategy for developing heat and drought resilient Indian mustard genotype *Aakrit Singh, Ayushi Singh, Kajal Mehra and Usha Pant*	17
Molecular characterization of genetic diversity and marker efficiency in Indian mustard (*Brassica juncea*) using SSR markers *Ravindra Kumar Meena, Ram Avtar and Rakesh Kumar*	18
Identification of novel and stable sources of white rust resistance in Indian mustard through long-term evaluation under natural epiphytotic conditions at Wellington *J Nanjundan, S. Logesh Kumar, Basith A, G Rindhiya, M Ashtalakshmi, Navinder Saini, Sikha Dubey, J Radhamani and Naveen Singh*	18
In vitro evaluation of Indian mustard (*Brassica juncea*) germplasm for drought tolerance at seedling stage *Kadam Kiran and Rakesh Choudhary*	19
Study of heterosis and inbreeding depression for seed yield and its contributing characters in Indian mustard [*Brassica juncea* (L.) Czern & Coss.] *JR Patel, Dixita K Patel, AM Patel and HN Zala*	20
Generation mean analysis for seed yield and its components characters in Indian mustard [*Brassica juncea* (L.) Czern & Coss.] *JR Patel, Dixita K Patel and AM Patel*	21
Development of new plant type in *B. rapa* obtained through inter-specific hybridization between *B. tournefortii* and *B. rapa* *Arun Kumar, Bhagirath Ram, Anubhuti Sharma, Hariom Sharma, Prashant Yadav and VV Singh*	22
Identification of stable genomic regions and candidate genes governing seed weight and yield traits in Indian mustard (*Brassica juncea*) through multi-environment GWAS *Yashpal Taak, Manoj Kumar Patel, Divya Badoni, Sudhakar Reddy Basu, Sneha Adhikari, Navinder Saini and Devendra Kumar Yadava*	23
Influence of biochemical contents in rapeseed-mustard on infestation of melon thrips, *Thrips palmi* (Karny) *Pragati Dabral and MS Khan*	24
Characterization of marker assisted derivatives for low erucic acid and white rust resistance in Indian mustard [*B. juncea* (l.) Czern. and Coss.] *Jashandeep Singh, Snehdeep Kaur, Gurdeep Kaur, Mehak Gupta and Gurpreet Kaur*	24

Title and Author(s)	Page
Rapid and non-destructive assessment of seed vigour in rapeseed and mustard using Near-Infrared Spectroscopy *Ayushi Yadav, Sangita Yadav, Rakesh Bhardwaj, Rashmi Yadav, Ravish Choudhary, Anbalagan Anumantharaj, Sushma Mudlupura Kumar, Kamini Kaushal, Dinesh Choudhary, Yashpal Taak, Navinder Saini, Sneha Adikari and Shiv Kumar Yadav*	25
Deciphering the genetic architecture of seed yield in *Brassica napus* using multi-trait mixed models *Arshdeep Singh, Indu Rialch and Gurpreet Kaur*	26
Establishing LD_{50} of EMS for mutation-based improvement of Sclerotinia stem rot resistance in Indian mustard *Nitish Rattan Bhardwaj, Pawan Saini, HK Sharma, Archana N Rai and VV Singh*	27
Meta-transcriptomic insights into temporal effector deployment by *Sclerotinia sclerotiorum* during oil seed Brassica infection *N R Bhardwaj, NC Gupta, Kushveer, Pankaj Sharma, Neeraj Budhlakoti, DC Mishra, SB Lal, HK Sharma, Prashant Yadav and VV Singh*	27
Optimization of photoperiod and light spectrum for speed breeding in *Brassica species* *Trishul C and Rakesh Choudhary*	28
Genome-wide association mapping uncovers key candidate genes governing pod shatter resistance and pod length in allohexaploid Brassica *Sonam, Javed Akhatar, Simarjeet Kaur Sra, Dhakshi Taneja, Vivek Kumar and Chhaya Atri*	29
Study of genetic variability between BiPs and F_3 populations among three different L×T crosses of Indian Mustard *Ruchi Bishnoi and PKP Meena*	29
Associating genome structural variations with fertility and seed traits in Brassica allohexaploid radiation panel *Sonam, and Chhaya Atri*	30
Expression analyses of cuticular wax biosynthetic genes in *Brassica juncea* *Urvashi Khatiyan and Priya Panjabi*	30
Integrating speed breeding with genome editing for high oilseed productivity *Balpreet Singh, Prashant Yadav, Arun Kumar, Bhagirath Ram, Anubhuti Sharma, NR Bhardwaj, HK Sharma and VV Singh*	31
GWAS-enabled identification of genomic regions and candidate genes for seedling-stage salinity tolerance in *Brassica juncea* (L.) Czern & Coss *Deepali, Sharma S, Atri C, Mittal M, Akhatar J, Goyal A, Mavi MS and Thaman S*	32
Variability and correlation coefficient in taramira (*Eruca sativa* Mill) genotypes for yield and its contributing characters. *Nisha Sekhawat, Manohar Ram, Karan Sachdeva, Raju Yadav and Deepak Gupta*	33
Genome-wide insights into *CKX* genes driving productivity in *Brassica juncea* *Balaji Balamurugan, Mansi Singh, Mahesh Rao, Ganapati Mukari, Dwijesh C Mishra and Navin C Gupta*	34
Introgression of white rust resistance in quality mustard varieties through MAS *Sneha Adhikari, Soubhik Nag, Manoj Kumar Patel, Sudhakar Reddy Basu, Divya Badoni, Shruthi K, Ashish Gupta, Yashpal Taak, Navinder Saini and DK Yadava*	34
Evaluation of Indian mustard (*Brassica juncea* l.) germplasm for seed yield and attributing traits *Shivani Choudhary, HK Sharma, G Roopa Lavanya, RS Jat and Rekha Choudhary*	35
Identification and characterization of resistance gene analogs (RGAs) in *Diplotaxis erucoides* *Pardeep Beniwal, Mehak Gupta, Karthick Babu Sivakumar, Gurdeep Kaur and Gurpreet Kaur*	35
Harnessing artificial intelligence for genetic enhancement and productivity gains in oilseed crops *M K Tripathi, Riya Mishra, Sandeep Singh Tomar, Ravi Yadav, Swati Singh Tomar, Jagendra Singh and VV Singh*	36

Title and Author(s)	Page
Ideotype for high-density planting can aid in yield enhancement in Indian soybean (*Glycine max*, L.) *V Nataraj, Shivakumar M, Santosh Jaybhay, Raghavendra N, Giriraj Kumawat, Aalok Shiv, Priya Meghwal, Satish Kumar Nagar, Sanjay Gupta and KH Singh*	38
Targeted editing of soybean genes via CRISPR/Cas9: Toward improving soybean yield, oil quality, resistance to pests and pod shattering *Milind B. Ratanparkhe, Dipankar Barman, Shubham Lad, Manisha Patil, Harsha Shrivastava, Prabhat, Rakesh Yadav, Gautam Jamra, Giriraj Kumawat, Shivakumar M., Viraj Kamble, Lokesh Meena, Prince Choyal, Ajay Kumar Singh, Sanjay Gupta and K H Singh*	38
Harnessing genomics through QTL mapping and candidate gene discovery to improve seed viability in soybean (*Glycine max*.) *Manisha Saini, Akshay Talukdar, R Ambika Rajendran, SK Lal, BP Mallikarjun and Sudipta Basu[1]*	39
Multi-trait–based identification of elite soybean germplasm for terminal drought resilience in India *Gyanesh Kumar Satpute, Sanjay Gupta, Prince Choyal, Vangala Rajesh, Milind Ratnaparkhe, Giriraj Kumawat, Santosh Kataria, Monish Waghmare, Rakesh Kumar Verma and Sanjeev Kumar*	40
Development of food-grade soybean in India *Vineet Kumar and Anita Rani*	40
Assessment of genetic variability and yield-contributing traits in soybean through association studies *Sharmila Kumari, BL Meena and Karan Sachdeva*	41
CRISPR/Cas9-mediated genome editing for the development of long-juvenile soybean genotype *Trupti Tayalkar, Anita Rani and Anajana Jajoo*	42
Influence of photosynthetic traits and canopy light interception in soybean (*Glycine max* (L.) Merill) recombinant inbred lines *R Mishra, M K Tripathi MK Shrivastava and PK Amrate*	43
Exploiting genetic variability and yield components for enhancing soybean productivity in temperate agriecology of Kashmir *Ajaz A Lone, Audil Gul,Sanjay Gupta, SA Dar, ZA Dar, M Rashid, FA Bahar, T Ahmad and M A Bhat*	44
Differential photo-thermo response of soybean genotypes under contrasting seasonal conditions *B Spoorthi, Gk Naidu, SK Deshpande, UV Mummigatti[3], G Somanagouda, S Huilgol, R Channakeshava Prakash H T and H Banu*	44
Designing of guide RNAs for the development of low phytic acid soybean genotype through CRISPR-Cas9-Mediated genome editing *Nandini Kashyap, Anita Rani, Vineet Kumar and Tasneem Rangwala*	45
Screening, identification and evaluation of waterlogged tolerant soybean (*Glycine max* L. Merrill) genotypes *Majji Sai Likitha, H Nanita Devi, Th Renuka Devi, T Sunanda Devi Nilima Karam and L Sophia Devi*	46
Genetic evaluation and trait association analysis for yield enhancement in soybean (Glycine max L. Merrill) *Jagendra Singh, Yamini Gautam, Riya Mishra, Ravi Yadav, Sandeep Singh Tomar and MK Tripathi*	47
Role of photoinsensitivity in the adaptation of soybean (*Glycine max* (L.) Merr.) to Indian environments *Sanjay Gupta, Vangala Rajesh, Rachana Tripathi, Nisha Agrawal, Giriraj Kumawat, Vennampally Nataraj and Gyanesh K. Satpute*	47
Assessment of genetic divergence in mini core collection of peanut (*Arachis hypogaea* L.) *Rajanna B, Mahesh Hullur, Lokesh GY, Shivakumar K, Raghavendra BT, Jayanth Kulkarni, Yaswanth Patil and Nisarga KV*	49
Character association and genetic diversity in groundnut (*Arachis hypogaea* L.) *KC Pradhan, S Paspureddy, AK Sethy, D Swain, AC Dash and SK Swain*	49
Genetic stability analysis of climate resilient groundnut genotypes using AMMI model *Suma C Mogali, BN Motagi, Laxmi Patil and Bhavani*	50

Title and Author(s)	Page
Assessment of stable groundnut (*Archais hypogaea* L.) genotypes in central India zone for pod and kernel yield using AMMI and GGE biplot *RS Sikarwar, Preeti Pachauri, Kumar Sanu, Sachin Shukla and Sanjeev Sharma*	50
Assessment of genetic variability for selection of elite lines in groundnut (*Arachis hypogaea* L.) *Anuj Kumar Choudhary, Vinay Kumar, Shashi Prakash Vishwakarma and Manoj Kumar*	51
Genetics of quantitative traits among the inter-specific BC_1F_4 populations of groundnut (*Arachis hypogaea* L.) *A Mothilal*	51
Evaluation of promising and advanced groundnut genotypes for yield and yield associated traits under rainfed conditions *L Madhavilatha, R Narasimhulu, C Kiran Kumar Reddy and BV Bhaskar Reddy*	52
Phenotypic characterization of groundnut germplasm lines *Mohan Kumar NV, Harishbabu BN, Kumar Naik and Vijay S Dhanraddy*	53
Assessment of genetic diversity in Spanish bunch groundnut (*Arachis hypogaea* L.) via integrated morphological and molecular markers *Anjali Kachhadia, Bhavya Desai and KF Satashiya*	53
Assessment of divergence and genetic parameters governing yield and its attributing traits in groundnut (*Arachis hypogaea* L.) germplasm lines *Kumar Sanu, Vimlesh Shakya, RS Sikarwar, Sanjeev Sharma and MK Tripathi*	54
Screening of groundnut (*Arachis hypogaea* L.) genotypes for major foliar diseases under natural epiphytotic conditions *Radhajeyalakshmi R, Meena B, Latha P, Sudhalakshmi C, Arulprakash A, Thavaprakaash N Rajalingam GV*	55
Study of mutagenic effect of EMS and sodium azide in groundnut (*Arachis hypogaea* L) *Pramesh Kh, Nada Yaku, Pusparani Senjam and Th. Renuka Devi*	55
Studies on genetic variability and character association for yield, kernal iron and zinc content in groundnut genotypes (*Arachis hypogea* L.) *Anisa M Nimbal, Arfa Ameen, Malavika Mokashi, Nandini B and Vijaykumar AG*	56
Opportunities of groundnut (*Arachis hypogaea* L.) cultivation for crop diversification and income enhancement in Tripura through integrated nutrient management (INM) *Bijoya Bhattacharjee, Pradip Kumar Sarkar, Rubai Podder, Rubina Debbarma and BU Choudhury*	57
Stability and adaptability of castor genotypes for yield and its components across environments using AMMI and GGE Biplot models *K Sadaiah, G Eswara Reddy, K Parimala, A Saritha, S Vanisri, M Sreedhar, V Divya Rani, G Madhuri, N Nalini and L Krishna*	58
Evaluation of castor varieties with yield potential comparable to hybrids for Telangana agro-climatic conditions *G Eswara Reddy, K Sadaia, V Divya Rani, G Madhuri, M Sreedhar and L Krishna*	58
Deciphering genetic mechanisms and environmental modulation of sex expression in castor hybrid GCH-7 *AM Patel, JR Patel, YN Patel, TA Desai, PC Patel and HN Zala*	59
Effects of crop resistance on tritrophic interactions among castor genotypes, capsule borer (*Conogethes punctiferalis*), and its larval parasitoid (*Eriborus trochanteratus*) *P Duraimurugan, T Manjunatha, Jawahar Lal Jatothu and S Senthilvel*	60
Genetic improvement of monoecious castor (*Ricinus communis* L.) for enhanced seed yield and productivity *P Arutchenthil, S R Venkatachalam, P Veeramani, M Rajesh and S Jaya Prabhavathi*	61
Combining ability, heterosis and stability studies in linseed (*Linum usitatissimum* L.) *R K Mahawar, D S Meena, B K Patidar and B L Meena*	61
Development of wilt resistant and climate resilient linseed genotype DLV 22 *Suma Mogali, GK Naidu, Gurupad Ballol and Bhavani*	62
GNNIG-5 (Aarohi): A high yielding niger variety identified for tribal India *PK Jagtap, PM Mistry, HE Patil, HD Pushpa, Rajani Bisen and Anand Shrivastava*	63

Title and Author(s)	Page
Assessment of genetic variability and character association in niger genotypes through PCA and cluster analysis *DN Damse, HM Patil, JS Chaure and AV Kolage*	63
Estimation of genetic variability for quantitative traits in niger (*Guizotia abyssinica* L. f. Cass) genotypes *Aruna D Ahirwar, Rajani Bisen and AK Vishwakarma*	64
Evaluation of Indian and exotic niger cultivars suitable for high altitude and tribal zone in Andhra Pradesh *K Bayyapu Reddy, A Appala Swamy, Anand Viswakarma and M Srinivasa Rao*	65
Assessment of genetic variability, heritability, genetic advance and diversity in niger (*Guizotia abyssinica* L.) germplasm *Rajani Bisen, Pooja Patel, Vijay Kumar Katara, Rishikesh Tiwari, Vikrant Khare, Swati Saraswat and AK Vishwakarma*	66
Genetic variability, heritability and trait association for seed and petal yield in safflower (*Carthamus tinctorius* L.) across multi-environments *N Sathees, C Vanniarajan, A Yuvaraja, R Renuka and ML Mini*	67
Trait-based screening of sesame genotypes under drought and waterlogging stress *Ratnakumar Pasala, K T Ramya, A Anil Kumar, Divya Ambati, K Ramesh, K Alivelu, AL Rathnakumar and RK Mathur*	67
Epistatic control and gene-effect estimation for phenology, yield and oil content in sesame using joint-scaling and six-parameter models *Roshan Parihar, Rajeev Shrivastava, Nandan Mehta, Jeevan lal Salam, Dev Chand Salam and Yogesh Kosariya*	68
A high yielding, high oil content and bold seeded variety of sesame (*Sesamum indicum* L.) recommended for Gujarat state *JR Patel, GP Gangwar, AM Patel, MK Chandaragi, AL Jat, BK Patel and L D Parmar*	69
Agronomic traits governing yield enhancement for effective selection in sesame (*Sesamum indicum* L.) *D Bharathi, K Navya Jyothi, R Isha Pearl, J Vasavi, V Sumathi and AK Viswakarma*	70
Genetic variability and character association studies for yield and yield contributing traits in bold seeded sesame (*Sesamum indicum* L.) *Anisa M Nimbal, Jayprakash, Vanishree, Prabhavati N Rao, Anand Vishwakarma, Rajani Beisin, Malavika Mokashi, HM Lavanya and Kiran Kareekatti*	70
Genetic variability studies in sesame (*Sesamum indicum* L.) *S Ganapathy, S Suganthi, R Kanchanarani and V Ravichandran*	71
Stability analysis of sesame genotypes across multi-environments *Nitesh Panwar and Rajani Bisen*	72
Stability analysis for seed yield and yield contributing traits in sesame (*Sesamum indicum* L.) *SD Rajput and RP Mahjan*	72
Identification of climate-resilient parental lines in sunflower through genetic variability and fertility restoration analysis *SP Pole, MV Dhuppe, SB Mirkad and PK Meena*	73
Exploiting genetic variability, self-fertility and yield-related traits for climate resilient breeding in sunflower (*Helianthus annuus* L.) *MV Dhuppe, SP Pole, SB Mirkad and AK Singh*	74
Regression-based prediction of heterosis using genetic divergence among parental lines in sunflower *Vineeta Kaila and Yukta Sharma*	74
Comparative evaluation of interspecific crosses and hybrids in sunflower (*Helianthus annuus* L.) for yield and associated traits under moisture stress *Alka and Vineeta Kaila*	75
Identification of candidate powdery mildew susceptibility *MLO* genes in sunflower as targets for CRISPR/Cas-mediated disease resistance *Megha S Sogalad, Gudimetla Seetha Rama Sastry, Sri Varshitha Gurijala, Usha Kiran and V Dinesh Kumar*	76

Title and Author(s)	Page
Large scale diversity studies and development of core germplasm collection for effective improvement of sunflower in India *M Y Dudhe*	77
Development of a GMS-assisted recurrent selection strategy for population improvement in safflower *Yarabapani Rushwanth Reddy, J Dhananjaya, P Vinod, Kasanaboina Krishna and Palchamy Kadirvel*	78
Restructuring of plant types for enhanced productivity, oil content and nutritional quality in sesame (*Sesamum indicum* L.) *Tamina Begum, Tapash Dasgupta, Arna Das, Anand Vishwakarma and Rajani Bisen*	79
Strengthening edible oil ecosystem of Jharkhand *vis-à-vis*-Eastern India for boosting oleiferous *brassica* production: Stepping towards "Atmanirvar Bharat" *Arun Kumar, Rajni Kiran Lakra, Shourya Jha and Namrata Birua*	80
Air desiccation-mediated cryopreservation of oil palm embryos for long-term germplasm conservation *Rohini M R and G Somasundaram*	81
Development of a GMS-assisted recurrent selection strategy for population improvement in safflower *Yarabapani Rushwanth Reddy, J Dhananjaya, P Vinod, Kasanaboina Krishna and Palchamy Kadirvel*	82
Investigation of variance components among yield and other traits in biparental progenies of RH 725 x Urvashi of Indian mustard [*Brassica juncea* (L.) Czern. & Coss.] *Ruchi Bishnoi, Aditya Mohan Maharishi and PKP Meena*	82
Non-destructive electromagnetic spectroscopy for genetic purity assessment in groundnut *Manzoor H Dar, Showkat A Waza, Amrita Pal, Anil Gaddameedi, Nelofar L A Mapnoo, Vijay L Sahani, Balla A Jonan and Amtul M Zikra*	83
Targeted editing of fatty acid pathways and yield in oilseeds using CRISPR/Cas system *Sachin Kumari, Dr. P.B. Singh and Abhijeet Purohit*	84
Niger (*Guizotia abyssinica* L.f.) as a viable *Rabi* oilseed for enhancing land use efficiency in Rice-Based Double Cropping in the North Bank Plain Zone of Assam *Yater Das, Prabal Saikia, Dhiren Chowdhury and Kishore Kumar Sharma*	84
Theme II : Strategies to Mitigate Biotic and Abiotic Stress in the Face of Climate Change	**[86-167]**
Abiotic stress management for optimum production of oilseed Brassica *Pushp Sharma*	86
Assessment of genetic diversity and antimycotic potential of Trichoderma isolates collected from mustard rhizosphere in Bundelkhand region of U.P. *Y Vinay Kumar, Kajol Kumari and Shubha Trivedi*	87
Plant-based novel biostimulants enhance drought tolerance, physiological resilience and yield of mustard under rainfed conditions *Narenjoy Tripura and Kavita*	87
Characterization of prevailing Alternaria species and management practices for leaf blight in mustard *Suman, Shivam and Shubha Trivedi*	88
Improving physiological performance of Indian mustard genotype RH 725 under terminal heat stress using orthosilicic acid *Kiran Kiran, Neeraj Kumar, Vinod Goyal, Anita Kumari and Ramavatar*	89
Influence of exogenously applied nanoparticles on Indian mustard (*Brassica juncea* L.) under terminal heat stress *Ashika Ansari and Vinod Goyal*	90
Physiological responses of mustard (*Brassica spp.*) germplasm to multiple abiotic stresses *CL Khatik, SK Attar, J Lal, SC Mahala, KC Verma, M Khan and D Tripathi*	90
Latent attributes of toria variety TS-67 under delayed sowing: Implications for yield and profitability during cold and dry winter in Assam *B Kalita, RN Borkakati, R Chakrabarty, PK Bordoloi, PK Deb Choudhury, HK Borah, and DC Nath*	91
Deciphering host-pathogen interactions in *Brassica juncea-Albugo candida* host-pathosystem *Nitish Rattan Bhardwaj, Prashant Yadav, Hariom Kumar Sharma, PD Meena and VV Singh*	92

Title and Author(s)	Page
Evaluation of biocontrol agents for the management of fungal diseases in rapeseed–mustard (*Brassica spp.*) *Ran Singh and Ravi Yadav*	92
Mitigation of drought stress Indian mustard (*Brassica juncea L.*) through foliar application of plant growth regulating substances across agro-climatic zones *LK Meena, Pushp Sharma, Vinod Goyal, Kavita and VV Singh*	93
Effect of Broomrape (*Orobanche sp.*) on yield and contributing traits in taramira (*Eruca sativa*) *Manohar Ram, Karan Sachdeva, Nitin Doda, BL Naga and SL Yadav*	94
Transcriptomic dissection of cross kingdom crosstalk in *Brassica juncea-Sclerotinia sclerotiorum* pathosystem *Kusum Rana, Chhaya Atri, Ankit Arora, Ashish Kumar Gupta and Surinder S Banga*	94
Epidemiology of white rust-downy mildew disease complex of rapeseed-mustard in relation to sowing time and weather conditions *Shweta, AK Tewari*	95
Characterization of Trichoderma isolates against *Sclerotinia sclerotiorum* causing stem rot of mustard *Dhanush Koti RM, AK Tewari and Pooja Bisht*	96
Impact of low temperature stress on yield of taramira (*Eruca sativa*) *Raju Yadav, Manohar Ram, Karan Sachdeva and Nisha Sekhawat*	97
Next-generation Brassica breeding: Integrating physiological acceleration with predictive analytics to combat biotic stress and enhance nutrition *Prashant Yadav, Arun Kumar, Bhagirath Ram, NR Bhardwaj, HK Sharma, Anubhuti Sharma and VV Singh*	97
Novel Cas protein variants and their functional significance in precision genome editing for sustainable crop improvement *Pavan Kumar, Neeraj Gurjar, Akshay Saini, Joshi Singh, Balpreet Singh, Prashant Yadav, Bhagirath Ram and VV Singh*	98
Plant growth-promoting bacteria (PGPB) mediated induced resistance against Alternaria blight in *Brassica juncea*: Unravelling biochemical defence signatures across genotypes *Ekumjot Kaur, Sanjula Sharma, Chhaya Atri, Prabhjodh Singh Sandhu and Pratibha Vyas*	99
Designing climate smart oilseed crops integrating genome editing and bioinformatics with special reference to Brassica *Namrata Birua and Arun Kumar*	100
Screening of Brassica genotypes against *Erysiphe cruciferarum* causing powdery mildew in Rapeseed-Mustard growing areas of Northern Madhya Pradesh under natural conditions *Ravi Yadav, Swati Singh Tomar, Jagendra Singh, SS Tomar, MK Tripathi and PD Meena*	100
Response of macro nutrient and bio-fertilizers in enhancing rapeseed mustard (*Brassica juncea* L.) productivity and soil health *SS Tomar, MK Tripathi, Ravi Yadav, Swati Singh Tomar and RS Jat*	101
Management of mustard aphid through crop diversification *RN Borkakati, PK Bordoloi, B Kalita, R Chakrabarty, HK Borah and AK Sharma*	102
Effect of abiotic stress on Alternaria blight disease of rapeseed (*Brassica rapa* var. toria) *Ranjana Chakrabarty, H Kalita, RN Borkakati, B Kalita, PK Bordoloi and HK Borah*	103
Biointensive integrated pest management to manage biotic stresses in Indian mustard (*Brassica juncea* L.) *MS Yadav, Rekha Balodi, JC Gupta, Raghavendra KV, SK Singh, Neelam Mehta and Raman Thangavelu*	103
Phytochemical-mediated aphid resistance in different Brassica crops at Hisar, Haryana *Dalip Kumar, Rakesh Punia, Ram Avtar, Neeraj Malik, Nisha Kumari, Uma Devi, Rajbir Singh Khedwal, Mahavir Bishnoi*	104
Smart delivery of herbicide for safe and effective control of Egyptian broomrape parasitizing Indian mustard *RS Jat, A Agrawal, S Kala, Nusrat, RL Choudhary, HV Singh, Shivani Choudhary, Prabhu Lal Kantwa, Rekha Choudhary, J Kumar and VV Singh*	104

Title and Author(s)	Page
Traits association among morpho-physiological attributes of Indian mustard [*Brassica juncea* (L.)] advanced breeding lines under rainfed and irrigated conditions *Kartikeya Srivastava, Darshan GP, B Arun, Govind Tiwari*	105
From plant resistance to climate-resilinent pest management : Leveraging defence mechanisms in Brassica against mustard aphid, *Lipaphis erysimi* (Kaltenbach) *Sarwan Kumar, Harvinder Singh Tiwana and Sanjula Sharma*	106
Nanoparticle-based mitigation strategies for terminal heat stress in Indian mustard *Ashika Ansari, Banita Gawaria, P Bhasker, Anita Kumari, Ramavatar and Vinod Goyal*	107
Quantitative and qualitative assessment of insect pest complex of mustard and their natural enemies *Amar Chand, Yonika Saini, Devki Nandan, AK Sharma, Vinod Kumar, RK Yogi and VV Singh*	107
Physiological regulation by mepiquat chloride improves productivity of taramira under water-limited conditions *Ashish Kulhery, MK Sharma and Manohar Ram*	108
Population dynamics and varietal preference of major insect pests of mustard [(*Brassica juncea*) (L.) Czern and Coss] *Amar Chand*	109
Aphid resistance in Indian mustard: Bridging molecular insights and field validation-A review *Sujaya Dewanjee and Hritik Sen*	109
Biostimulant-driven physiological optimization of Indian mustard under late sown conditions *Banita Gawaria, KD Sharma, P Bhasker, Ramavatar and Vinod Goyal*	110
Analysis of physiological, biochemical, and genetic responses of Indian mustard (*Brassica juncea* (L.) Czern. & Coss.) genotypes under moisture deficit stress *Govind Tiwari, K Srivastava, Shivangi Saha, RK Verma, Sahil S and Sanchika Snehi*	111
Drought-resilient mustard production: The interplay of conservation agriculture, sap, and plant bioregulators *RL Choudhary, RS Jat, HV Singh, ML Dotaniya, VD Meena, MK Meena and VV Singh*	111
Assessment of new molecule fungicides for the management of *Alternaria spp.* isolate under in-vitro conditions *Devchand Salam, Roshan Parihar, Niranjan Khare, Prahlad Singh Netam and Suresh Kumar Sahu*	112
Identification of heat tolerant genotypes of Indian mustard (*Brassica juncea*) for abiotic stress resilience *Sandeep Kamdi, Sarad Bhure, Diksha Tajne, Prathamesh Kalpande, PM Gadge, Achal Sharnagat, Arjun Verma, Mohit Peshkar, Somnath Dahiphale and Sakshi Sonowane*	113
Genetic analysis of inheritance pattern of Alternaria blight resistance in Indian mustard (*Brassica juncea* L.) *Manidipa Pan, Ayushi Singh, Kajal Mehra, Aakriti Singh, AS Jeena and Usha Pant*	113
Emerging crop protection tools for insect pest management in mustard *Yougendra Singh, Akhter Hussain, Suman*	114
Fertilizer and micronutrient strategies for managing aphid stress in mustard under climate variability *Abhinav, MS Khan and M S Negi*	114
Micro and secondry nutrient fortified farm yard manure to bio-stimulate Indian mustard yield and nutrient availability *MK Meena, ML Dotaniya, MD Meena, RS Jat, VD Meena, RL Choudhry, Har Vir Singh and VV Singh*	115
Comparative analysis of heat-stress responses across *Brassica* species *Simarjeet Kaur Sra, Chhaya Atri and Dhakshi Taneja*	116
Characterization of intergeneric derivatives developed from the hybridization between *Brassica napus* and *Diplotaxis erucoides* *Bhalodiya Vivek Dhirajlal, Mehak Gupta, Pardeep Beniwal, Gurdeep Kaur and Gurpreet Kaur*	117
Understanding yellow mosaic virus resistance in soybean *Sakshi Mehta, Milind Ratnaparkhe and Archana Kumari*	118

Title and Author(s)	Page
Application of RenSeq approach for accelerated discovery of disease resistance gene for prevalent diseases of soybean in India *Aalok Shiv, Vennampally Nataraj, Giriraj Kumawat, Sanjeev Kumar, Vangala Rajesh, Hemant Maheshwari, Sarika Sahu, Pawan Kumar Amrate, Manisha Saini, Munmi Borah, Milind B. Ratnaparkhe, Sanjay Gupta and KH Singh*	118
Regeneration plasticity in Indian soybean cultivars *Viraj G Kamble, Ratnaparakhe Milind, Giriraj Kumavat, Satpute GK, Veerta Solanki, Vangala Rajesh, Sathe PS, V Nataraj, Vishal Thorat, Sanjeev Kumar, Lokesh kumar Meena, and Gupta S*	119
Harnessing multivariate trait architecture to identify charcoal rot resilient soybean genotypes under climate change *Avijit Roy, Mukesh Raj, Deeksha Joshi, Pawan Amrate, Sunil Kumar Singh, Parminder Pandit and SK Lal*	120
Agro-climatic dynamics and their impact on soybean yield prediction using deep learning *Ram Manohar Patel, Kamal Bunkar and Chhaya Arya*	121
Antixenosis and antibiosis studies on some selected soybean genotypes against *Spodoptera litura* *Lokesh Kumar Meena, V. Rajesh and Mahaveer Prasad Sharma*	121
Morphological, cultural and molecular variability in *Rhizoctonia solani* isolates causing aerial blight (RAB) of soybean *Sanjeev Kumar, Raksha Vishwakarma, Laxman Singh Rajput, H.S. Maheshwari, M.B. Ratnaparkhe, Palak Solanki, Pawan Saini, Jyoti Kag, Rajni Singh Sasode, K.P. Singh, Shilpi Rawat, Pezangulie Chakruno, Kunwar Harendra Singh*	122
Influence of sulfur-oxidizing bacteria and siderophore-producing bacteria in the soybean-mustard cropping system recovered from extreme habitats *Hemant Singh Maheshwari, Yashraj Singh Devda, Deepika Parmar, Aakash Gour, Akanksha Patel, Sanjeev Kumar, Laxman Singh Rajput, Palak Solanki, Raghvendra Nargund, Aalok Shiv, Mahaveer Prasad Sharma and Kunwar Harendra Singh*	123
A hybrid modified ConvFormer and TransFormer architecture with ASPP integration for soybean leaf disease detection and multi-class classification *Sujata Gudge, Aruna Tiwari, Milind Ratnaparkhe and Annamshetti Sumanth*	123
CRISPR-Cas9 knockout of *GmERA1* isoforms to enhance drought tolerance in soybean *Ajay Kumar Singh, Sushma Awaji, Pawan Mainkar, Sanket Balpande, Gopika Mote, Snehal Yermalwar, Vaishnavi Gaikwad and Rutuja Patil*	124
In-vitro evaluation of fungicides against *Rhizoctonia solani* causing aerial blight of soybean *Palak Solanki, Sanjeev Kumar, Laxman Singh Rajput, H.S. Maheshwari, M.B. Ratnaparkhe, Pawan Saini, Jyoti Kag, Raksha Vishwakarma, Rajni Singh Sasode, K.P. Singh, Shilpi Rawat, Pezangulie Chakruno and Kunwar Harendra Singh*	125
Evaluation of herbicide and microbial strains on productivity and economics of soybean *G. Somanagouda, Shalini N Huilgol, GK Naidu, Harshiya Banu, Roopa U and Nagesh Rathod*	125
Efficacy of herbicides with PGPR on growth, yield and weed dynamics of soybean (*Glycine max* L. Merrill) *T Sunanda Devi, H Nanita Devi, L Sophia Devi and Nilima Karam*	126
Synergistic effects of moisture-stress-tolerant endophytic bacteria and AM fungi on growth, nodulation, and yield of soybean under field conditions. *Purva Dubey, Dipanti Chourasiya, Tapas Chowdhury and Mahaveer P Sharma*	127
Antixenotic effect of soybean on growth and development of tobacco caterpillar (*Spodoptera litura* Fab.) under Manipur conditions *Kumar Akash Dee, Nilima Karam, Jeti Konsam, Ksh Sumita and Rani Asheibam*	128
AI-enabled novel method for detection of groundnut foliar diseases using CNN *Gurupada Balol , Shail Bala, A KKanade, MP Potdar, SV Hugar, Suma Mogali, SI Harlapur, KN Vijaykumar and B Veekshita*	129

Title and Author(s)	Page
Adaptive groundnut management using agromet advisory services to enhance climate resilience under erratic monsoon regimes *Kumar Naik AH and Amith G*	130
Host plant resistance for sustainable management of multiple foliar fungal diseases in groundnut *Gurupada Balol , Suma Mogali, SV Hugar, BS Yenagi, Nirupadi Angadi, B Veekshita and MSL Rao*	131
Management of insect pests through entomopathogenic fungus in Kharif groundnut *Shiddalingappa V Hugar, Rohini Sugandhi, Gurupad Balol, BS Yenagi and Nataraja V Maheshala*	131
Extent of adoption of integrated white grub management practices in groundnut: evidence from Saurashtra region of Gujarat *Adupa Shanmuka and Nataraj Maheshala*	132
Effect of zinc on productivity and quality of groundnut (*Arachis hypogaea* L.) in arid region of Rajasthan *SP Singh, Rahul Yadav and BDS Nathawat*	133
Unraveling seasonal insect pest dynamics in groundnut: evidence from fifteen years of monitoring data *Shreevani GN, Rajanna B, Timmanna, Raghavendra BT, Poornima Veena T, Mallareddy and Bharathi S*	134
Spodoptera and leaf miner in groundnut: Measuring the yield impact in hotspot regions *Shreevani GN, Rajanna B, Raghavendra BT, Timmanna, Poornima, Veena T, Mallareddy and Bharathi S*	134
Influence of pre and post emergence herbicides on the productivity of groundnut (*Arachis hypogaea* L.) *Baskaran R*	135
Influence of pre and post emergence herbicides on weed control, growth, yield and economics of Kharif groundnut *P Maheswara Reddy, A Srividhya, B Rupesh Kumar Reddy and S Tirumala Reddy*	136
Prevalence of soil-borne diseases in groundnut in Tamil Nadu and their management *Ravichandran V and Paramasivan M*	136
Bio-efficacy of sequential herbicide application on weed dynamics and productivity of groundnut in Saurashtra region of Gujarat *CS Praharaj, Aaradhana Chilwal, Kiran Reddy, Nitin Gudadhe and Hardi Kansagara*	137
Influence of weather on the occurrence of foliar diseases of groundnut *BV Bhaskara Reddy and K Vemana*	138
Estimation of yield losses and management of late leaf spot in groundnut (*Arachis hypogaea* L.) using Tebuconazole *AC Game, DV Dahat and SB Gawade*	139
Impact of toxigenic *Aspergillus* flavus on the nutritional composition of groundnut kernels *Varshitha S, Raghavendra BT, Ajithkumar K, Pramesh D, Rajanna B, Shreevani GN and Prajwal Piraddi*	139
Herbicide-based weed management in Kharif groundnut (*Arachis hypogaea* L.) *Gurinder Singh, Tarundeep Kaur and Simerjeet Kaur*	140
Ready-mix herbicidal application: a new approach to weed management in Kharif groundnut (*Arachis hypogaea* L.) *Rajib Kundu, Tarun Sarkar, Golam Moinuddin, Arindam Sarkar and Sunil Gunri*	141
Pest surveillance and contemporary status of the major insect pests in groundnut *A Geetha*	142
Integrated weed management strategies for productivity and profitability of Kharif groundnut (*Arachis hypogaea* L.) *D Anitha, D Sampath Kumar, N Ramesh Naik and BV Bhaskar Reddy*	142
Nano-biotechnology-driven strategies for groundnut crop improvement *Durgesh Kumar Tripathi, Rukam Singh Tomar and Sandip Kumar Bera*	143

Title and Author(s)	Page
Identification of stable sources of late leaf spot resistance in groundnut through multi-generation cross evaluation *Sanjeev Sharma, RS Sikarwar, MK Tripathi, Kumar Sanu, Riya Mishra and Sachin Shukla*	144
Exploiting endophytic Bacillus strains GEB 1 and GEB 6 with antagonistic activity and antifungal metabolites against late leaf spot and rust in groundnut *Harish S, Saravanakumari K and Saranya PS*	144
Groundnut (*Arachis hypogaea* L.) genotypes *S Divya Sree, B Rupesh Kumar Reddy, M Shanthi Priya and AR Nirmal Kumar*	145
Screening of groundnut genotype for cold and heat tolerance *Narendra Kumar, Ajay BC, Raja Ram Choudhary, RS Tomar and SK Bera*	146
Evaluation of alternate hosts of groundnut bruchid, *Caryedon serratus* for their host suitability *Nataraja Maheshala, Harish Gangaiah, Shreya Acharya and Urja Bhimani*	147
Identification of differentially expressed genes (DEGs) responsible for defence against *Puccinia arachidis* and *Cercospora arachidicola* in groundnut (*Arachis hypogaea*) *Rukam S Tomar, Durgesh Kumar Tirpathi and Sandip Kumar Bera*	148
Integrated fungicidal approaches for the management of wilt (*Fusarium oxysporum* f.sp. *ricini*) in castor *(Ricinus communis* L.) *V Divya Rani, G Madhuri, G Eswara Reddy, K Sadaiah, N Nalini, M Santa Lakshmi Prasad, M Sreedhar and L Krishna*	149
Field evaluation of newer insecticides for the management of leafhopper (*Empoasca flavescens*) in castor (*Ricinus communis* L.) *G Madhuri, V Divya Rani, K Sadaiah, G Eswara Reddy, N Nalini, P Duraimurugan, M Sreedhar and L Krishna*	150
Bio-efficacy of endophytes against soil borne diseases in castor *M Santha Lakshmi Prasad, M Avanija, K Sankari Meena and V Ramya*	150
Seasonal incidence of insect pests and its natural enemies of castor in Salem district of Tamil Nadu *S Jaya Prabhavathi, P Duraimurugan, M Senthil Kumar, P Veeramani, S Elangavi, P Arutchenthil and S R Venkatachalam*	152
Niger diseases and their management strategies *K N Gupta and AK Vishwakarma*	153
Sesame diseases and their management strategies *K N Gupta and AK Vishwakarma*	153
Bacterial diversity in healthy and phyllody infected sesame plants revealed through metagenomics and culturomics *K Sakthivel and Aundy Kumar*	154
Unraveling sesame resistance to *Antigastra catalaunalis* Duponchel (Lepidoptera: Crambidae): insights from morphological, physiological, and biochemical traits *T Boopathi, N Swetha, Praduman Yadav, B S L Ramani, A Tejaswini, AL Rathnakumar, K T Ramya, N Anusha and R K Mathur*	154
Assessment of sesame genotypes for *Macrophomina* stem and root rot resistance and eco-friendly management practices *Neelam Geat, Shalini Pandey, KN Gupta and AK Vishwakarma*	155
Impact of meteorology variable on the incidence of sesame insect pests in Bundelkhand region of Madhya Pradesh *Shobharam Thakur and Shiv Ratan*	156
Integrated management of major diseases of sesame *N Sumalatha, N Balram, D Padmaja, N Sandhya Kishore and G Ishwarya*	157
Influence of weather parameters and management strategies for phytophthora blight in sesame caused by *Phytophthora parasitica* var. *sesame* *Naveen Kumar Dhakad, KN Gupta, AK Vishwakarma and Aruna*	157
Climate-resilient management of powdery mildew in sesame through ready-mix fungicide strategies under changing climatic conditions *Chiragkumar M Bhaliya and KK Kanzaria*	158
Combined application of *Trichoderma asperellum* and AM fungi reduces root rot disease incidence	

Title and Author(s)	Page
(*Macrophomina phaseolina*) in sesame *A Sangeetha, A Mahalingam, G Gayathry and R Baskaran*	159
Plant growth regulator mediated crop growth responses, physiological efficiency and seed yield of sesame *Nainee Dehariya, AK Vishwakarma, Subrata Sharma, Gyanendra Tiwari, Rohit Kumawat, Ram Kumar Patel, Priya Chourasiya, Sandeep Bamaniya and Neha Sen*	159
Survey, epidemiology, physiology for sesame phyllody and its ecofriendly management *M Paramasivan, V Ravichandran, P Indiragandhi, C Harisudan, A Mahalingam, K N Gupta, Anand Viswakarma and R Baskaran*	160
Exploring novel chitosan based nano particles for antimicrobial activity against *Macrophomina phaseolina* causing stem and root rot in sunflower *Suresh Madugula, Reshma Shaik and KSVP Chandrika*	161
Screening of sunflower genotypes for moisture stress tolerance based on physiological and biochemical parameters *Vikas V Kulkarni, Pannati Rasagna and T C Suma*	162
Cultural and morphological variation of *Alternaria species* causing leaf blight of sunflower *Poornima, Ashwini, Gururaj Sunkad, Sreedevi S Chavan, Vikas V Kulkarni and GN Shreevani*	162
Influence of weather parameters on charcoal rot incidence in sunflower *Muskan, Pankaj Sharma, Krishan Kumar Sharma and Prabhjodh Singh Sandhu*	163
Nano double-emulsion of crude metabolites of *Bacillus subtilis* BST8 and BST18 as a potential strategy to control Alternaria leaf blight in sunflower *Aditya Abhijeet Guha, S Harish and M Kannan*	163
Screening of sesame germplasms against major insect pest shoot and capsule borer – *Antigastra catalaunalis* Duponchal (Crambidae: Lepidoptera) *P Indiragandhi, AK Pandey, M Paramasivan, C Harisudan, A Mahalingam, R Baskaran and Anandh Viswakarma*	164
Safeguarding the oilseed frontier: A decade and a half of quarantine interceptions in imported oilseed germplasm (2011–2025) *Jameel Akhtar, Pardeep Kumar, Bharat Raj Meena, Raj Kiran, Sangeeta Pandey and V Celia Chalam*	165
Effect of weather parameters on the incidence and progression of amphobotrys gray mold in Tamil Nadu *M. Rajesh, SRVenkatachalam, P Arutchenthil and P Veeramani*	166
Technology assessment and yield gap analysis of Indian mustard (*Brassica juncea*) affected by Sclerotinia rot through on-farm testing (OFT) under farmers' fields of STCs. *Sunil Kumar, SK Sharma, BL Ola, SK Rastogi, PC Garhwal, AK Verma, Aditiya Mohan Maharishi and VV Singh*	166
Theme III : Resource Utilization and Enhancing Production	
Triple superphosphate as an efficient alternative phosphorus source for higher productivity and profitably of mustard under a maize–mustard cropping system *Sanjay Singh Rathore*	**[168-233]** 168
Effect of different planting methods on resource utilization and productivity of Gobhi Sarson in Pigeonpea-Gobhi Sarson cropping system under sub-tropical conditions *Gurpreet Kaur and Kulvir Singh Saini*	168
Evaluating the impact of different management interventions on water use in canola in Central Punjab *Abhishek Sharma and BB Vashisht*	169
Precision nitrogen management strategies for enhancing productivity, profitability and nitrogen use efficiency in mustard (*Brassica juncea* L.) *VD Meena, ML Dotaniya, MD Meena, RS Jat, MK Meena, RL Choudhary, Harvir Singh and VV Singh*	170
Resource conservation technologies for enhancing rapeseed mustard productivity in arid and semi-arid region *Kajal Arora*	171
The potential applications of rapeseed mustard protein isolates	

Title and Author(s)	Page
Nisha Kumari, Jyoti Duhan, Ram Avtar and Renu Yaduvanshi	172
Evaluation of drip irrigation water in Indian mustard (*Brassica juncea* L.) under different crop geometry *Jitender Kumar, Navish Kumar, Dharam Bir Yadav, Parmod Kumar Yadav, Ashok Kumar Dehinwal and Dhram Praksah*	173
Role of bee attractants in enhancing pollinator activity in *Brassica campestris* (BSH-1) *Riya and MS Khan*	173
Impact of nutrient management practices and sowing time on yield, quality, and sustainability of Indian mustard (*Brassica juncea* L.) under climate variability *Swapnashree Sahoo and JK Singh*	174
Performance of nitrogen and phosphorus nano-formulations on growth, yield and quality of Indian mustard (*Brassica juncea* L.) *Rajeev Bharat, Anjali Chauhan and Rahul Gupta*	175
Economics of predominant rabi crops (mustard, linseed) in post-paddy cropping systems in rice fallow areas of Eastern Vidarbha, Maharashtra *Sharad Bhure, Sandeep Kamdi, Diksha Tajane, PM Gadge, Achal Sharnagat, Arjun Verma, Sakshi Sonowane, Somnath Dahiphale and Mohit Peshkar*	175
To study the genetic heritability and genetic advance of an Indian mustard (*Brassica juncea* L.) *Vivek Tripathi and K Srivastava*	176
Enhancing rapeseed–mustard productivity and farmer confidence through certified seed availability, quality assurance and high yield performing varieties in India *Bhagirath Ram, Muskan Rajput, Ramraj Singh Bakshi, AK Sharma, HK Sharma, RL Choudhary, Arun Kumar, Vinod Kumar and VV Singh*	177
Relative contribution of area and yield to the total output growth of rapeseed-mustard crop in Rajasthan *Himani and Vikram Yogi*	178
Evaluation of combined effect of conventional and nano-fertilizers to increase the productivity of *Brassica juncea* L. *Radha Upadhyay, MS Negi, Anil Shukla and Riya*	178
In-vitro effect of bio-agents for control of alternaria blight of Indian mustard incited by *Alternaria brassicicola* *Ravi Regar, SK Goyal, S Godika, Shankar Lal Yadav, AK Meena, Pinki Sharma and Manohar Ram*	179
Optimizing nutrient management for yield, water productivity and profitability in maize–mustard cropping system under semi-arid conditions *Har Vir Singh, RS Jat, RL Choudhary, ML Dotaniya, VD Meena, MK Meena and VV Singh*	180
Role of sulphur oxidizing bacteria and phosphate solubilizing bacteria in mustard crop *Vijay Kumar, Priya Tanwar and Leela Wati*	180
Effect of organic sources on mustard yield and soil health parameters in saline soils *ML Dotaniya, MD Meena, RL Choudhary, MK Meena, VD Meena, HV Singh, RS Jat and VV Singh*	181
Role of improved brassica varieties in enhancing oilseed production in Jammu & Kashmir *Praveen Singh, Danish M Khanday and Ankita Kapoor*	182
Changes in phosphorus fractions and soil microbial activities amended with compost and mineral fertilizers *MD Meena, ML Dotaniya, MK Meena, RS Jat, MS Sujith Kumar and VV Singh*	182
Study for nutraceutical traits in leafy mustard landraces of Manipur *Pushparani Senjam, Surbani Laishram, Diana Shamurailatpam, Pramesh Kh and New Muskan Yadav*	183
Sustainable crop intensification through oilseeds for efficient resource utilization in western red and lateritic dry region of West Bengal *Shyamali Das Uttam Rajguru and Tapas Kumar Roychowdhuri*	184
Optimization of crop residue in conservation agriculture-based maize-mustard system for improving	

Title and Author(s)	Page
productivity, profitability and soil health *Rishi Raj, TK Das, Subhash Babu and Sanjay Singh Rathore*	184
Growth and productivity of Indian mustard (*Brassica juncea* L.) as influenced by integrated nutrient management options *Aman Preet, VK Sardana and Gurpreet Kaur*	185
Performance of mustard under customized fertilization practices *Pratibha Singh, Seema Sharma, Shweta Gupta and Rahul Singh Jantwal*	185
Response of macro and micro nutrient bio-fertilizers of liquid consortia for enhancing mustard productivity and profitability *BS Meena, SK Yadav, SN Meena, RK Bairwa and Pursottam Bijarniya*	186
Response of mustard (*Brassica juncea* L.) genotype to macro- and micro nutrient bio-fertilizers in the acidic and lateritic soils of Jharkhand *Rajni Kiran Lakra and Arun Kumar*	187
Integrated use of microbial consortia and fertilizers for sustainable soybean production *S A Jaybhay, BD Idhol, BN Waghmare and DH Salunkhe*	188
Crop diversification with soybean in scarce rainfall zone of Andhra Pradesh *K Raghavendra Chowdary, PSujathamma, K Ashok Kumar, KTejeswara Rao, B Sahadeva Reddy and T Srinivas*	189
Influence of nitrogen and phosphorus fertilization on growth and productivity of soybean (*Glycine max* L.) *RK Meena, BS Meena, Hitesh Genan and Kiran Prajapat*	189
Isolation and characterization of *Bacillus haynesii*: A sustainable bioinoculant for agrochemical remediation *Aaditi Wangikar, SupriyaRatnaparkhe and Aparna Saraf*	190
An integrated AI-Based decision support system for soybean disease and insect forecasting *Savita Kolhe, BU Dupare, Sanjeev Kumar, Lokesh Kumar Meena, Makhan Khumbhkar and Rahul Sharma*	190
Residue-incorporated permanent broad bed furrow enhances soil microbial dynamics, carbon cycling (*cbbL* gene abundance), and sustains soybean productivity in long term cropping systems *Prem Ranjan, Diptimayhee Das, Rakesh Kumar Verma, Aketi Ramesh, Kumar M and Mahaveer P. Sharma*	191
Harnessing microbial symbionts to enhance soybean productivity and soil carbon sequestration *Mahaveer Prasad Sharma, Abhishek Bharti, Dipanti Chourasiya, Richa Agnihotri, Hemant Singh Maheshwari and Aketi Ramesh*	192
Yield and economics of different soybean [*Glycine max* (L.) Merrill] varieties under different phosphorus levels along with inoculation of PSB *Shivani Paliwal and Dr. Vikas Gupta*	193
Effect of herbicides on growth, yield attributes and yield of soybean [*Glycine max* (L.) Merrill] *DS Meena, RK Mahawar and BK Patidar*	194
Exploration of agronomic traits and genetic factors influencing soybean suitability for mechanized harvesting *Santosh A Jaybhay, Yashwanthakumar K J, M D Oak, BN Waghmare, BD Idhol and AJ Ghumatdar*	194
Quality and yield of soybean (*Glycine max* L. Merrill) as influenced by various level of phosphorus, sulphur and iron *Ms. Himansha Tanwar and Tauseef Ahmad Bhat*	195
Herbicidal weed control and its effect on oil out-turn in groundnut cultivation (*Arachis hypogaea* L.) *Priyanka Khadav and ML Mehriya*	197
Effect of foliar application of nitrogen through nano urea and urea phosphate on growth, yield and economics of summer groundnut (*Arachis hypogaea* L.) *DV Dahat, BC Game and DB Patil*	197
Saturation vapor pressure and mean temperature as eco-climatic factors affecting groundnut productivity in India *Ajay BC, Narendra Kumar, Nataraj MV, Tomar RS and Bera SK*	198

Title and Author(s)	Page
Evaluating triple super phosphate as an alternative phosphorus source for improving phosphorus use efficiency in groundnut-mustard cropping system *Aaradhana Chilwal, CS Praharaj, SS Rathore, Nitin Gudadhe and Kiran Reddy*	199
Metal organic framework fertilizers: The future of micronutrient management in oilseed crops *Nitin N Gudadhe, Aaradhana Chilwal, Kiran K Reddy and CS Praharaj*	200
Enhancing system productivity and phosphorus use efficiency in a groundnut-wheat cropping sequence through phosphorus management and biological mobilization *Kiran Reddy, Hardi Kansagara, Aaradhana Chilwal, Nitin Gudadhe and CS Praharaj*	200
Sustainable groundnut production through crop diversification and tillage systems in central plateaus *Nisha Singh*	201
Microbial culture-mediated enhancement of phosphorus utilization and yield in summer groundnut (*Arachis hypogaea* L.) *SP Kachhadiya, RN Daki, ND Dholariya and RB Madariya*	202
Response of groundnut to spacing and fertilizer levels *Bavaji Gudi Shobha Rathod, M Sreedhar and L Krishna*	202
Integrating deep learning and remote sensing for monitoring growth and yield of oilseed crops: A modern approach for enhancing India's edible oil security *Saurabh Tripathi*	203
Strain-specific effects of rhizobia symbiosis on productivity and economic returns of groundnut (*Arachis hypogaea* L.), under semi-arid eastern plain of Rajasthan *Bheem Pareek, Malu Ram Yadav, Shweeta Gupta, Seema Sharma, Kavita Bhadu, Ram Niwas Choudhary, Rani Saxena, Pratibha Singh, Anju Khangarot and KC Gupta*	204
Climate change and groundnut (*Arachis hypogaea* L.) production: Impacts and adaptation-mitigation strategies *Nikhil, Khushkarandeep Singh, Kajal Arora, Rahul Sharma*	204
Yield optimization of Rabi groundnut through nano DAP application *AK Sethy, A Chowdhury, KC Pradhan, S Tripathy, AC Dash, SK. Swain, G Prameela, Y Mohanty and A Dalai*	205
GPBD 4: A proven high-volume groundnut variety sustaining India's seed supply chain *Shashidhara N, T. R. Shashidhara, AG. Vijaykumar, CJ. Kumar., Kallesh, DT, Kumari Basamma and Malik Rehan*	206
Dh 256: An emerging groundnut variety with gradual integration into the seed production system *Shashidhara N, TR Shashidhara, AG Vijaykumar, CJ Kumar, Kallesh, DT, Kumari Basamma and Malik Rehan*	207
Effect of tillage and residue management practices on performance of groundnut based cropping systems in western Rajasthan *Raja Ram Choudhary and Narendra Kumar*	207
Impact of nano urea and urea phosphate on productivity and profitability of groundnut (*Arachis hypogea*) *Amarjeet Nibhoria, Ashok Kumar Dehinwal, Jitender Kumar, Navish Kumar, Satyajeet and Dharam Bir Yadav*	208
Screening of groundnut genotypes for identification of resistance sources to leafhopper and thrips *D Geetha*	209
Impact of technological change on groundnut production in major groundnut-growing states of India: A temporal and regional analysis *Paladugu Praveen Kumar and SV Ramana Rao*	210
Performance of irrigated groundnut under nano urea and urea phosphate foliar spray in Puducherry *S. Ravi*	210
Effect of different tillage practices and groundnut based intercropping systems in castor under rainfed conditions *P Veeramani, SR Venkatachalam, P Arutchenthil, M Rajesh, S Jaya prabhavathi and G Suresh*	212
Nature of gene action and epistasis for seed yield traits in castor (*Ricinus communis* L.) *AM Patel, JR Patel, YN Patel, TA Desai, PC Patel, NB Patel and HN Zala*	213

Title and Author(s)	Page
Integrated climate-resilient crop and nutrient management for sustainable productivity and profitability of rice–linseed cropping system *S K Dwivedi, V Kumar, VK Tripathi, S Chitale, N Mehta and H Sahu*	214
Response of different fertility level for different AVT genotype in niger crop [*Guizotia abyssinica* (L.f.) Cass.] *Aruna D Ahirwar, AK Vishwakarma and Rajani Bisen*	214
Agronomic performance of niger (*Guizotia abyssinica* L.) in association with foxtail millet in the North Eastern Zone of Tamil Nadu *K Sathiya, P Ayyadurai, R Brindavathy and S Thiruvarassan*	215
Quantifying economic gains from aphid resistance in safflower under differential insecticidal spray schedules *P Satya Srinivas*	216
Calibration and validation of the DSSAT simulation model for safflower (*Carthamus tinctorius* L.) for the Indian conditions *P Padmavathi and C Sarada*	216
Economic analysis of rainfed sesame under different organic nutrient sources *Md Salman, K B Suneetha Devi, Bavaji Gudi Shobha Rathod and K Chandra Shaker*	217
Chemical weed management and its impact on weed biomass and productivity of sesame in Western Rajasthan *Lokesh Kumar Jain*	218
Performance of nano urea integrated with neem-coated urea on productivity and profitability of sesame (*Sesamum indicum* L.) in Western Rajasthan *Rakesh Choudhary, Mamta Nehra, Durgashankar Meena, Sarita and AK Vishwakarma*	218
Response different levels of potassium and sulphur on yield and economics of summer sesame *KF Satashiya, VR Akabari and VN Gohil*	219
Evaluation of sesame genotypes for variability in yield *D R Mishra, T Begum, S Sahoo and A Viswakarma*	220
Performance of sesame to organic management modules in a soybean-sesame cropping systems in the summer season *K Ramesh, Aziz Qureshi, P Duraimurugan, Praduman Yadav, PC Latha, T Boopathi, C Manimurugan and Sankari Meena*	220
Lignin-based seed pelleting for small-seeded crops: Importance, functional advantages, and multi-input delivery using IIOR biopolymer matrices *KSVP Chandrika, Manimurugan, RD Prasad, Ratna Kumar Pasala, K Ramesh, M Suresh and RK Mathur*	221
Effect of herbicidal weed management on growth and yield performance of sesame (*Sesamum indicum* L.) *Sandeep Bamniya, AK Vishwakarma, Surabhi Jain, RK Sahu, Saurabh Singh, Teena Patel, Ram Kumar Patel, Priya Chourasiya and Neinei Dahariya*	222
Study on integrated application of fertilizers and nano fertilizers on growth and yield of sesame (*Sesamum indicum* L.) *Priya Chourasiya, AK Vishwakarma, Surabhi Jain, Abhijeet Kumar Dubey, HK Rai, Teena Patel and Sandeep Bamniya and Nainee Dehariya*	223
Accessing the variability for key agro-morphological traits and oil content in diverse sesame (*Sesamum indicum* L.) germplasm *Deepanshu Garg, Meenakshi Mittal, Sanjula Sharma and Vineet Kumar*	223
Enhancing the effectiveness of source-sink partitioning to increase sesame (*Sesamum indicum* L.) productivity *C Harisudan, S Srinivasan, Nisha Sapre, AK Vishwakarma, M Paramasivan, P Indiragandhi, A Mahalingam and R Baskaran*	224
Combined application of conventional urea fertilizer and nano urea foliar nutrition on productivity and profitability of irrigated sunflower *M Senthivelu, S Harish, R Sasikala and R Kalaiyarasi*	225

Title and Author(s)	Page
Sustainable technologies to enhance nutrient use efficiency in sunflower *Chopde Vijay Sree, KSVP Chandrika, B Padmaja, T Ramprakash, S Susmitha, P Ramya and Abdul Aziz Qureshi*	225
Unlocking immobilized phosphorus through functionalization strategies in sunflower *P Ramya, KSVP Chandrika, K B Suneetha Devi, P Ratna Kumar, S Susmitha and Chopde Vijaya Sree*	226
Influence of crop geometry on morphophysiological traits and yield of sesame (*Sesamum indicum* L.) *Neha Sen, A.K. Vishwakarma, Gyanendra Tiwari, Subrata Sharma, Rohit Kumawat, Ram Kumar Patel, Teena Patel and Nainy Daheriya*	227
Impact on productivity and economics of technological interventions under CFLD on Niger (*Guizotia abyssinica* L.) in Madhya Pradesh *S K Ahirwar, R L Raut and Aruna Devi Ahirwar*	228
Impact of technological interventions of CFLD on soybean (*Glycin max* L.) Merrill productivity and profitability in Madhya Pradesh *S K Ahirwar, R L Raut and Aruna Devi Ahirwar*	228
Compositional diversity and multivariate identification of nutritionally superior oil palm germplasm from west and central Africa grown under Indian conditions *Prathap V, P Anitha, G Ravichandran, Shaik Sanafrian and K Suresh*	229
Response of Groundnut to the foliar application of nano urea and urea phosphate *B. S. Yenagi[1], Mamatha Shree, C. M[2]., Suma Mogali[2], Shiddalingappa, V. Hugar[2] and Gurupad Balol[2]*	230
Innovations in Weed Control through Biodegradable Mulches in Oilseed Production Systems *Susmitha[*], KSVP Chandrika, G Suresh, CH Vijaya Sree and P Ramya*	230
Role of artificial intelligence in oilseed development in India *Ritu Gameti[1], R.P. Meena[2], J. Choudhary[1] and Sachin Kumari[3]*	231
Sustainable development of oilseed crops through organic package of practices *Ankit Kumar, Dr. J. Choudhary and Abhijeet Purohit*	232
Enhancing the growth and productivity of gobhi sarson with different rice residue management methods and nitrogen levels under rice-gobhi sarson (Oryza sativa L.- Brassica napus L.) rotation *Poonam[*], Harmeet Singh and Jagroop Kaur*	233
Theme IV : Knowledge Centric Technology Transfer and Digital Outreach	**[234-250]**
Impact of integrated crop management technologies on productivity and energy budgeting of mustard under cluster frontline demonstrations in Sawai Madhopur District, Rajasthan *Nupur Sharma, BL Meena and Sushil Kumar Sharma*	234
Unlocking mustard yield potential through frontline demonstrations and yield gap analysis in rice fallow areas of Eastern Vidarbha, Maharashtra. *Sandeep Kamdi, Sharad Bhure, Diksha Tajane, PM Gadge and Arjun Verma*	234
Transforming mustard cultivation through frontline demonstrations in Haryana *Rajbir Singh Khedwal, Ram Avtar, Neeraj Kumar, Rakesh Punia, Dalip Kumar, Uma Devi, Mahavir Bishnoi and Aakash*	235
Performance of different improved varieties of rapeseed–mustard under front line demonstration in rice–fallow areas of Assam *Yonika Saini, Devki Nandan, Amar Chand, AK Sharma, Vinod Kumar, RK Yogi and VV Singh*	236
Impact of different improved varieties under front line demonstration *Devki Nandan, Yonika Saini, Amar Chand, AK Sharma, Vinod Kumar, RK Yogi and VV Singh*	236
In-situ imaging of Orobanche development for assessing growth and infestation intensity in Indian mustard *RS Jat, Prabhu Lal Kantwa and KN Meena*	237
Farm level impact of cluster frontline demonstration program in sub tropic of Jammu region *Shivam Yadav, Rakesh Sharma, Udangshri Brahma, Khub Ram, Vivek Sharma and Deeksha Kumari*	238

Title and Author(s)	Page
Effectiveness of social and digital media for efficient dissemination of soybean production technology *B.U. Dupare and Savita Kolhe*	239
Soybean gyan: An AI-powered mobile application for enhanced soybean cultivation *Savita Kolhe, BU Dupare, Sanjeev Kumar and Lokesh Kumar Meena*	240
Realizing the potential of agri-business incubation in soybean value addition, byproduct utilization, and allied sectors for startup & entrepreneur development *Abhishek Bharti, Mahaveer P. Sharma, Neha Pandey, Yogesh Sohani, Punam Kuchlan, Vineet Kumar, Aketi Ramesh, BU Dupare and Kunwar Harendra Singh*	240
Demonstration of early and medium duration soybean cultivars under the soybean-wheat cropping system in Madhya Pradesh *BU Dupare, Uma Shankar Bagri, Deepak Pahariya, Ritesh Patil, Deepak Yadav, Angad Rathore, Nitesh Sagore, Rakesh Kumar Verma, Raghavendra Nargund and KH Singh*	241
Yield gap of frontline demonstrations (FLDs) on soybean conducted under the National Mission on Edible Oils - Oilseed (NMEO-OS) *BU Dupare, Ram Chopra, Sunil Dangi and KH Singh*	242
Assessing women's participation, empowerment and decision-making in groundnut farming: gender analysis from Saurashtra region of Gujarat *Adupa Shanmuka, Manjunath Paled, Nataraj Maheshala, Jayshree Lakhanotra and Sidhdharth Rajani*	243
Model value chain development in oilseeds focusing on SC communities *P Aswani, GDS Kumar, Mangesh Y Dudhe and Praduman Yadav*	244
Bridging the yield gaps in sesame through front line demonstrations under farmers' field conditions *A K Vishwakarma, K N Gupta, Namrata Jain, Surabhi Jain, Nisha Sapre, Rajani Bisen, Roshni Sahu, Ram Kumar Patel and Teena Patel*	244
Performance of sesame in Rajasthan - Agro eco region approach *Bammidi Ujjwala, SV Ramana Rao, C Sarada and K Alivelu*	245
Developing smart FPOs for strengthening the oilseeds value chain *GDS Kumar, T Manjunatha G Suresh A Aziz Qureshi RD Prasad and Ch Sarada*	246
Reaching farmers digitally: Innovations in oilseeds information sharing *Vinod Kumar, Ashok Kumar Sharma, Raj Kumar Yogi and Vijay Veer Singh*	247
Exploring entrepreneurial behaviour among rapeseed–mustard farmers:empirical insights from Assam *Priyakshi Buragohain, Bidyut P Gogoi and Goutami Kataki*	247
Productivity and yield gap of toria (var. TS-38)- A cluster-based analysis in Tinsukia district of Assam *N Kalita, M Gogoi, RK Kakoti, BK Saud and PK Bordoloi*	248
Impact of krishi vigyan kendra interventions on adoption of improved agricultural practices and farmers' livelihoods in Kotputli-Behror district, Rajasthan *Sandeep Kumar Rastogi, Sunil Kumar, PC Garhwal and Sushil Kumar Sharma*	249
Performance and yield gap of sesamum variety (RT-351) under KVK cluster front line demonstrations *Sushil Kumar Sharma, Sunil Kumar, Sandeep Kumar Rastogi, PC Garhwal, Aditya Mohan Maharishi, Surbhi Gour and VV Singh*	249
Theme V : Market and Policy Imperatives	**[251-262]**
Enhancing productivity and sustaining area growth in *Brassica* spp.: Insights from recent advances in India *RK Yogi, AK Sharma, Vinod Kumar and VV Singh*	251
Mutations for biochemical traits in *Brassica juncea* *Anubhuti Sharma, Prashant Yadav, Meghna Garg and Sanjay Jambhulkar*	252
Sustaining soybean acreage in India through break-even and iso-Return analysis of competitive crop dynamics in MP and Maharashtra *Vishal S. Thorat and BU Dupare*	253
Enhanced functionality of soy protein-kappa-carrageenan conjugates using combined pulsed electric field and microwave treatments *Neha Pandey, Ashutosh Upadhyay and KH Singh*	253

Title and Author(s)	Page
Multi-location evaluation of soybean genotypes based on multiple food grade traits *L Sophia Devi, T Sunanda Devi, H Nanita Devi, Nilima Karam and V Nataraj*	254
Management of leaf blight and wilt disease of groundnut (*Arachis hypogaea* L.) *BDS Nathawat and SP Singh*	255
Who gets the price? Groundnut market linkages and farmer returns in Andhra Pradesh *Saket Panbude, Saikumar C Bharamappanavara, and Biswaranjan Baraj and Muralidhar G*	255
Is groundnut productivity input-driven or technology-driven?: Evidence from state-level TFP analysis *Manjunatha P Paled, Upasana D Bhopala, Nataraja MV and SK Bera*	256
Policy imperatives for revitalizing India's groundnut sector: Production, markets, and value chain integration *Shashidhara, N, TR Shashidhara, AG Vijaykumar, CJ Kumar, Kallesh, DT, Kumari Basamma and Malik Rehan*	257
Empowering women farmers in groundnut processing under farmers first programme *Velpula Jhansi Rani, SV Ramana Rao and GDS Kumar*	258
Linseed oil based omega-3 fortification of dairy product: post-harvest value addition approach *Anand A Zanwar, AL Rathnakumar, Divya Ambati, Pramod Farde and Mahabaleshwar Hegde*	259
Value addition of linseed for functional bakery applications: development of omega-3 fortified bread and cake *Anand A Zanwar, AL Rathnakumar, Divya Ambati, Pramod Farde and Mahabaleshwar Hegde*	260
Biochemical profiling and lipid analysis of niger seed (*Guizotia abyssinica* Cass.) of different germplasms of Gujarat *Odedra Vanita, Priti Faldu and Nilima Karmakar*	260
Sunflower trend and decomposition analysis after Post-TMO *Syed Maaz Ahmed, Paladugu Praveen Kumar, Amir Ilyas and Devan Sharma*	261
An ideal packing material for oil palm seed storage *Somasundaram G, G Ravichandran, Rohini MR, P Anitha and Neema M*	262

THEME - I

RESEARCH FOR RESILIENT CROP BREEDING

Induction and genetic confirmation of a glossy leaf mutant in *Brassica rapa* (Pant sweta) via combined mutagenesis

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Mutation breeding remains a cornerstone for enhancing genetic diversity in crops like *Brassica rapa*, particularly for traits such as leaf glossiness that influence agronomic performance and disease resistance. This study details the induction and characterization of a glossy leaf mutant from the Pant sweta variety of *Brassica rapa* at the Crop Research Centre (CRC), Govind Ballabh Pant University of Agriculture and Technology, Pantnagar. Seeds of Pant Sweta were exposed to physical (gamma rays), chemical (EMS), and combined mutagens to generate M_1 populations, which were advanced to M_2 and M_3 generations for mutant screening. In the M_2 generation, a single glossy mutant plant was identified among approximately 5,000 progeny screened across treatments, exhibiting a distinct shiny leaf phenotype compared to the normal matte green leaves of the parent. This mutant was self-pollinated and bulk-harvested to produce M_3 progeny. Segregation analysis in M_3 revealed 142 glossy and 428 normal plants, approximating a 1:3 ratio indicative of single recessive gene inheritance. To validate the genetic basis, a chi-square goodness-of-fit test was performed. Expected frequencies were calculated as 142.5 glossy and 427.5 normal plants (total 570) under a monogenic recessive model ($df = 1$). The computed $\chi^2 = 0.012$ ($p > 0.90$) confirmed no significant deviation from the expected ratio, supporting the hypothesis of control by a single recessive locus. This glossy mutant holds promise for introgression into elite Brassica rapa lines to improve photosynthetic efficiency and reduce pest adhesion. Further studies on stability, linkage mapping, and field performance are underway. These findings underscore the efficacy of combined mutagenesis in uncovering novel recessive traits for crop improvement in oilseed mustard.

Keywords**:** *Brassica rapa, mutagenesis, rapeseed-mustard*

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Evaluation of early maturing advanced breeding lines of Indian mustard (*Brassica junc*ea L. Czern & Coss) for heat stress tolerance

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Heat stress at seedling stage is one of the major factors responsible for the low productivity of crop plants and has become an increasing threat for agriculture. Indian mustard grown under rain-fed conditions is usually affected by heat stress at seedling stages resulting in negative effect on yield. The growing of Rapeseed-Mustard in Rajasthan is mostly carried out under conserve soil moisture conditions where sowing commences after southwest monsoon rains. Early rains may lead the farmers to sow the crop early in the season to take advantage of conserved moisture in the soil. However, at the time of early sowing (second fortnight of September to the first fortnight of October), the mean surface soil temperature may reach as high as 45° C. Therefore, efforts to strengthen resilience by genetic up-scaling of heat stress at seedling and terminal stage in Indian mustard would be vital to stabilize the productivity of the crop in India. Therefore, a study was carried out at the research farm of ICAR-IIRMR, Bharatpur, Rajasthan during Rabi 2023-24 and 2024-25 to evaluate early maturing advanced breeding lines at physiological and seed yield contributing traits level in order to identify some of the promising heat tolerant lines from amongst a pool of advanced breeding lines. The crop was raised strictly under conserved moisture early sown heat stress conditions. Results indicated that most genotypes respond differently

under normal and high temperature stress conditions. The membrane stability index (%) decreased with increasing heat stress in all environments in all genotypes. However, the decrease was lesser in DRMRHT-20-18, DRMRHT-20-63, DRMRHT-20-53, DRMRHT-20-82 and DRMRHT-20-70. Among the genotypes, minimum excised leaf water loss recorded in DRMRHT-20-18 (16.54 % in E_1; 17.12 in E_2), DRMRHT-20-63 (16.64 % in E_1; 19.60 % in E_2), DRMRHT-20-53 (15.96 % in E_1; 21.05 in E_2), DRMRHT-20-82 (16.58 % in E_1; 19.19 in E_2) and DRMRHT-20-70 (17.56 % in E_1; 20.09 in E_2) under stress conditions, while it was maximum in DRMRT-20-132 and DRMRT-20-26 in both the environment. Among other physiological parameters, investigated water retention capacity of leaves (%) and relative water content (%) recorded maximum in DRMRHT-20-18, DRMRHT-20-63, DRMRHT-20-53, DRMRHT-20-82 and DRMRHT-20-70. Among the genotypes, DRMRHT-20-18 (2500.56 kg/ha E_1; 2648.13 kg/ha E_2), DRMRHT-20-63 (2173.73 kg/ha E_1; 2296.28 kg/ha E_2), DRMRHT-20-53 (2080.05 kg/ha E_1; 2018.50 kg/ha E_2) and DRMRHT-20-82 (2056.45 kg/ha E_1; 2071.59 kg/ha E_2) recorded maximum seed yield (kg/ha) in both environments. From the results of the study, it can be concluded that the heat stress-tolerant genotypes DRMRHT-20-18, DRMRHT-20-63, DRMRHT-20-53, DRMRHT-20-82 and DRMRHT-20-70 had higher capacity to tolerant heat stress. These genotypes shall be included in breeding programme for accumulation of favorable alleles.

Keywords**:** *Indian mustard, resilient crop, thermo-tolerant*

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Developments in Indian mustard for salinity tolerance

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Globally, saline soils cover approximately 397 million hectares, while sodic soils encompass an estimated 434 million hectares. In India specifically, it is estimated that 6.73 million hectares are impacted by salinity, highlighting a significant concern, particularly in arid and semi-arid regions. Indian mustard (*Brassica juncea* L.) is a major oilseed crop of India, contributing significantly to edible oil production. However, soil salinity is an increasing abiotic stress that severely limits mustard productivity, particularly in arid and semi-arid regions. Approximately 2.9 million hectares of salt-affected fields in India are allocated to oilseed Brassicas, out of a total of 8.9 million hectares, predominantly located in arid regions with various salinity levels. Developing salinity-tolerant mustard varieties is therefore essential to sustain yield stability and expand cultivation in salt-affected soils. The research study was conducted using a RILs mapping population (CS 614-1-1-100-13 x CS 56) of Indian mustard genotypes. Experiment was carried out under controlled and field conditions with varying levels of salinity ($EC_{e/iw}$ 0 and 12 dS/m) induced through saline irrigation or salt-amended soils. A randomized complete block design with three replications was followed. Observations were recorded on agro-physiological traits. Genotyping-By-Sequencing (GBS) was performed using double digest Restriction site Associated DNA (ddRAD) method to map QTLs and linked SNPs. Considerable genetic variability was observed among mustard genotypes for salinity tolerance. Salinity stress significantly reduced growth and yield parameters; however, tolerant genotypes exhibited higher germination rates, better seedling establishment, and reduced sodium accumulation compared to susceptible ones. Maintenance of a favorable Naz /Kz ratio, higher chlorophyll retention, and improved membrane stability were key physiological traits associated with tolerance. Certain advanced breeding lines outperformed existing varieties under saline conditions, indicating successful introgression of tolerance traits through breeding efforts. The results suggest that selection based on physiological and ionic traits, in combination with yield performance, can effectively enhance salinity tolerance in Indian mustard. Furthermore, mutation-derived salt-sensitive lines, specifically CS 614-1-1-100-13 is being utilized within recombinant inbred lines for QTL mapping via Genotyping-By-Sequencing (GBS) and linkage mapping. Through the application of double digest Restriction site Associated DNA (ddRAD) sequencing, this population analysis has achieved a coverage of 1127.85 cM, resulting in the identification of 2506 SNPs and 12 significant QTLs for various traits, including days to 50% flowering (qDFsB07.1), days to maturity

(qDMsB08.1), number of primary branches per plant (qPBRcA05.1 and qPBRsA07.1), main shoot length (qMSLsB05.1 and qMSLcB05.1), seeds per siliqua (qSPScA09.1), yield per plant (qYPPsB06.1), transpiration rate (qEsA01.1), Na^+ concentration in stem tissues (qSNasA01.1), K^+ concentration in stem tissues (qSKsB03.1), and K^+ concentration in root tissues (qRKsB01.1), all accompanied by linked SNP markers. Innovations such as genome editing, marker-assisted selection (MAS), and backcrossing leverage SSR and SNP markers to pinpoint quantitative trait loci (QTLs) associated with polygenic traits like salt tolerance and seed yield, thus facilitating more precise breeding efforts.

Keywords**:** *Indian mustard, gbs, ril, salinity-tolerance*

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Identification of QTLs conferring aluminium toxicity tolerance in *Brassica carinata* derived *Brassica juncea* introgression lines

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Aluminium (Al) toxicity in acidic soils is a major constraint to rapeseed–mustard productivity, particularly affecting Indian mustard (*Brassica juncea*) cultivation in acid-prone regions. To enhance productivity under acid stress, 87 *B. carinata*-derived *B. juncea* introgression lines (ILs) were developed at ICAR-IARI, New Delhi, to introgress beneficial genomic segments and create selectable genetic variability. These ILs were evaluated under Al toxicity stress at ICAR–IIAB, Ranchi, under hydroponic conditions following a completely randomized design and under field conditions using an augmented randomized complete block design. Aluminium toxicity was imposed by supplementing the nutrient solution with 200 µM aluminium chloride hexahydrate ($AlCl_f \cdot 6H, O$). ILs were evaluated for morpho-physiological traits under control and Al stress conditions and agro-morphological traits under natural acidic soils. Genotyping-by-sequencing was used for linkage map construction, yielding 7,434 SNP markers distributed across 18 chromosomes, spanning 3,234.9 cM with an average marker interval of 2.3 cM. Quantitative Trait Loci (QTL) mapping identified 38 significant QTLs, 17 for morpho-physiological traits, 14 for agro-morphological traits, and 7 for stress tolerance indices. Major QTLs included qRV.1B.1 for root volume (26.3% PVE), qNF.3B.3 for number of forks (26.0% PVE), qD50F.1A.1 for days to 50% flowering (55.4% PVE), and qSYplot.10A.1 for seed yield per plot (27.6% PVE). Five QTL hotspots were identified, including a prominent hotspot on chromosome 2B harbouring QTLs for four stress tolerance indices: qRTI.2B.2, qRR.2B.2, qSSI.2B.2, and qRRG.2B.2. In silico candidate gene analysis revealed functionally relevant genes involved in abiotic stress tolerance, such as COBRA-like, peroxidase 72, cytochrome P450, GATA and SAUR-like transcription factors and zinc-knuckle and DNA damage-inducible proteins. This study highlights the potential of interspecific hybridization for broadening the genetic base of *B. juncea*, identifies key genomic regions and candidate genes associated with Al toxicity stress tolerance and provides genomic resources developing Al-tolerant cultivars suited to acid-soils.

Keywords: *Abiotic stress tolerance, indian mustard, genotyping-by-sequencing (GBS), quantitative trait loci*

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Effect of female-to-male planting ratios on seed yield in Ogura CMS-based hybrid seed production of Indian mustard

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Rapeseed-mustard is the third most important oil commodity after soybean and palm. Among different Brassica species, Indian mustard [*Brassica juncea* L. Czern & Coss.] is the most important with more than 85% area under cultivation nationwide. Thus, enhancing its productivity is essential to meet the growing demand for edible oil. Exploitation of heterosis through cytoplasmic male sterility (CMS)-based hybrids is a promising approach, where optimization of the planting ratio of parental lines is crucial for economical hybrid seed production. The main focus of present study was to determine the optimum planting ratio for CMS-based hybrid seed production using an Ogura A line and a common restorer (R) line. A randomized block design with four replications was carried out during Rabi 2017-18 at the Oilseeds Research Area, CCS Haryana Agricultural University, Hisar. Different female-to-male planting ratios planting ratios were evaluated and observations were recorded on yield and yield-attributing traits. Results indicated that planting ratios significantly affected seeds per siliqua and seed yield, while 1000-seed weight was not significantly affected. Experimental results concluded that the 3:1 (female: male) planting ratio was optimal for large-scale hybrid seed production in Indian mustard.

Keywords**:** *Brassica juncea, hybrid seed, planting ratio, heterosis*

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Population structure and cluster analysis of Indian mustard genotypes

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Rapeseed-mustard is the third most important oilseed crop after oil palm and soybean. Among different *Brassica* species, Indian mustard [*Brassica juncea* L. Czern & Coss.] is most important, containing 38-40% oil and covers approximately 90% of the total area under rapeseed-mustard cultivation in the country. Assessment of population structure and genetic relationships is vital for efficient germplasm utilization and parent selection in crop improvement programs. In the present investigation, 42 Indian mustard (*Brassica juncea* L.) genotypes were analyzed using SSR-based genetic dissimilarity estimates. Jaccard's dissimilarity coefficient ranged from 0.070 to 0.230, indicating wide genetic variability among the genotypes. The maximum genetic dissimilarity was observed between M191 and CDL-2, followed by M191 and M-76, suggesting their potential use as diverse parents in hybridization programs. The minimum dissimilarity was recorded between DRMR-DL-2 and CDL-7, reflecting close genetic relatedness. Cluster analysis grouped the genotypes into three major clusters, each further subdivided into sub-clusters. The observed clustering pattern and wide genetic divergence provide valuable insights for germplasm management and strategic breeding of Indian mustard.

Keywords: *Cluster analysis, dissimilarity coefficient, Indian mustard, population structure*

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Molecular genetic diversity of Indian mustard using SSR markers

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Rapeseed-mustard, particularly Indian mustard (*Brassica juncea* L. Czern & Coss.), is the third most important oilseed crop globally and occupies more than 85% of the total mustard-growing area in India. Despite its economic significance, information on molecular genetic diversity within Indian mustard germplasm remains limited. The present study was undertaken to assess genetic diversity among 42 Indian mustard genotypes using simple sequence repeat (SSR) markers. A total of 105 SSR markers were employed, of which 61 were polymorphic and amplified 124 alleles. The average number of alleles per locus was 1.74, while the mean polymorphic information content (PIC) was 0.48, indicating moderate to high marker informativeness. The study highlights the efficiency of SSR markers in detecting molecular variation and reveals substantial genetic diversity among Indian mustard genotypes, which can be effectively exploited in future breeding programmes for crop improvement.

Keywords: *Genetic diversity, indian mustard, polymorphic information content, ssr markers*

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Genotypic variation in oil quality and nutraceutical traits in Ethiopian mustard (*Brassica carinata*)

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Ethiopian mustard (*Brassica carinata* A. Braun) is an emerging oilseed crop with considerable potential for nutritional, industrial, and climate-resilient agriculture. The present study evaluated a diverse set of *B. carinata* genotypes to characterize variability in oil quality traits, antioxidant components, fatty acid composition, and anti-nutritional factors, with the objective of identifying superior genotypes for targeted breeding and value addition. Substantial genotypic variation was observed for phytosterols, fatty acid fractions, oxidative stability, bioactive compounds, and carbohydrate-related traits. Phytosterol content, a key nutraceutical attribute, ranged widely across genotypes, with DRMRIC 20-12 recording the highest concentration (5.17 %), highlighting its potential for functional oil development. Fatty acid profiling revealed significant differences in erucic acid levels, an important quality determinant for edible and industrial oils. DRMRIC 20-14 exhibited the lowest erucic acid content (2.23%), making it particularly suitable for quality oil breeding. Monounsaturated fatty acids (MUFA), desirable for oxidative stability and human health, were highest in DRMRIC 20-13 (57.64%), while polyunsaturated fatty acids (PUFA) peaked in DRMRIC 20-20 (38.90%). The highest oxidative stability index (OSI), indicative of oil shelf life, was observed in DRMRIC 20-39 (2.07), which also recorded the highest phospholipid content (1.33%). Among antioxidant parameters, total antioxidant capacity (TAC) varied considerably, with DRMRIC 20-56 showing exceptionally high TAC (100.85 mg/g AAE), suggesting strong free radical scavenging potential. Tocopherol content was highest in DRMRIC 20-40 (0.72 mg/g), reinforcing its role as a natural antioxidant-rich genotype. Oil content ranged broadly across entries, with the released variety Pusa Swarnim recording the maximum oil percentage (41.95%), along with the highest chlorophyll a, chlorophyll b, pheophytin a, and pheophytin b contents, reflecting its superior pigment profile. Carbohydrate content showed marked variation, with DRMRIC 20-43 recording the highest value (770 mg/g, indicating its potential utility in energy-rich feed or bio-based applications. Anti-nutritional factors also varied significantly among genotypes. The lowest tannin content was recorded in DRMRIC 20-4 (0.0038 %), while DRMRIC 20-59 exhibited

the lowest phytate concentration (0.386 %), enhancing mineral bioavailability. Oxidative degradation indicators such as peroxide value were minimal in DRMRIC 20-44 (0.012 meq/kg), indicating superior oil quality and storage stability. Overall, the study highlights DRMRIC 20-12, DRMRIC 20-14, DRMRIC 20-13, DRMRIC 20-20, DRMRIC 20-39, DRMRIC 20-56, and Pusa Swarnim as promising genotypes for specific quality traits. These genotypes represent valuable genetic resources for breeding programs aimed at improving oil quality, nutritional attributes, and industrial suitability of *B. carinata*.

Keywords**:** *Bioactive compounds, carbohydrate, ethiopian mustard, fatty acid profile, oxidative stability, phytosterols*

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Line × Tester analysis for morphological and physiological traits in Indian mustard [*Brassica juncea* (L.) Czern and Coss.]

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Brassica juncea L. is important rabi oilseed crop in the country and contributes more than 80% of total rapeseed-mustard production in India. Over the past few years, the demand for edible oil has grown at a rapid rate. It puts tremendous pressure on the identification and development of hybrids and high-yielding mustard cultivars. The heterosis breeding is one of the great prosperous breeding strategies being applied to enhance the yield potential. A Line × Tester analysis was carried out at the ICAR- Indian Institute of Rapeseed-Mustard Research, Bharatpur, in 2021–22 after crosses were attempted in 2020–21 in the same manner, to illustrate the GCA (general combining ability) and SCA (specific combining ability) of parental lines and heterobeltiosis of twenty-four F_1 of *Brassica juncea*. The research stuff comprised 24 *Brassica juncea* F_1 hybrids and 11 parental lines (varieties/germplasm/ promising breeding lines), with 8 of those being used as lines and remnant 3 serving as testers. A Randomised Block Design was used to sow all of the crosses and paternal lines in three replications during Rabi 2021–2022. Results revealed that both non-additive and additive gene actions, with a preponderance of non-additive gene actions, controlled or influenced seed yield and yield contributing characters. The best hybrids identified based on SCA effects also showed a close association among heterosis and SCA effects. A series of hybrids were found to have significant SCA effects for seed yield, test weight, number of secondary branches per plant, number of siliqua per plant, and other attributing traits in a desirable direction. Hybrid combinations BPR-1784-85-109 × DRMR-150-35, DRMR-1616-47 × Kranti and DRMR-1260 × NRCHB-101, revealed highly significant and positive magnitude of SCA effects and better parent heterosis and improved per se performance for seed yield per plant. Under various environmental circumstances, hybrids with high SCA effects and better parent heterosis may produce transgressive segregants for seed yield and characteristics that contribute to seed yield.

Keywords**:** *Brassica juncea, gca, heterosis, hybrid, sca*

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Identification of functional *DGAT2* variants for seed oil enhancement in *Brassica juncea* (L.) Czern. through an integrated multi-omic analysis

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Brassica juncea germplasm exhibits wide natural variation in seed oil content, yet the molecular drivers of oil accumulation remain poorly understood. To elucidate the underlying genetic pathways, we compared

the transcriptomes of contrasting high- and low-oil genotypes (two each) at two critical seed-filling stages: 20 and 35 days after pollination (DAP). Differential expression analysis across eight pairwise contrasts, followed by Gene Ontology (GO)-based prioritization, identified 1,742 candidate genes linked to fatty acid biosynthesis, triacylglycerol (TAG) assembly, lipid storage, and transcriptional regulation. A conserved core of 332 genes was found common to all comparisons, while 161 and 85 genes were preferentially associated with the 20- and 35-DAP stages, respectively, suggesting distinct early and late transcriptional networks translate these expression signals into tractable genetic markers, a broad variant scan was performed across the prioritized gene set. It detected 87 SNPs mapping to 16 biologically relevant genes. Fifteen of these SNPs, also represented in the NASF *B. juncea* diversity panel, were advanced for association testing. Two SNPs within a *DGAT2* homolog showed clear and reproducible allelic differences between high- and low-oil genotype groups. Post-hoc comparisons confirmed that these alleles segregated with phenotypic classes rather than random variation. This was further validated by allele-substitution plots, which revealed consistent directional effects on oil Best Linear Unbiased Predictions (BLUPs). While a simple regression model using these two markers exhibited only a limited predictive power, expected for a polygenic trait, the strength and consistency of the associations underscored their biological relevance. These findings highlight *DGAT2* as a key target and provide validated candidate markers for precision breeding in *B. juncea*.

Keywords: *Differential gene expression, go-based prioritization, snp allele variation*

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Development and validation of a KASP marker for Ogura fertility restorer in *Brassica juncea* (L.) Czern. & Coss. and *Brassica napus* L.

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Hybrid cultivars of *Brassica juncea* are extensively grown in regions such as Canada, Europe, and Australia, where they consistently deliver high yield advantage over traditional open-pollinated varieties. Hybrid seed production in *B. juncea* predominantly relies on the Ogura cytoplasmic male sterility (CMS) system, which is widely adopted by both public and private breeding programs. In the present study, we describe the development of a co-dominant Kompetitive Allele-Specific PCR (KASP) marker linked to the fertility restorer gene (*Rfo*), aimed at facilitating precise purification of restorer lines. The genomic sequence of the Ogura *Rfo* gene, previously characterized as a pentatricopeptide repeat (PPR) gene, was retrieved from published *B. juncea* genome assemblies, a cloned Rfo sequence, and an in-house assembled Rfo dataset. Comparative sequence analysis identified informative single nucleotide polymorphisms (SNPs), which were subsequently exploited for KASP primer design. The resulting marker, designated Pau_ogu, was evaluated across a diverse panel comprising more than 500 germplasm accessions of Indian, Chinese, and East European origin, including both CMS and fertility restorer lines. The marker reliably discriminated between homozygous and heterozygous genotypes carrying the *Rfo* allele. Additional validation was performed using an F, population of 100 individuals derived from crosses between CMS lines and the restorer line. The genotypic classification obtained using Pau_ogu showed complete agreement with phenotypic fertility restoration. Overall, this co-dominant KASP marker provides a rapid and accurate tool for identifying fertility restorer genotypes and ensuring genetic purity in Ogura CMS-based hybrid mustard breeding, thereby addressing a key requirement for efficient hybrid development.

Keywords: *CMS, hybrid mustard, kasp markers*

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Evaluation of promising strains of Indian mustard for yield and attributing traits

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Rapeseed–mustard group of crops are grown in diverse agro-climatic conditions ranging from north-eastern/north-western hills to down south under irrigated/rainfed, timely/late-sown, saline soils and mixed cropping. Indian mustard is predominantly grown species in this group and accounts for 80% of the cultivated area in India. Rapeseed–mustard group of crops are grown in diverse agro-climatic conditions ranging from north-eastern/north western hills to down south under irrigated/rainfed, timely/ late-sown, saline soils and mixed cropping. Indian mustard is predominantly grown species in this group and accounts for 80% of the cultivated area in India. It is a predominantly self-pollinating crop with an extent of 8–12% cross-pollination. Considerable variation has been recorded for morphological, physiological and agronomic traits. Assessment of genetic diversity in a crop species is prerequisite to its improvement. The experimental material for the present investigation consisted of eight genotypes against two checks viz. RH-725 and RB-50 at CCS HAU, Regional Research Station, Bawal (Rewari). The experiment was conducted in Randomized Block Design (RBD) during Rabi-2021-22 at RRS Bawal. Each genotype was accommodated in seven rows of 5.0 m length with a spacing of 45 cm between row and 15 cm between plants. Five entries RB-110 (36.20 q/ha), RB-113 (29.80 q/ha), RB-114 (28.92 q/ha), RB-109 (28.76 q/ha) and RB-116 (28.68 q/ha) yielded higher than the best check RH-725 (27.38 q/ha). Maximum test wt. was recorded by the entry RB-110 (6.26 g) followed RB-113 (6.10 g) RB-116 (6.00 g). Maximum oil content (%) was recorded by the check RB-50 (39.9 %) followed by RB-110 (39.5 %) and RB-113 (39.4 %) The entry RB-113 (14.04 q/ha) was promoted from IVT to AVT-I (timely sown, rainfed) showing 10.8 % increase over the best check Kranti (12.67 q/ha) in Zone-V. This genotype may be used in the improvement programs to broaden the genetic base of mustard cultivars.

Keywords: *Diversity, oil content, seed yield, variability*

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In-silico and expression analysis of an H-isoform oleosin gene in Indian mustard

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Oleosin is a structural protein that helps to keep the oil body (OB) stable and intact. Several plant species produce seeds with high (H) and low (L) molecular weight isoforms of oleosin. Because *Brassica juncea* (Indian mustard) is an oilseed crop, understanding the gene(s) that control oil storage is critical. A 636 bp cDNA encoding H-isoform oleosin was extracted from the pod stage (thirty days after flowering) of Indian mustard, with a complete ORF of 211 amino acid residues, a molecular weight of 22.1 kDa, and a theoretical pI of 9.66. The gene is named *BjOLE*. It features a hydrophobic domain that spans 72 amino acid residues and the proline knot (PX5SPX3P), which separates oleosin's structure from other proteins. Peak expression of the *BjOLE* gene occurs during the pod stage (thirty days after flowering), and it is tightly correlated with plant development. The expression levels in genotypes with high and low oil content are similar, demonstrating that the gene is essential for OB development and stability. A ligand binding site in *BjOLE* with a projected photosystem activity points to a potential role in seed germination and carbon dioxide fixing. In addition, runs of regularly spaced leucine residues, akin to a leucine-zipper motif, might indicate an involvement in abiotic stress. The GXSXG motif, a distinctive motif for lipase and is thought to be involved in the lipolysis of stored oil for post-germination and seedling development, is present in the protein's N-terminal region. Lastly, a phosphorylation site at the C-terminal region of *BjOLE* implies that it is highly regulated and may interact with other cellular components to modulate OB stability during seed

germination and under stressful situations.

Keywords: *Indian mustard, h-isoform, oleosin, ob stability*

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Development of STS and InDel based molecular markers for *Sinapis arvensis* L.

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Brassica juncea (L.) Czern & Coss (Indian mustard) is a major oilseed crop of the Indian subcontinent. It is an allotetraploid (AABB, 2n = 36) species that arose through hybridization between two diploid species, *B. rapa* (AA, 2n = 20) and *B. nigra* (BB, 2n = 16), followed by spontaneous chromosome doubling. It is valued for its edible oil for human consumption and protein rich extraction meal for animal intake. However, its productivity is limited by multiple biotic and abiotic stresses. *Sinapis arvensis* (2n =18) is a wild relative of crop Brassica that exhibit several desirable traits including resistance to major pathogens (*Alternaria spp*., *Sclerotinia sclerotiorum*, *Leptosphaeria maculans* and Turnip mosaic virus), tolerance to auxinic herbicides, cold and drought tolerance, and high photosynthetic efficiency. Introgression of these traits into cultivated Brassica species is therefore highly desirable. The molecular markers can help to precisely identify the proportion of alien genome in backcross progenies of cultivated species with wild species and subsequent mapping of QTLs governing targeted traits from the alien genome. We used publicly available reference genome assemblies of *S. arvensis* and *B. juncea* for marker development that could discriminate the genomes of *B. juncea* and *S. arvensis*. The entire genome of *S. arvensis* was partitioned into bins, each of 1Mb in size. The bait region of 50kb was extracted from each bin and filtered to remove repetitive sequences. The repeat free bait regions were aligned against whole genome sequences of *B. juncea* to detect orthologous regions. The orthologous regions were subjected to Multiple Sequence Alignments (MSAs) using ClustalW tool. The conserved regions among the sequences of *S. arvensis* and *B. juncea* flanking the polymorphic InDel regions and unique regions of *S. arvensis* in the MSAs were targeted to design InDel and STS based primers, respectively. Primers were designed using Primer3web version 4.1.0 and validated for amplification on agarose gels. A total of 150 molecular markers were developed in silico using reference genome assemblies of *S. arvensis* and *B. juncea*. Of these, 25 markers were InDel based while rest were genome specific STS markers. Around 100 primer pairs were experimentally tested on genomic DNA of *S. arvensis* and multiple genotypes of *B. juncea* through PCR amplification. A total of 91 primers pairs (69 STS and 22 InDel based) exhibited clear polymorphism between *S. arvensis* and *B. juncea*. The developed molecular markers would be very useful for effective utilization of *S. arvensis* for the genetic improvement of *B. juncea*.

***Keywords*:** *Brassica juncea, molecular markers, sinapis arvensis*

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Genetic variability and multivariate analysis in Indian mustard [*Brassica juncea* (L.) Czerns & Coss] germplasm

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Oilseed crops are of immense global significance and play a crucial role in the Indian economy. Among them, oleiferous Brassica species, collectively known as rapeseed–mustard, occupy a prominent position as major oilseed crops in India. However, a widening gap between oilseed production and consumption growth has caused economic losses and dependence on imports. Amid climate change threats, boosting oilseed productivity and resilience is imperative for achieving edible oil self-sufficiency. The present investigation was carried out in augmented design during rabi, 2022-23 with 208 genotypes of Indian mustard [*Brassica juncea* (L.) Czern & Coss.] were evaluated for twelve agro-morphological traits and four physiological traits. Analysis of variance (ANOVA) revealed significant differences for most of characters viz., number of days to maturity, days to 50 percent flowering, number of primary branches per plant, leaf area index, 1000-seed weight, number of siliquae per plant and seed yield per plant. The estimates of phenotypic coefficient of variation (PCV) were found to be higher than genotypic coefficients of variation (GCV) for all the characters studied. Higher estimates of PCV and GCV were observed for seed yield per plant and chlorophyll content at 90 DAS. High heritability estimates were observed for the traits like leaf area index, 1000-seed weight and seed yield per plant. High heritability coupled with high genetic advance were found for traits 1000-seed weight and seed yield per plant. The seed yield per plant had a positive and significant correlation with leaf area index, plant height, siliqua length, number of siliquae per plant, number of primary branches per plant, number of secondary branches per plant, number of seeds per siliqua and 1000-seed weight. Number of days to 50 percent flowering and number of days to maturity had a negative and significant correlation with seed yield per plant. A critical perusal of path coefficient analysis revealed that high direct effects on seed yield per plant were exerted by total number of siliquae per plant. Multivariate methods, specifically cluster analysis and Principal Component Analysis (PCA), demonstrated significant genetic diversity. The cluster analysis revealed notable variation between the identified cluster groups. Furthermore, the PCA results showed that the first six principal components were collectively accounting for 64.73% of the total variability, surpassing the contribution of the remaining components.

Keywords: *Correlation, cluster analysis, genetic variability, Indian mustard, path analysis, principal component analysis*

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Development of a white rust–resistant Indian mustard (*Brassica juncea* L. Czern & Coss.) strain DRMRIJ 12-44

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White rust caused by *Albugo candida* (Pers. ex Lev.) Kuntze is one of the most devastating diseases of Crucifers and causes severe losses in Indian mustard (*Brassica juncea*). Symptoms of the disease may appear at vegetative stage itself and sustain even at flowering stage. Maximum damage is caused by stag head formation due to malformation of flowering buds directly causing the yield losses. Indian germplasm of *Brassica juncea* generally has been reported to have susceptibility against existing pathogen. Breeding efforts, however, have brought few successes in form of developing resistant cultivars like JM1, Basanti and JM3. One germplasm line Bio-YSR (IC 443623) has earlier been registered as white rust resistant genetic stock derived from exotic source. Genetic studies have revealed dominance of resistance over susceptibility. Resistance to white rust has

been shown to be governed by a single dominant gene. DRMRIJ 12-44 is an inbred line derived from a cross between NRCHB 101 X ZEM 2 (exotic germplasm) followed by individual plant selection. Cross was attempted during 2012-13 between NRCHB 101 and ZEM 2 followed by individual plant selection. Shuttle breeding was followed by raising F_2 generation at IARI Regional Station Wellington during 2014. DRMRIJ 12-44 was inducted to AICRP-RM during 2022-23 for multi-location testing and had been evaluated for two years during 2022-23 and 2023-24. White rust reaction on leaves was recorded at 100 days stage, while staghead formation was recorded at flowering stage. Candidate strain DRMRIJ 12-44 expressed resistant reaction against white rust and disease reaction against white rust on leaves at 100 days stage was recorded at four locations viz., Hisar, Pantnagar, Morena and Bharatpur which included two hot spots (Pantnagar and Morena). On the basis of mean disease index over all four locations, candidate strain DRMRIJ 12-44 expressed 0.9% which is superior than resistant check Bio-YSR (6.4%) and susceptible check NRCHB 101 (31.7%) under artificial conditions. Observations on staghead formation were recorded at Morena and Pantnagar, and on the basis of mean disease index DRMRIJ 12-44 had 0.0 % disease incidence in comparison to resistant check, Bio-YSR (7.1 %) and susceptible check NRCHB 101 (7.6 %). The already reported IP markers AcB1-A4.1 from Heeraand AcB1-A5.1 from Donskaja (Panjabi-Masand et al., 2010, Theor Appl. Genet.) are validated in the concerned strain, DRMRIJ 12-44. It has been found that this genotype possesses locus/genes from Heera and Donskaja which governs resistance for white rust. So, this genotype may be useful in developing mapping population for tagging of WRR gene in future research endeavours.

Keywords: *Disease reaction, indian mustard, white rust resistance*

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Phenotypic and genomic insights into phosphorus use efficiency and resilience in Indian mustard (*Brassica juncea* L. Czern & Coss)

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Phosphorus (P) is an essential macronutrient required for plant growth, energy metabolism, and maintenance of cellular integrity. However, limited availability of soluble inorganic phosphate, high soil phosphorus fixation, and low fertilizer recovery significantly constrain rapeseed-mustard productivity under field conditions. Improving phosphorus use efficiency (PUE) through genetic approaches is therefore critical for enhancing productivity and resilience in Indian mustard (*Brassica juncea* L. Czern & Coss). The present study aimed to dissect the genetic architecture of yield and yield-related traits associated with PUE using field-based phenotypic evaluation and genome-wide association analysis. A diversity fixed foundation set (*BjDFFS*) comprising 280 Indian mustard genotypes was evaluated during the Rabi season at the research farm of Punjab Agricultural University, Ludhiana, under three phosphorus fertilizer levels, namely control (0 kg/ha P), 50% recommended dose (15 kg SSP/ha), and 100% recommended dose (30 kg SSP/ha). Phenotypic observations were recorded for plant height, main shoot length, number of siliquae on the main shoot, number of seeds per siliqua, thousand-seed weight, and seed yield per plant. Analysis of variance was performed to assess genetic variability and genotype × phosphorus level interactions. Best linear unbiased predictors (BLUPs) derived from field phenotypic data were used for genome-wide association studies (GWAS). GWAS was conducted using the GAPIT3 framework, and significant marker–trait associations (MTAs) were identified based on Manhattan and quantile-quantile (Q-Q) plot diagnostics. Field evaluation under contrasting phosphorus regimes revealed highly significant genotypic variation (P d” 0.01) for yield and yield-related traits, indicating substantial genetic diversity for PUE. Mean seed yield declined markedly under phosphorus-deficient conditions, with an overall reduction of approximately 30-45% under control (0 P) compared to the 100% recommended phosphorus dose, while the 50% phosphorus level exhibited an intermediate reduction of 12-20%. Significant genotype × phosphorus level interactions highlighted differential

genotypic responses to phosphorus stress. Genotypes DRMRIJ-17-43, EC-564544, IC-597867, IC-597882, IM-46, RVM-2, and Shivalik exhibited lower yield penalties (H"15-25%) than the population mean under low-phosphorus conditions. GWAS identified 34 genomic regions across both genomes, with A-genome chromosomes (A01, A03, A05, A08) predominantly associated with yield components and B-genome chromosomes (B02, B03, B04, B08) contributing to phosphorus acquisition and utilization efficiency. Key candidate genes included *PHO1* and *CIPK23* (phosphorus homeostasis), *PAH2* and *PLAIVA* (membrane lipid remodeling), *PAP11* and *RNS3* (phosphorus remobilization), and LOG3, AFB5, and GA1 (growth and yield regulation). These findings provide breeding-relevant genomic resources for improving PUE and yield stability in Indian mustard under low-input conditions.

Keywords: *Brassica juncea, genome-wide association mapping, phosphorus use efficiency, resilient crop breeding, yield-related traits*

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Pre-breeding for climate-ready trait introgression in Indian mustard [*Brassica juncea* (L.) Czern & Coss.]

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The productivity and yield stability of Indian mustard (*Brassica juncea* L.) are increasingly challenged by genetic uniformity, emerging biotic stresses and *climate*-induced abiotic constraints. Pre-breeding has become a cornerstone strategy to unlock cryptic genetic variation from unadapted germplasm and wild Brassica gene pools for targeted trait introgression. In Indian mustard, extensive pre-breeding efforts have successfully utilized primary, secondary and tertiary gene pools, including *B. rapa*, *B. nigra*, *B. carinata*, *Sinapis alba* and resynthesized Brassica, to enhance resistance against various biotic and abiotic stresses. Introgression of white rust resistance through *B. juncea* landraces and alien introgression lines, coupled with marker-assisted pyramiding of major resistance loci (e.g., Ac genes), has resulted in stable, broad-spectrum resistance sources. Pre-breeding populations developed from interspecific crosses and backcross derivatives have also contributed alleles conferring tolerance to terminal heat stress, drought and salinity, with several lines exhibiting superior physiological traits such as improved canopy temperature depression and root system architecture. Quality-oriented pre-breeding has enabled the incorporation of low-erucic acid and reduced glucosinolate alleles from exotic donors into agronomically acceptable backgrounds, supporting the development of canola-quality mustard. Recent integration of molecular cytogenetics, high-density SNP genotyping, genome-wide association studies and genomic selection has accelerated the identification and deployment of favourable haplotypes while minimizing linkage drag. Furthermore, pre-breeding lines enriched for enhanced nutrient-use efficiency and higher oil content have been mainstreamed into national breeding pipelines, serving as elite donors for varietal development. Collectively, these advances underscore the pivotal role of advanced pre-breeding platforms in generating climate-resilient, disease-resistant and quality-enhanced genetic resources essential for the sustainable intensification of Indian mustard production.

Keywords: *Alien introgression, linkage drag minimization, high density snp genotyping, pre breeding*

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Multivariate diversity analysis for Sclerotinia stem rot in diverse genotype set of Indian mustard (*Brassica juncea* L.)

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Sclerotinia stem rot caused by *Sclerotinia sclerotiorum* is a major biotic constraint limiting the productivity of Indian mustard in conducive environments. Identification of genetically diverse and disease-tolerant genotypes is essential for effective resistance breeding. The present study was undertaken to assess genetic variability and diversity among mustard genotypes under disease stress conditions. A total of 173 genotypes, including checks, were evaluated during Rabi 2024–25 under artificial inoculation conditions. Disease severity, disease incidence, and area under disease progress curve (AUDPC) were recorded along with yield and yield-attributing traits. Disease reaction was categorized using a modified disease rating scale proposed by Garg et al. (2010). Based on disease response, genotypes were classified into five categories: resistant (7.51%; 13 genotypes), moderately tolerant (10.40%; 18 genotypes), moderately susceptible (18.49%; 32 genotypes), susceptible (19.65%; 34 genotypes), and highly susceptible (43.93%; 76 genotypes), indicating wide variability in response to *S. sclerotiorum*. Analysis of variance revealed significant differences among genotypes for disease parameters and agronomic traits, confirming the presence of substantial genetic variability. Correlation analysis revealed strong positive associations among disease parameters, validating the reliability of disease assessment, whereas grain yield exhibited a significant negative association with AUDPC and disease incidence, indicating yield penalties under increased disease pressure. Grain yield exhibited positive correlations with major yield-attributing traits, highlighting their role in maintaining productivity under disease stress. Principal component analysis revealed that the first three principal components explained 62.24% of the total phenotypic variation, with yield-related traits contributing predominantly to PC1 (27.59%) and PC3 (15.06%), while disease-related parameters were mainly associated with PC2 (19.57%). Genotypes positioned in the low-disease and high-yield quadrant of the PCA biplot were identified as promising sources of tolerance. Hierarchical cluster analysis grouped the genotypes into five distinct clusters, indicating considerable genetic divergence, with Cluster I characterized by low disease severity and AUDPC coupled with superior seed yield. Genotypes from divergent clusters can be exploited to harness heterotic potential. The integrated application of disease reaction grouping, correlation analysis, and multivariate diversity approaches enabled effective classification of mustard genotypes and precise identification of Sclerotinia stem rot–tolerant and genetically diverse lines, which can serve as valuable donor parents for resistance breeding and provide a strong foundation for heterosis breeding, advanced generation selection, and multi-environment evaluation.

Keywords: *Brassica juncea, cluster analysis, disease tolerance, genetic diversity, pca, Sclerotinia stem rot*

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MTSI based selection of high yielding and stable genotypes in yellow sarson

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Multi-environment trials (METs) represent a critical stage of breeding pipelines prior to the release of region-specific or broadly adapted cultivars. Relying on individual traits for selection can lead to misleading conclusions; therefore, robust multi-trait models are essential for accurately identifying superior genotypes. In the present study, the Multi-Trait Stability Index (MTSI) was applied to forty-one accessions of *Brassica*

rapa var. yellow sarson evaluated across three environments to concurrently assess performance and stability across eleven traits. Factor analysis grouped traits into four components-FA1, FA2, FA3 and FA4. Selection differentials were positive for all traits, with maximum gains for seed yield and primary branches and the lowest for oil content. Based on the lowest MTSI scores, six accessions were identified as the most desirable, combining high performance and multi-trait stability. Among them, PYS-2015-3 and PYS-2016-13 were consistently stable for seed yield and key yield components across all models, confirming their resilience. Other accessions such as PYS-2020-7 and PYS-2018-2, though not consistently stable for yield alone, showed stability across multiple traits, demonstrating the advantage of MTSI in capturing overall ideotype proximity rather than single-trait superiority. The results confirm that MTSI enhances the efficiency and accuracy of genotype ranking under heterogeneous environments, outperforming AMMI, GGE and Eberhart-Russell when multi-trait stability is targeted. This underscores the potential of MTSI to support informed selection decisions and accelerate the development of climate-resilient, high-yielding mustard cultivars.

Keywords: *Crop resilient breeding, mtsi, multi-environment trials stability, yellow sarson*

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Genetic insights into yield improvement of Indian mustard [*Brassica juncea* (l.) czern & coss.] through association studies

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Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is major oilseed crop and assessing genetic variability is vital for yield improvement. A study was conducted during Rabi 2022-23 at the Agricultural Research Station, Ummedganj, Kota to assess genetic variability and character associations for yield and its attributing traits in forty Indian mustard genotypes using a Randomized Block Design with three replications. Analysis of variance revealed significant differences among genotypes for all thirteen characters studied. High PCV was observed for number of secondary branches per plant, while moderate GCV and PCV were recorded for biological yield per plant, harvest index, 1000-seed weight and number of primary branches per plant. High heritability coupled with high genetic advance as percent of mean for traits such as 1000-seed weight, number of secondary branches per plant, harvest index and biological yield per plant indicated their suitability for improvement simply through selection. Correlation analysis revealed that number of siliquae per plant, biological yield per plant, primary and secondary branches, harvest index, 1000-seed weight and plant height had significant and positive associations with seed yield at both genotypic and phenotypic levels. Biological yield and harvest index exerted the strongest direct influence on seed yield, while plant height, number of siliquae per plant, 1000-seed weight and secondary branches also had direct positive effect on seed yield. Emphasis on these key traits would significantly improve the efficiency of breeding strategies aimed at developing high-yielding Indian mustard varieties. Genotypes RKM 544, RKM 513, RKM 562, RKM 593 and RKM 530 were identified as superior for seed yield and associated traits, highlighting their potential use in future Indian mustard breeding programs.

Keywords: *Character association, gcv, indian mustard, seed yield, pcv*

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Preliminary varietal screening of *Brassica spp.* against mustard aphid, *Lipaphis erysimi* (kalt.)

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The mustard aphid, *Lipaphis erysimi* (Kaltenbach), is recognized as one of the most destructive insect pests of Brassica crops, inflicting substantial yield losses and quality deterioration across major mustard-growing regions of India. Owing to its rapid multiplication, phloem-feeding habit, and ability to transmit plant stress through honeydew secretion and sooty mould development, effective management of this pest remains a persistent challenge. Host plant resistance offers a sustainable and environmentally safe approach for mitigating aphid damage and reducing reliance on chemical insecticides. In this context, the present investigation was undertaken to evaluate the resistance levels of diverse Brassica genotypes under natural field conditions during the Rabi season of 2024-25. The field screening was conducted under both early and late sowing conditions to examine aphid infestation dynamics across different crop growth stages and environmental scenarios. A total of eleven Brassica entries representing multiple species, namely *Brassica juncea*, *B. rapa*, *B. nigra*, *B. alba*, *B. napus*, *Eruca sativa*, *Crambe abyssinica*, and *B. carinata*, were evaluated. The experiment was laid out in a completely randomized design with three replications. Five plants per genotype in each replication were randomly tagged for observation. Weekly observations were recorded from the initial appearance of aphids until peak infestation, following the standardized methodology described by Dhillon et al. (2018). Data collection included aphid population per plant, aphid population index (API), aphid damage index (ADI), and aphid resistance index (ARI), providing a comprehensive assessment of host response. The results revealed significant genotypic variation in aphid infestation levels and damage intensity under both sowing regimes. Among the tested entries, *Eruca sativa* (T27) and *Brassica napus* (GSC-7) consistently exhibited low aphid populations, reduced damage symptoms, and favourable resistance indices, indicating a high degree of resistance. In contrast, genotypes such as *Brassica rapa* (BSH-1), *Brassica juncea* (PM-30), and *B. alba* were highly susceptible, registering elevated aphid densities and severe damage symptoms, particularly under late sowing conditions. Delayed sowing markedly enhanced aphid buildup and accelerated infestation across most genotypes, highlighting the strong influence of sowing time on pest pressure. Overall, the study underscores the importance of identifying and utilizing resistant genotypes such as *Eruca sativa* (T27) and *Brassica napus* (GSC-7) in integrated aphid management and resistance breeding programs. Continuous evaluation of Brassica germplasm across diverse agro-climatic conditions will be essential for developing durable and stable resistance against mustard aphid.

Keywords: *Aphid resistance, Brassica, economic threshold level, lipaphis erysimi, mustard, varietal screening*

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Oilseed crops in India: Status, challenges, technological advances and future prospects

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Oilseed crops are a vital component of India's agricultural economy, playing a key role in food security, farmer livelihoods, employment generation, and the provision of raw materials for industrial and value-added products. Despite significant gains in production over recent decades, India continues to rely heavily on edible oil imports due to persistent gaps between domestic output and rising demand. This review provides a comprehensive synthesis of the current status of oilseed production in India, including major kharif and rabi crops, regional production trends, and agronomic challenges. It critically examines production constraints, encompassing climatic variability, resource limitations, pest and disease pressures, market inefficiencies, and economic vulnerabilities. The review further highlights technological and agronomic interventions, such as high-yielding and climate-resilient cultivars, precision farming, integrated pest management, and digital tools for yield forecasting and market access. Policy frameworks, including minimum support prices, subsidies, import regulations, and public-private partnerships, are discussed in relation to their impact on farmer welfare, market stability, and value addition. Emphasis is placed on sustainable and coordinated strategies that integrate technological innovation, efficient resource management, and supportive policy measures to enhance productivity, improve farmer income, reduce import dependence, and strengthen India's oilseed sector in the context of evolving climatic and market challenges.

Keywords: *Agronomic interventions, food security, oilseed crops*

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Phenotypic and molecular characterization of diversity fixed foundation set for phosphorus use efficiency in Indian mustard (*Brassica juncea* L. Czern & Coss)

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Phosphorus deficiency is a persistent constraint to mustard productivity due to low availability of plant-accessible inorganic phosphate, high soil fixation, and poor fertilizer recovery, often resulting in substantial yield losses. A diversity fixed foundation set (*BjDFFS*) comprising 280 Indian mustard genotypes was evaluated under controlled hydroponic and multi-location field conditions. Hydroponic screening was conducted at low (5 ìM), normal (250 ìM), and high (1 mM) inorganic phosphate levels, and genotypes were characterized for detailed root architectural traits (primary root length, lateral root density, root volume, root-shoot ratio) and root and leaf acid phosphatase activity. Field evaluations were carried out at 3 locations under three phosphorus fertilizer doses: control (0 kg P/ha), 50% recommended dose (15 kg P/ha), and 100% recommended dose (30 kg P/ha). Statistical analyses revealed highly significant genotypic effects and genotype × environment interactions (P d" 0.01) for all traits. Across locations, mean seed yield under control (0 P) conditions was reduced by approximately 30-45% compared with the

recommended phosphorus dose. GWAS for root architectural traits under hydroponic conditions identified approximately 40 significant genomic regions, predominantly located on A04, B04, B05, B08, and A09 chromosomes, with multiple SNPs associated with genes regulating root growth, root hair development, phosphorus transport, and membrane lipid remodelling. Key candidate genes included *LOG1/LOG7, EXPA5, EXPA14, RACK1A, CIPK23, LPR2, PHO1;H9, PHT4;6, PGPS2, SOS4,* and *IBR5,* indicating diverse molecular mechanisms governing phosphorus acquisition. For root and leaf acid phosphatase activity, GWAS identified 14 genomic regions encompassing 15 candidate genes, distributed mainly across A- and B-genome chromosomes, with SNPs associated with PAP family genes (PAP10, PAP16), PNP, AT5G51260 (HAD superfamily), *PLC2, PLAIVA/PLAIVC, HXK1,* and *ABR1*, highlighting genetic control of phosphorus remobilization and internal recycling. Field-based GWAS for yield and yield-related traits at individual locations identified 34 candidate genes at Ludhiana, 20 at Abohar, and 10 at Faridkot, while pooled analysis across locations detected 25 stable genomic regions. These loci were distributed across A01, A03, A05, A08, A09, B02, B03, B04, and B08 chromosomes, indicating contributions from both A and B subgenomes. Candidate genes regulating yield under phosphorus stress included *PHO1, CIPK1, CIPK23, ALMT3, PEPC1, PAPs, WRKY75, ZAT6, LOG3, AFB5, GA1, PLAIVA, PAH2*, and *RNS3*, linking phosphorus homeostasis with hormone-mediated growth and reproductive development. Transcriptome profiling of two contrasting genotypes under low and normal phosphorus conditions validated nine phosphorus-responsive genes, several of which were common between GWAS and expression analyses, thereby strengthening the functional relevance of identified loci. Based on consistent multi-environment field performance, genotypes DRMRIJ-17-43, DRMRIJ-17-46, EC-564544, IC-597867, IC-597882, IM-46, RVM-2, and Shivalik exhibited comparatively lower yield penalties under phosphorus-deficient conditions.

Keywords: *Acid phosphatase, b. juncea, phosphorus use efficiency, root architectural traits, yield related traits*

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Harnessing early sowing as a selection strategy for developing heat and drought resilient Indian mustard genotype

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Indian mustard (*Brassica juncea* L. Czern & Coss.) is a major oilseed crop in the Indian subcontinent, yet its productivity is increasingly constrained by climate variability, particularly terminal heat and erratic rainfall. Early sowing is emerging as a promising management strategy to help the crop escape late season stress, but systematic evaluation of genotypic responses under early sowing is limited. its effective use requires development of genotypes specifically adapted to early-sown environments and resilient across variable climates. The breeding programme under early sowing focuses on identifying genotypes with rapid early vigor, optimized phenology (timely flowering and maturity), cooler canopies, and robust root and shoot growth to efficiently utilize the extended growing period. Conventional methods such as pedigree breeding, biparental mating and backcrossing are used to combine earliness, stress tolerance, and yield stability from diverse parents, while recurrent selection is applied to gradually improve populations for performance. Hybrid breeding using cytoplasmic male sterility and well-characterized restorers is integrated to exploit heterosis for seed yield, heat tolerance and resource-use efficiency in early-sown environments. To strengthen resilience, early-sown trials are used as managed selection environments to screen segregating generations, advanced lines and hybrids for traits like early ground cover, stay-green, canopy temperature depression, thousand seed weight, oil content and resistance to major diseases. Marker-assisted selection and quantitative trait locus-based approaches can be deployed, wherever available, to introgress and pyramid loci for heat tolerance, drought avoidance, and superior seed quality into early sown adapted genetic backgrounds. Overall, combining early sowing as a deliberate selection

pressure with conventional, hybrid and molecular breeding methods provides a robust pathway to develop Indian mustard cultivars that are resilient, high-yielding and quality-oriented under current and future climate variability.

Keywords: *Canopy temperature depression, climate-resilient cultivars, cytoplasmic male sterility (cms), drought avoidance, genotypic response, marker-assisted selection*

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Molecular characterization of genetic diversity and marker efficiency in Indian mustard (*Brassica juncea*) using SSR markers

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Genetic diversity assessment is essential for effective utilization of germplasm in crop improvement programmes. In the present investigation, 95 Indian mustard [*Brassica juncea* (L.) Czern & Coss.] genotypes were evaluated using 107 SSR markers to quantify molecular diversity and marker efficiency. Out of these, 90 markers showed successful amplification, of which 65 were polymorphic and used for further analysis. The polymorphic SSRs generated a total of 151 alleles, with allele number per locus ranging from 1 to 5 and an average of 2.32 alleles per marker, indicating adequate allelic richness in the studied material. Polymorphic information content (PIC) values ranged from 0.375 to 0.500 with a mean of 0.434, reflecting moderate to high informativeness of the markers. Observed heterozygosity varied from 0.001 to 0.500 (mean 0.322). Marker efficiency parameters revealed an effective multiplex ratio ranging from 0.021 to 3.126 and discriminating power from 0.001 to 1.000, with several markers exhibiting high genotype differentiation ability. Markers such as BG 272 and BG 280 amplified the highest number of alleles, while BG 264, BG 293, BG 330 and BG 344 showed maximum PIC values, indicating their suitability for diversity studies. The combined evaluation of allelic diversity, PIC and efficiency parameters confirmed the utility of the selected SSR markers for reliable genetic diversity assessment and their potential application in Indian mustard breeding programmes.

Keywords: *Genetic diversity, marker efficiency, polymorphic information content, ssr markers*

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Identification of novel and stable sources of white rust resistance in Indian mustard through long-term evaluation under natural epiphytotic conditions at Wellington

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White rust (WR), caused by *Albugo candida* (Ac), is one of the most destructive diseases of Indian mustard, resulting in yield losses ranging from 23 to 89.9%. Since the majority of indigenous Indian mustard germplasm is highly susceptible to WR, breeding programs in India have largely depended on East European resistant donors such as Heera and Donskaja. However, overreliance on these limited exotic sources increases the risk of resistance breakdown and disease epidemics. Therefore, the present investigation aimed to identify novel and stable sources of WR resistance from Indian mustard germplasm. A diverse panel of 96 Indian mustard accessions was evaluated under natural epiphytotic conditions at Wellington for 15 consecutive seasons to assess the consistency of resistance against Ac. The accessions

exhibited differential reactions to the pathogen across seasons, indicating genetic variation in response to the "mixed isolates" of Ac prevalent at Wellington. Notably, seven accessions - WRW 28, WRW 34, WRW 38, WRW 41, WRW 71, WRW 142, and WRW 151 consistently displayed resistant reactions across all 15 seasons of evaluation. Based on long-term phenotypic observations, it was inferred that at least three distinct isolates of Ac are operational at Wellington. The stable resistance exhibited by the seven accessions suggests the presence of resistance (R) gene(s) effective against all prevailing isolates at Wellington. Inheritance studies revealed that all F• s derived from seven "Resistant × Susceptible" crosses (using Rohini as the susceptible parent) expressed complete resistance, indicating dominance of resistance. Further genetic analysis suggested that resistance to the mixed Ac isolates is governed by two dominant genes in WRW 38, WRW 142, and WRW 151, whereas resistance in WRW 28, WRW 34, WRW 41, and WRW 71 is controlled by either one or two dominant genes. Allelism tests involving 14 "Resistant × Resistant" crosses (using Heera and Donskaja as reference resistance sources) showed segregation in the F, populations of WRW 28 × Heera and WRW 28 × Donskaja, fitting a 15:1 ratio. This indicates that WRW 28 harbours resistance gene(s) non-allelic to those present in Heera and Donskaja. Molecular characterization using previously reported WR-linked markers (BjuA015829 linked to *AcB1.4.1*; WR-D IV and WR-360 linked to *AcB1.5.1*) further supported this finding, as WRW 28 failed to amplify resistance-associated alleles at these loci, suggesting the presence of a novel resistance locus. The identification of seven stable WR-resistant accessions, particularly WRW 28 with a potentially new resistance locus, provides valuable genetic resources for mapping novel WR resistance genes and for developing Indian mustard varieties with durable and broad-based resistance to Ac.

Keywords: *Broad based resistance, hot spot, Indian mustard, inheritance of resistance, white rust*

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In vitro evaluation of Indian mustard (*Brassica juncea*) germplasm for drought tolerance at seedling stage

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Drought stress is a critical constraint limiting mustard (*Brassica juncea*) productivity in the semi-arid Bundelkhand region, characterized by erratic rainfall, high temperature, and frequent moisture deficits. Identifying drought-tolerant genotypes at the seedling stage is essential for developing climate-resilient cultivars adapted to Bundelkhand's challenging agro-climatic conditions. Polyethylene glycol (PEG 6000) serves as an effective osmotic stress simulator for screening salt and drought-sensitive plants under controlled laboratory conditions, as demonstrated in recent studies on *Brassica* and other crops. The objective of this study was to identify drought-tolerant Indian mustard genotypes from a diverse germplasm collection using standardized PEG 6000-induced osmotic stress protocol at the seedling stage, specifically targeting adaptation to Bundelkhand region conditions. A comprehensive two-phase experimental approach was followed into two phases: Protocol standardization and large-scale germplasm screening. PEG 6000 concentration was standardized using select mustard genotypes across five levels (0%, 10%, 20%, 30%, and 40%) following ISTA standards. Surface-sterilized seeds (1% sodium hypochlorite treatment) were arranged at 50 seeds per autoclaved petriplate and incubated under controlled conditions. Observations including germination count (5th and 7th day), root and shoot length, fresh weight (10th-12th day), and dry weight were recorded. All 281 Indian mustard genotypes were evaluated under two conditions: control (0% PEG) and optimized stress treatment (20% PEG 6000). Standard morphological parameters along with Seed Vigor index were assessed to identify superior performers under drought stress conditions representative of Bundelkhand's drought scenarios. Protocol standardization identified 20% PEG 6000 as the optimal concentration for effectively inducing osmotic stress while permitting adequate germination and growth responses, consistent with findings from similar PEG-based screening studies in *Brassica* and other crops. From the comprehensive screening of 281 germplasm accessions, 20 drought-tolerant genotypes were identified that exhibited superior performance under 20% PEG treatment relative to

control conditions, as evidenced by maintained germination rates, enhanced root-shoot development, and higher vigor indices. The standardized PEG 6000 protocol effectively discriminates drought-tolerant from susceptible Indian mustard genotypes at the seedling stage. The identified drought-tolerant accessions represent valuable genetic resources for developing climate-resilient mustard varieties specifically adapted to Bundelkhand region conditions and serve as potential donor parents for marker-assisted breeding programs targeting drought-prone semi-arid environments.

Keywords: *Brassica juncea, climate resilience, drought tolerance, osmotic stress, peg 6000, seedling stage*

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Study of heterosis and inbreeding depression for seed yield and its contributing characters in Indian mustard [*Brassica juncea* (L.) Czern & Coss.]

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Indian mustard (*Brassica juncea* L.) is an important oilseed crop which occupies premier position in Indian agriculture. Developing high yielding genotypes has been a major breeding objective in Indian mustard. The experiment was conducted in compact family block design with three replications during rabi 2022-23 at Centre for Oilseeds Research, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat in order to study heterosis and inbreeding depression for seed yield and its contributing characters in Indian mustard [*Brassica juncea* (L.) Czern & Coss.]. The expression of heterosis and heterobeltiosis was maximum for seed yield per plant followed by number of siliquae per plant, number of secondary branches per plant and 1000 seed weight. For seed yield per plant, cross III (GDM 4 × PM 30), cross IV (GM 6 × PDZM 31) and cross VI (RB 50 × NUDHYJ 4) depicted significant and positive relative heterosis and heterobeltiosis. These crosses also showed significant desirable heterosis and heterobeltiosis for number of others yield contributing traits. The cross III also showed significant and desirable estimates of relative heterosis and/or heterobeltiosis for days to flowering, days to maturity, number of primary and secondary branches per plant, number of siliquae on main branch, number of siliquae per plant and 1000 seed weight, while cross IV exhibited significant and desirable relative heterosis and/or heterobeltiosis for days to flowering, days to maturity, number of secondary branches per plant, number of siliquae per plant, length of siliqua and oil content. Cross VI showed significant relative heterosis and/or heterobeltiosis in desirable direction for days to flowering, number of primary branches per plant, number of secondary branches per plant, length of main branch, number of siliquae per plant and length of siliqua. Therefore, these crosses may be exploited for commercial cultivation on the availability of workable CGMS system and effective hybrid seed production technology. The magnitude of inbreeding depression was found positive and significant for days to maturity, plant height and erucic acid in cross VI. While significant negative inbreeding depression was observed for 1000 seed weight [cross V (DRMR 150-35 × LES 44)]; oil content (cross VI); oleic acid [cross II (ANDM 14-9 × GM 3) and cross V] and linoleic acid (cross VI), hence these crosses would likely to yield transgressive segregants for the characters under consideration.

Keywords: *Heterosis, inbreeding depression, Indian mustard, seed yield*

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Generation mean analysis for seed yield and its components characters in Indian mustard [*Brassica juncea* (L.) Czern & Coss.]

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Indian mustard [*Brassica juncea* (L.) Czern and Coss.] is one of the prime oilseed crops of the country occupying largest area among the Brassica group of oilseed crops. An understanding of the mode of inheritance of the yield and yield components is necessary for the intelligent choice of breeding procedures for developing high yielding varieties/hybrids. In view of these facts, the present investigation was carried out at Centre for Oilseeds Research, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar during rabi 2022-23 in order to estimate gene effects, heritability and expected genetic advance for seed yield and its components. The experimental material, comprising of six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2) raised from six crosses viz., cross I (SKM 1746 × SKM 1620), cross II (ANDM 14-9 × GM 3), cross III (GDM 4 × PM 30), cross IV (GM 6 × PDZM 31), cross V (DRMR 150-35 × LES 44) and cross VI (RB 50 × NUDHYJ 4) were grown in a compact family block design with three replications. The individual scaling test/s and/or c^2 value of joint scaling tests were significant in all the crosses for various characters except length of siliqua in cross II and cross III and number of seeds per siliqua in cross II indicating the inadequacy of additive-dominance model and presence of inter-allelic interactions and/or linkages. The estimates of gene effects revealed the presence of only additive gene effect for the expression of plant height in cross IV; length of main branch in cross I; number of siliquae on main branch in cross V and cross VI; length of siliqua in cross II and cross III and number of seeds per siliqua in cross II and cross VI. The non-additive gene effect was found for number of primary branches per plant in cross IV and cross V; number of secondary branches per plant and number of siliquae per plant in cross III, cross IV and cross VI. The results further revealed the involvement of both additive and non-additive gene effects for days to flowering and days to maturity in all the crosses; plant height in cross I, cross II, cross III, cross V and cross VI; number of primary branches per plant in cross I, cross II, cross III and cross VI, number of secondary branches per plant in cross I, cross II and cross V; length of main branch in all crosses except cross I, number of siliquae on main branch in cross I, cross II, cross III and cross IV; number of siliquae per plant in cross I, cross II and cross V; length of siliqua in cross I, cross IV, cross V and cross VI; number of seeds per siliqua in cross III and cross IV; seed yield per plant, 1000 seed weight, oil content, oleic acid, linoleic acid, linolenic acid and erucic acid in all the crosses. High estimates of narrow sense heritability along with high genetic advance was observed for seed yield per plant and number of siliquae per plant in cross I (SKM 1736 × SKM 1620), cross III (GDM 4 × PM 30), cross IV (GM 6 × PDZM 31) and cross VI (RB 50 × NUDHYJ 4) suggested the preponderance of additive/fixable gene effect and hence these characters could be further improved by adopting selection in succeeding segregating generations. However, high values of narrow sense heritability coupled with moderate values of expected genetic advance were identified for most of the characters in various crosses; this indicated that inheritance of these characters could be controlled by both additive and non-additive gene effects. In general, with the consideration of results revealed by different genetic parameters for all the crosses, additive and/or non-additive gene effects were important for most of the characters, so population improvement through inter se /bi-parental mating and cyclic selection such as reciprocal recurrent selection would be most effective to stabilize additive genes, to elevate population mean and also to generate as well as to retain variability for several cycles of selection.

Keywords: *Gene action, genetic advance, heritability, Indian mustard*

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Development of new plant type in *B. rapa* obtained through inter-specific hybridization between *B. tournefortii* and *B. rapa*

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The Brassicas are an important group of crops in India yielding oils and many vegetables. For improving cultivated Brassicas, the distant relatives are of considerable value. Wide hybridization is the way which could combine the valuable features of parental species into the hybrid. Crosses between *B. tournefortii* (2n=20, TT) and *B. rapa* (2n=20, AA) by sexual mating. The F_1s were obtained only when *B. tournefortii* was used as female parent. Morphological, cytological and sequence tagged microsatellite sites (STMS) based molecular analyses were carried out to confirm the hybrid nature of F_1 plants. Morphologically, the F_1 plants were intermediate for most of the morphological attributes. From F_3 selected progenies maintained and advanced up to F_{11} generations. Present study also indicated that inter-speciûc hybridization in Brassica could be a potential source for generating variability besides broadening the genetic base and segregants with desirable agro-economical characteristics were selected for further advancement and evaluation. Here, we report successful synthesis of interspecific hybrids between *B. tournefortii* and *B. rapa* var. yellow sarson (NRCYS-05-02) by sexual matings followed by their characterization in terms of morphological attributes, genome homology and differentiation pattern based upon crossability, meiotic behaviour of chromosome and fertility factors. Besides, sequence tagged microsatellite (STMS) analysis of the parents. Reciprocal interspecific crosses between plants of the cultivated *B. rapa* var. yellow sarson (NRCYS-05-02) and *B. tournefortii* were attempted to produce interspecific hybrids. Unopened flower buds of *B. rapa* were emasculated in the afternoon, covered with paper bags and pollinated with freshly collected pollens of *B. tournefortii* in the following morning and rebagged. The seeds collected from the crosses as well as from the parents were sown in pots under field conditions. The F_1 hybrid plants were medium in height, profusely branched and intermediate to their parents for most of the morphological and inflorescence attributes. The leaves were light green in colour with sparsely hairy, petiolate, lobed and lyrately pinnatified. The F_1 plants were tall and exhibited enhancement in values of attributes like primary and secondary branches, main raceme length, siliquae on main raceme and siliquae per plant. The least significant difference (LSD) at 5% of plant height, days to flowering, number of primary and secondary branches per plant, main raceme length and seeds per siliqua of the F_1 plants were recorded to be significant between the parents The seeds of hybrids were small in size, similar to those of *B. tournefortii*, and light brown in colour. In the present study, four interspecific hybrid plants were obtained through sexual hybridization between *B. tournefortii* and *B. rapa* var. yellow sarson (NRCYS-05-02). Interspecific hybrid plants were obtained when *B. tournefortii* was used as a female parent and all the hybrids grew up to maturity. The F_1 hybrid plants (2n=20) obtained were found to be intermediate and vigorous in terms of many phenotypic features and inflorescence attributes of both the parents. These observations are in congruence with the earlier report. The occurrence of characteristics from both progenitor species in the hybrids indicates that the F_1 plants inherited genomes of both parental species crossed. This is an advantage, since it would allow better selection for specific attributes in segregating progenies. Meiotic studies of F_1 hybrids (2n=20) not only confirmed the hybridity of F_1 but also indicated extent of genome homoeology between the parents. Similarly, in the *B. rapa* haploid, Armstrong and Keller (1981) reported a maximum association of 1III + 2II resulting from auto-syndesis within the A genome. These findings suggest that a total of at least 2III + 4II or 6II might theoretically be possible due to auto-syndesis within both the T and A genomes. In the present investigation, 35 STMS markers derived from *B. napus*, *B. nigra*, *B. oleracea* and *B. rapa* were used for the molecular analysis of parents and the hybrid plants.

Keywords: *B. rapa, b. tournefortii, interspecific hybrids, pre breeding, stress tolerance*

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Identification of stable genomic regions and candidate genes governing seed weight and yield traits in Indian mustard (*Brassica juncea*) through multi-environment GWAS

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Indian mustard [*Brassica juncea* (L.) Czern. & Coss.] accounts for more than 90% of the rapeseed–mustard cultivated area in India, with a substantial portion grown under rainfed conditions. Climate change, however, poses a growing threat to rainfed mustard production, leading to considerable yield reductions. Conventional breeding approaches for developing climate-resilient varieties are time-consuming and resource-demanding. Marker-assisted selection offers an efficient alternative to address these limitations. Accordingly, this study was undertaken to detect genomic regions associated with yield and its component traits through genome-wide association studies (GWAS). A diverse panel of 142 Indian mustard genotypes was assessed for 15 yield and yield-related traits across rainfed and irrigated environments during the *rabi* seasons of 2021–22, 2022–23, and 2023–24, showing significant genotypic variation. The panel was genotyped with the Brassica 90K SNP array (Illumina). Population structure and diversity analyses divided the panel into three subpopulations, while linkage disequilibrium (LD) decay was established at 1.05 Mb. GWAS conducted using the BLINK model identified a total of 955 markers–trait associations (MTAs), comprising 317, 376, and 262 MTAs across the three respective seasons; two ecologies and fifteen yield and yield-attributing traits. Of these, fourteen MTAs exhibited high stability (detected in more than four environments) for traits such as days to 50% flowering (DF), main shoot length (MSL), plant height (PH), siliqua length (SL), seeds per siliqua (SPS), 1000-seed weight (TSW), and oil content (OC). In silico examination of genomic regions flanking these stable SNPs identified candidate genes implicated in relevant molecular, physiological, and biochemical pathways. As 1000-seed weight is a critical trait in oilseed *Brassica*, GWAS pinpointed two highly stable SNPs—Bj-B3-p17726495 (PVE: 17.77%; chromosome B03) linked to *SAMBA* and Bj-B4-p10707039 (PVE: 18.05%; chromosome B04) linked to *NAC TF25*. Sequencing and cloning of these genes from contrasting parents revealed numerous SNPs and InDels, underscoring their likely contribution to phenotypic variation. Markers derived from these MTAs were successfully validated in the F, population derived from DRMRIJ-31 × RLC-3. Using comparative mapping of prominent seed weight QTLs on chromosome A09 of *B. napus* highlighted *ARF18* as another promising candidate gene. Sequencing of *ARF18* in bold- and small-seeded *B. juncea* lines uncovered multiple SNPs and InDels; an InDel-based marker targeting this region was developed and validated in a germplasm set, explaining 10.79% of phenotypic variance. Together, the three loci (Bj-B3-p17726495, Bj-B4-p10707039, and ARF18) exhibited additive effects contributing 35.79% PVE. This foundational investigation of seed weight-related candidate genes and molecular markers in *Brassica juncea* will support future improvements in seed size through marker-assisted breeding or genome-editing approaches. Furthermore, the remaining identified genes for other key traits can be further explored and harnessed to enhance precision in future breeding programs.

Keywords: *Candidate genes, gwas, Indian mustard, marker-assisted breeding rainfed, multi-environment, stable mtas, 1000-seed weight*

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Influence of biochemical contents in rapeseed-mustard on infestation of melon thrips, *Thrips palmi* (Karny)

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Rapeseed-mustard is an important oilseed crop grown extensively during the Rabi season in India. Among the sucking insect pests, recently melon thrips, *Thrips palmi* (Karny), has emerged as a constraint to rapeseed-mustard production by causing damage and reducing crop vigour and yield. Host plant resistance is an eco-friendly and sustainable approach for managing thrips infestation. Biochemical constituents such as glucosinolates, phenols, and sugars are known to influence plant–insect interactions. Therefore, understanding the relationship between biochemical traits of mustard varieties and thrips infestation is essential for identifying resistant genotypes. The present study was conducted during Rabi 2025 at Pantnagar, Uttarakhand. Promising and susceptible rapeseed-mustard varieties namely YST 151 (*Brassica rapa* var. yellow sarson), BSH 1 (*Brassica rapa*), DRMR IJ-31 (*Brassica juncea*), PM30 (*Brassica juncea*), GSC-7 (*Brassica napus*), *Brassica nigra*, *Brassica alba*, and T27 (*Eruca sativa*), identified through field screening against *T. palmi* were selected for biochemical analysis. Seed samples were analyzed for total glucosinolates, total phenols, total soluble sugars using standard biochemical estimation methods. The mean thrips population recorded on respective varieties was correlated with the biochemical parameters using appropriate statistical tools to determine the nature and strength of their association. Biochemical analysis of seeds revealed significant variation among the tested varieties. Total phenol content exhibited a significant negative correlation with thrips infestation (r = –0.781**), indicating its strong role in imparting resistance against *T. palmi*. Similarly, glucosinolate content showed a significant negative correlation (r = –0.759*), suggesting its involvement in reducing thrips preference and feeding. In contrast, total sugar content was found to be positively correlated with thrips infestation (r = 0.824*), indicating that higher sugar levels may enhance host attractiveness and susceptibility to thrips attack. Varieties possessing higher phenol and glucosinolate content consistently recorded lower thrips population, whereas susceptible varieties showed elevated sugar levels and higher infestation. The findings clearly indicate that biochemical constituents play a decisive role in determining the resistance or susceptibility of mustard varieties to *Thrips palmi*. Higher glucosinolate and phenol content likely act as feeding deterrents, while increased sugar levels enhance host suitability for thrips. These biochemical traits can serve as reliable indicators for screening and developing thrips-resistant mustard varieties. Incorporation of such traits in breeding programs can contribute to sustainable pest management and reduced reliance on chemical insecticides.

Keywords: *Insect resistance, rapeseed-mustard, thrips*

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Characterization of marker assisted derivatives for low erucic acid and white rust resistance in Indian mustard [*B. juncea* (l.) Czern. and Coss.]

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Indian mustard (*B. juncea* L.), a member of family Brassicaceae, is an economically important oilseed crop cultivated for its oil rich seeds, tender leaves and used as condiment. Despite its economic importance, the crop's productivity and oil quality are affected by high erucic acid content in seed oil and susceptibility to white rust. The seed oil of Indian mustard contains 40-57% erucic acid which poses serious health risks due to its association with elevated cholesterol levels and cardiovascular disorders. Additionally, Indian mustard cultivation is seriously threatened by white rust, which is brought on by the oomycete Albugo candida and results in large yield losses. Erucic acid content and white rust resistance in Indian

mustard are controlled by well defined genes, namely the *FAE1* paralogs (*FAE1.1* and *FAE1.2*) for erucic acid biosynthesis and AcB1 loci for white rust resistance, the availability of tightly linked marker enabled efficient marker-assisted pyramiding of low erucic acid and white rust resistance traits in improved mustard genetic backgrounds. Present study was undertaken in which BC_3F_1 generation was raised from a cross between PBR357 and RLC3 (PBR357/RLC3//PBR357). RLC3 is a Canola type and white rust resistant variety of PAU and was used as donor parent. The genomic DNA extractions were carried out with minor modifications of CTAB method (Doyle and Doyle 1990). Biochemical traits such as Erucic acid, oil content were measured using standard techniques. White rust screening was done by standard procedure (Fox and Williams 1984) on 0-9 scale (AICRP).The morphological superior plants from BC_3F_1 were selected and selfed to generate BC_3F_2 during Rabi season 2024-25. The offseason sowing was done at Keylong. Gene specific markers for erucic acid and white rust were used for genotyping the BC_3F_2 generation. Marker assisted selection using SSR markers (*FAE1.1, FAE1.2* for erucic acid and At2g36360 for white rust) was done to identify homozygous plants for erucic acid and white rust. Out of total 489 plants, 33 plants were found to be homozygous for low erucic acid and white rust resistance. The Selected plants were sown to generate BC_3F_3 during rabi season 2025-26 in randomized block design (RBD) with two replications in paired rows and are under evaluation for morphological and biochemical traits.

Keywords: *Canola, erucic acid, gene-specific markers, indian mustard, marker-assisted selection, white rust*

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Rapid and non-destructive assessment of seed vigour in rapeseed-mustard using Near-Infrared Spectroscopy

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Rapeseed and mustard are among the most important oilseed crops contributing significantly to edible oil production in India, where seed quality plays a critical role in ensuring uniform crop establishment and productivity. Seed vigour is a key determinant of rapid germination, seedling growth and field performance; however, conventional seed vigour assessment methods are time consuming, labour-intensive and destructive, thereby limiting their application for rapid seed quality assessment. In this context, near-infrared spectroscopy (NIRS) offers a rapid, non-destructive and high throughput alternative for assessing physiological seed quality through indirect measurement of chemical composition. The present study was undertaken to use NIRS for predicting seed vigour parameters in rapeseed and mustard. A total of 300 genotypes representing different brassica species were evaluated for standard seed quality parameters including germination percentage, seed vigour index-I and seed vigour index-II using established testing procedures. Seeds were scanned using a FOSS NIRS DS3 instrument and reflectance spectra were recorded in the near-infrared region. Chemometric calibration and validation models were developed by regressing reference seed vigour data with spectral information using appropriate derivative treatments. Considerable variability was observed among genotypes for germination and vigour parameters, providing a robust dataset for model development. The NIRS spectra revealed characteristic absorption features associated with functional groups related to oil, moisture and nitrogen containing compounds, indicating the sensitivity of the technique to biochemical constituents underlying seed vigour. Predictive models developed for germination percentage, seed vigour index-I and seed vigour index-II showed good performance with coefficients of determination (R^2) ranging from 0.73 to 0.78 and ratio of performance to deviation (RPD) values close to 2.0 during validation. These results demonstrate the ability of NIRS to

reliably discriminate between seed lots differing in vigour status and to predict key vigour parameters with acceptable accuracy. The study highlights the potential of NIRS as a rapid, non-destructive and cost-effective tool for seed vigour assessment in rapeseed and mustard, with practical implications for seed testing laboratories, breeding programmes and the seed industry. Adoption of this technology can facilitate faster decision-making, improve seed quality assurance and contribute to enhanced oilseed productivity, supporting the broader goal of edible oil security in India.

Keywords: *Near infrared spectroscopy, non-destructive, rapeseed and mustard, seed vigour*

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Deciphering the genetic architecture of seed yield in *Brassica napus* using multi-trait mixed models

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Oilseed Brassica crops are among the most extensively cultivated oilseed species globally. In India, they constitute the principal source of edible oil, contributing nearly 45% of the country's total vegetable oil production. The present investigation was conducted on *Brassica napus* to estimate variance components, genetic parameters, and genotypic performance across multiple years using best linear unbiased prediction (BLUP) approach. Additionally, a stepwise regression analysis was employed to identify key seed yield associated traits and to develop a path diagram illustrating the direct and indirect effects of these traits on seed yield. A panel of 100 diverse accessions was assessed for 19 agro-morphological and yield-related traits across two seasons during rabi 2023-24 and 2024-25 using an alpha lattice design. Variance components were estimated from pooled multi-environment data through analysis of variance (ANOVA) using META-R software. Best linear unbiased predictors (BLUPs) were computed for each genotype across years within a location and across all environments (single location over two years). Pearson's correlation coefficients among genotypic traits were calculated based on BLUP values using R software (version 3.5.1). To determine the most influential agronomic traits affecting seed yield per plant, a stepwise regression model was fitted. Significant genotypic variability and strong genotype x environment interactions were detected for most of the traits. The genetic variance was found to be highly significant (P d" 0.01) for the individual and under pooled analysis for all evaluated traits, demonstrating a vast reservoir of genetic variability that offers substantial opportunities for exploitation in future breeding programmes. High heritability, coupled with high genetic advance and genotypic coefficients of variation, was observed for secondary branching, biological yield/plant and seed yield/plant; hence, a superior genetic gain is anticipated through the selection of these traits in subsequent generations. Yield contributing traits including main shoot length, siliquae length, total siliquae per plant, seeds per siliquae, and harvest index showed strong positive correlations with seed yield, a pattern further supported by principal component analysis, which clustered major yield attributes together. Stepwise regression analysis indicated that primary branches per plant, days to flower initiation, plant height, total siliquae per plant, seeds per silquae, biological yield/ plant and harvest index were the most significant contributory traits for seed yield/plant. The effectiveness of selection in crop improvement programs largely depends on the magnitude of genetic variability and the reliability of heritability estimates. The results of the present study demonstrated substantial genetic variation among the evaluated traits, indicating ample potential for achieving further genetic improvement. The application of BLUP-based estimates improved selection accuracy by reducing residual variation, facilitating the identification of promising genotypes for Brassica breeding programs. Additionally, these findings provide valuable guidance for enhancing seed yield through the selection of traits exhibiting strong and favourable correlations with yield.

Keywords: *B. napus, canola, multi-trait mixed models*

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Establishing LD_{50} of EMS for Mutation-based improvement of Sclerotinia stem rot resistance in Indian mustard

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Mutation breeding is a promising approach for generating Unique genetic variation which are not been reported earlier, involved in crop improvement, particularly for disease resistance breeding. Various chemical and physical mutagens are responsible for this. Ethyl methanesulfonate (EMS) is a broadly used chemical mutagen because of its high mutation efficiency. The current study was undertaken to ascertain the median lethal dose (LD_{50}) of EMS to induce mutation in oilseed Brassica, a prerequisite for successful mutation breeding programs, to obtain a mutant population with the expectation of developing resistance to Sclerotinia stem rot in Indian mustard (*Brassica juncea* (L.) Czern. & Coss.). For that purpose, two varieties of Indian mustard, including DRMR IJ 31 and NRCHB 101 was taken and their biological responses, such as germination percentage, were evaluated. Results demonstrated the significant influence of EMS dosage and treatment period on seed germination with respect to control/untreated. The optimised LD_{50} value for NRCHB 101 was 0.897 %, whereas for DRMR IJ 31 was slightly higher, 0.974 % at an exposure duration of 6 hr, indicating genotypic variation in mutagen sensitivity. Results will further be utilised for large-scale mutagenesis to aim for a mutant population. Mutants will be further screened for the various traits, with particular emphasis on identifying resistance sources against S. sclerotiorum. The current study establishes a foundational framework for mutation breeding to enhance disease resistance in Indian mustard.

Keywords: *EMS, Indian mustard, mutation breeding, stem rot*

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Meta-transcriptomic insights into temporal effector deployment by *Sclerotinia sclerotiorum* during oilseed Brassica infection

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Sclerotinia sclerotiorum is a globally important necrotrophic fungal pathogen that causes Sclerotinia stem rot in oilseed Brassica, leading to substantial yield losses. The pathogenic success of *S. sclerotiorum* relies heavily on the coordinated expression of effector proteins that facilitate host tissue colonization, immune suppression, and metabolic adaptation. Although several transcriptomic studies have explored effector expression during infection, their conclusions are often limited by specific experimental conditions and infection stages. To identify conserved and time-resolved effector strategies, we performed a focused meta-analysis of two pathogen-centric RNA-seq datasets, PRJNA327437 and PRJNA777355, representing multiple infection time points. Raw sequencing data were uniformly processed using a standardized bioinformatics workflow, including quality filtering, genome alignment, transcript assembly, and differential expression analysis. Candidate effector proteins were predicted using EffectorP, supported by signal peptide and transmembrane domain screening, followed by functional annotation using Gene Ontology and KEGG pathway analyses. The meta-analysis revealed a distinct, phased effector deployment strategy in S. sclerotiorum. Early infection stages were characterized by the strong induction of apoplastic

effectors, including polygalacturonases, cutinases, and GDSL lipases, which are primarily involved in host cell wall degradation and penetration. In contrast, later stages showed enhanced expression of cytoplasmic effectors associated with immune modulation, oxidative stress regulation, and nutrient acquisition, supporting sustained necrotrophic growth. Notably, a core set of effector genes was consistently expressed across both datasets and multiple time points, indicating a conserved virulence repertoire essential for pathogenicity. These conserved effectors represent high-confidence molecular targets for functional validation and host-induced gene silencing approaches. Overall, this study demonstrates that meta-transcriptomic integration of pathogen-focused datasets provides robust insights into effector biology and advances our understanding of *S. sclerotiorum* infection strategies in oilseed Brassica.

Keywords: *effector-protein, host-pathogen interaction, stem rot, transcriptome*

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Optimization of photoperiod and light spectrum for speed breeding in *Brassica species*

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The world is moving at a fast speed reaching targets with short time. Breeders often shoulder the responsibility of the world, the ever raising population demands breeders to come up with cultivars to match the pace of requirements. Speed breeding, a rapid generation advancement procedure is one such tool to solve these obstacles, which is based on extending the light duration providing crop favourable conditions thereby reducing time duration also leading to increased genetic gain per cycle. Breeders all over the globe are working on its adaptability on different crops. Although works have been carried out on canola, mustard a prime oilseed in our country is yet to be fully explored under this new tool. Through our study we aimed to set a protocol for light duration and light spectrum for 4 species of *Brassica* namely 3 varieties *B. juncea* comprising early mid and late maturing variety, one each of *B. campestris, B. napus and B. carinata.* 4 different light spectrum of Red: Blue light was provided in the ratio 1:2, 2:1, 1:1 and a control treatment combination under 2 different light duration treatments of 22 hours light and 18 hours light. An End of day far red light of 30 minutes was provided prior the start of dark period. Observations such as days to flowering plant height, canopy temperature, chlorophyll content, photosynthetic efficiency and days to maturity were recorded. The treatments with higher Red: Blue promote faster growth since red light induces flowering and blue light primarily induces vegetative development. A temperature 24–26°C during day and 17–18°C during night with a relative humidity of 60–65% was maintained. Light intensity of 300-450 PPFD during vegetative stage, in reproductive stage of 400-600 PPFD and during maturity phase 300-500 PPFD was maintained. The best found treatments will make way for providing the ideal conditions for crop cultivation under speed breeding environment. This work can also be used for future programmes and save time. Thereby the study can contribute to development of new cultivars under rapid generation advancement conditions helping breeders to overcome decade long wait for release for new varieties.

Keywords: *Brassica species, genetic gain, light spectrum, rapid generation advancement, speed breeding*

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Genome-wide association mapping uncovers key candidate genes governing pod shatter resistance and pod length in allohexaploid Brassica

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Pod shatter resistance represents an important breeding objective in global Brassica improvement programmes due to its significant role in reducing seed losses at crop maturity and mechanical harvesting. We evaluated a Brassica allohexaploid panel (AABBCC; 2n= 54) comprising 63 mutated allohexaploid progenies, 10 selections made from late-generation progenies of primary allohexaploids and 17 selfed generations of freshly synthesized allohexaploid genotypes to understand the genetic control of pod shatter resistance and its association with pod length under timely sown (E1) and late sown conditions (E2) in augmented design along with 4 checks (GSC-7, PBR-357, PC-6 and Giriraj). Pod shatter resistance is measured as rupture energy (mJ). Rupture energy (RE) ranged from 3.79 mJ to 13.06 mJ and 3.95mJ to 11.84 mJ in E1 and E2, respectively. This was in comparison to the average energy required to rupture pods in *B. juncea* (9.6 mJ for both PBR-357 and Giriraj in E1 and 6.5 mJ for PBR-357 and 8.5 mJ for Giriraj in E2), *B. carinata* (7.3 mJ in E1 and 5.2 mJ in E2), and *B. napus* (5.9 mJ in E1 and 4.4 mJ in E2). Pod Length (PL) ranged from 2.79 cm to 5.03 cm in E1 and 2.61 cm to 5.71 cm in E2 as compared to the average pod length in *B. juncea* (4.1 cm and 4.4 cm for PBR-357 and Giriraj, respectively in E1; and 5.4 cm and 5.2 cm for PBR-357 and Giriraj, respectively in E2), *B. carinata* (4.6 cm in E1 and 5.1 cm in E2), and *B. napus* (6.7 cm and 6.9 cm in E1 and E2 respectively). The analysis of variance (ANOVA) revealed significant differences for both the traits. Correlation studies revealed a positive association between pod length (cm) and rupture energy (mJ) in both the environments. Mean versus stability plots for these traits revealed that P_Hexa_1, P_Hexa_11, Hexa_L_14, P_Hexa_9 and P_Hexa_12 are the five best-performing genotypes, which are stable across both environments. SNP-Genome Wide Association Studies (SNP-GWAS) and SV-GWAS revealed complex genetic architecture underlying these traits. Significant marker trait associations and annotation of genomic space around peak SNPs facilitated prediction of the importance of LAC2 in the genetic regulation of shatter resistance in Brassica allohexaploid. *NAC007, POM1, SSE1 and CYP86A8* appear to be important for pod length. This study provides potential gene targets to understand molecular mechanisms and improve pod shatter resistance and pod length in Brassica crops.

Keywords: *Analysis of variance, brassica allohexaploid, correlation, gwas*

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Study of Genetic variability between BiPs and F_3 populations among three different L×T crosses of Indian mustard

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The present investigation was carried out to assess the genetic variability generated as biparental progenies (BiPs) and F_3 populations from the crosses, RH 725 × Urvashi (cross I), DRMRIJ 31 × Urvashi (cross II) and PM 27 × Urvashi (cross III) in Indian mustard [*Brassica juncea* (L.) Czern & Coss] under field during Rabi 2021-24. Both biparental and F_3 progenies exhibited significant variability for seed yield and most yield-related traits across all the three crosses, except for plant height in cross II. However, the mean performance of BiPs was generally higher than the corresponding F_3 progenies, indicating the generation of significant genetic variability, shedding light on the dynamics of genetic inheritance and expression within Indian mustard. While the BiPs showcased superior mean performance in pivotal

traits, F_3 generation displayed competitive superiority in traits including days to 50% flowering, plant height, number of secondary branches per plant, number of seeds per siliqua, 1000-seed weight, biological yield per plant and oil content. It is evident that good recombination occurred from intermating, and also the dominance and epistasis components might have played some role in the increase in the mean of BiPs, compared to F_3. For a few traits, the genetic variability carried over to the F_3 generation and made selection effective. The study reflected that the use of genetically divergent parents such as RH 725, DRMRIJ 31 and PM 27 crossed with Urvashi enhanced recombination potential and the crosses seem to have facilitated the appearance of novel segregants in both F_3 and BiPs and offered enhanced opportunities for selecting transgressive segregants, giving enhanced yield and oil content gain.

Keywords: *Biparental progenies, F_3 progenies, Indian mustard, mean, variability*

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Associating genome structural variations with fertility and seed traits in Brassica allohexaploid radiation panel

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A synthetic Brassica allohexaploid has the potential to evolve into a new synthetic species with increased productivity, crop resilience and genetic diversity. Present investigation aimed to catalogue phenotypic variation available in an assembled set of 90 allohexaploid genotypes and unravel the underlaying genetic architecture. This was considered important as there are still many genetic obstacles like genome instability, a narrow genetic base and little or no information about the genetics underlaying the available phenotypic diversity. Previous work at PAU has facilitated the development of stable allohexaploids, but the genetic base of available genotypes remains low. The present investigation aimed to enhance the genetic base through induced mutagenesis in a stable allohexaploid selection and inclusion of a few freshly synthesized allohexaploids. This study assessed key economic traits across 90 Brassica allohexaploid genotypes in two environments created by varying sowing dates. The analysis of variance revealed significant differences for all traits, except for days to 100% flowering and harvest index in E2. Only a few allohexaploid genotypes outperformed the crop allotetraploid checks under timely or late sown conditions. SNP-Genome-Wide Association Studies (GWAS) and SV-GWAS revealed the complex genetic architecture behind flowering, yield-related and shattering traits and allowed identification of many important candidate genes. RNASeq analysis in the pollinated and unpollinated pistils of Brassica allohexaploid and the progenitor species facilitated prediction of many important genes linked to the processes of micro and megasporogenesis. Present results are expected to pave the way for directed evolution of a new synthetic crop species.

Keywords: *Evolution, genetic diversity, gwas, polyploidy, synthetic crop species*

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Expression analyses of cuticular wax biosynthetic genes in *Brassica juncea*

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Brassica juncea, is an economically important oilseed crop of the family Brassicaceae, valued for diverse culinary, medicinal, and industrial applications. The aerial organs of *B.juncea*, like other plants, are covered by the hydrophobic cuticular waxes that serve as a waterproof barrier protecting plants against desiccation, ultraviolet radiation, and pathogens. Cuticular wax is composed of a variety of compounds including alkanes, alkenes, primary and secondary alcohols, aldehydes, ketones and esters that are made up of

very long chain (VLC) fatty acids. Among which VLC alkanes constitutes a major fraction of the total wax load in most plants including *Arabidopsis thaliana* and Brassica species. *Cer1* and *Cer3* are the key genes involved in alkane biosynthesis and catalyze the conversion of VLCFAs to aldehydes and then to alkanes. Although the roles of *Cer1* and *Cer3* have been well characterized in *A. thaliana*, but their functional relevance and expression dynamics in *B. juncea* remains largely unexplored. The present study aims to investigate the relative expression profiles of *Cer1* and *Cer3* homologs of *B.juncea* cv. Varuna (BjCer1 and BjCer3), across different leaf developmental stages. For transcript profiling of the two gene paralogs, leaf tissue samples were collected at different days of plant growth post germination (DPG), starting from 1day to 54DPG at five-day interval. Total RNA was isolated from leaves using TRIzol™ reagent (Invitrogen, Carlsbad, CA, USA), followed by cDNA synthesis. Quantitative real-time PCR (qRT-PCR) was performed using paralog specific primers, and relative expression levels were calculated using an internal reference gene, Tonoplastic Intrinsic Proteins-41(TIPS41). In-silico analysis identified two BjCer1 and five BjCer3 paralogs. BjCer1 paralogs were found to be highly conserved with 97.4% identity and showed a 3 bp difference in the length of the coding sequence (CDS; 1884 bp, 1887 bp). All BjCer3 paralogs had a 1893 bp long CDS and shared 88.03% to 95.88% sequence identity. The qRT-PCR expression analysis revealed that of the two BjCer1 paralogs, BjCer1_A09,exhibited low level of expression across all the stages studied. In contrast, BjCer1_B08 expression was high during early developmental stages. Among the BjCer3 paralogs, BjCer3_B08, was found to have higher expression both during the early (1 and 5DPG) and again during the late developmental stages (44 and 49DPG). Expression of BjCer3_A10 was particularly high at 24DPG and that of BjCer3_A02 was consistently lower across all stages. In conclusion, the paralogs of both genes exhibited differential expression, with BjCer1_B08 and BjCer3_B08 as the most highly expressed paralogs across specific leaf developmental stages in *B. juncea* cv. Varuna. The present study is an initial attempt towards gaining molecular insights into the role of *BjCer1* and *BjCer3* gene paralogs in alkane biosynthesis of leaf development that will enable further understanding of cuticle-mediated responses towards abiotic and biotic stress.

Keywords: *Alkanes, brassica juncea, cuticular wax, cer1, cer3, developmental stages, qrt-pcr*

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Integrating speed breeding with genome editing for high oilseed productivity

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In the context of accelerating climate change, stagnating genetic gains, and a rapidly expanding global population projected to reach nearly 10 billion by 2050, the demand for resilient and high-yielding edible oilseed varieties has become increasingly important for nutritional security of the country. Speed breeding has emerged as a transformative approach by enabling multiple generations per year through the optimization of environmental parameters such as extended photoperiod, controlled temperature, light intensity, humidity, and CO_2 concentration in controlled growth facilities. This strategy substantially reduces breeding cycle duration and accelerates the development of homozygous lines without compromising genetic integrity. When integrated with genome editing technologies, particularly the CRISPR/Cas system, speed breeding further enhances breeding efficiency by enabling rapid allele validation, trait fixation, and assessment of pleiotropic effects associated with stress tolerance, yield, and quality traits. As a proof of concept, targeted CRISPR/Cas9 editing of multiple *BnEOD1* homologs in *Brassica napus* increased seed weight by approximately 14%, indicating yield enhancement through precise gene modification. When combined with speed breeding, rapid allele fixation, faster generation turnover, and early phenotypic evaluation of yield, oil content, and stress resilience are achieved, improving overall breeding efficiency. The approach also supports efficient crop cycling through single seed descent (SSD) and early seed harvesting, enabling faster genetic stabilization of edited lines. Recent applications across wheat, barley, rice, and tomato demonstrate the practical success of this integrated strategy in developing climate-resilient and high-

performing cultivars. Protocol refinements for long-day and short-day crops further strengthen its adaptability across diverse agro-climatic systems. Collectively, the convergence of speed breeding and genome editing represents a powerful, scalable platform for accelerating crop improvement and ensuring sustainable agricultural productivity under future climate and food security challenges.

Keywords: *Crispr/cas, gene editing, modern breeding techniques, rapeseed-mustard, speed breeding*

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GWAS-enabled identification of genomic regions and candidate genes for seedling stage salinity tolerance in *Brassica juncea* (L.) Czern & Coss

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Brassica juncea (Indian mustard) is a key oilseed crop in India. It suffers major yield losses under soil salinity. Salinity impairs seedling establishment and reduces yield. Exploiting germplasm variations for seedling-stage salt tolerance is a most promising path to sustain productivity under salinity stress. Achieving this objective requires identification of salt-tolerant genotypes and establishing their physiological basis. This study aimed to quantify variation for seedling-stage salinity tolerance and identify SNPs/genes controlling key traits in *B. juncea*. A diversity panel comprising 90 *B. juncea* accessions, together with tolerant checks, was evaluated under controlled petriplate conditions across a gradient of electrical conductivity (EC) levels from 1.5 to 10.0 dS/m in three replications. Seedling-stage traits were assessed at defined time points following salt stress imposition, with germination rate recorded daily for five days after treatment initiation, and shoot length, root length, fresh shoot weight, and root weight measured two weeks after exposure to salt stress. Salinity stress affected all traits, with low to moderate salinity (1.5–3.0 dS/m) having minimal impact, whereas high salinity levels (6.0–10.0 dS/m) strongly reduced shoot and root growth. The STI for germination rate (GR) and shoot length (SL) declined with increasing salinity varying from 0.995 and 1.023 at 1.5 dS/m to 0.861 and 0.873 at 10.0 dS/m, respectively. The STI for root length (RL) was relatively stable across salinity treatments, while STI values for shoot weight (SW) and root weight (RW) peaked at 10.0 dS/m (1.266 and 1.289), suggesting that the identified salt-tolerant genotypes maintained or enhanced biomass retention under high salinity. Based on the overall performance under stress conditions, eleven salt-tolerant genotypes namely CS52, CS60, IC-766097, IM-170, DRMRIJ_17-38, NC-660, EC-564949-1, NPJ-113, CN-101813, IM-108 and RE-7-1 were identified. A genome-wide association study (GWAS) was performed to identify single-nucleotide polymorphisms (SNPs) associated with salinity tolerance. Q–Q plots were used to identify the best-fitting GWAS model. At –log10(P) e" 3.0, 1,245 SNP–trait associations were identified. These included 799 on the A genome and 446 on the B genome. Several candidate genes were identified within 50-kb regions of peak SNPs and annotated through BLAST searches against the Arabidopsis thaliana database using Blast2GO v5.0. Of these, eight putative genes (*AHK3, SAT32, RCY1, LTL1, MYB15, CHIC, SLK1*, and *MYBR1*) were located near 69 SNPs, predominantly on the A genome, suggesting a potential role in salinity stress tolerance. *AHK3* and *SAT32* have been reported to play roles in cytokinin- and stress-responsive signaling that support salt tolerance. *RCY1* and *LTL1* contribute to cellular protection and osmotic adjustment under salinity. *MYB15* and *MYBR1* regulate stress-responsive gene expression influencing early-stage salt sensitivity, while *CHIC* participates in hormone and stress signaling, and *SLK1* negatively regulates salt and osmotic stress tolerance. In conclusion, this study documented substantial genetic variation for seedling-stage salinity tolerance in *B. juncea*. The identified tolerant genotypes and

associated genomic regions provide valuable targets for marker-assisted and genomic selection to develop varieties adapted to saline environments in India.

Keywords: *Electrical conductivity, genetic variability, germination, putative stress genes, root and shoot growth*

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Variability and correlation coefficient in taramira (*Eruca sativa* Mill) genotypes for yield and its contributing characters

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Taramira (*Eruca sativa*), a drought-tolerant oilseed, is primarily researched for its role in arid agricultural systems, particularly for its high erucic acid content (<"40%) and use in mustard oil blending. The present investigation entitled "principal component analysis for seed yield and its contributing characters in taramira (*Eruca sativa* Mill.)" was carried out in a set of 31 germplasm lines of taramira along with four check varieties, evaluated in randomized block design with three replications during Rabi, 2023-24 at Instructional Farm of Sri Karan Narendra College of Agriculture, Jobner, Jaipur. The analysis of variance showed significant differences among the germplasm lines for all the characters studied viz., days to 50 per cent flowering, plant height, days to maturity, primary branches per plant, secondary branches per plant, siliqua on main shoot, siliqua per plant, siliqua density, siliqua length, seeds per siliqua, 1000-seed weight, chlorophyll content (SPAD value) and seed yield per plant. This indicates the existence of sufficient variability among the germplasm lines.On the basis of mean, germplasm lines viz., RTM-2267, RTM-2238, RTM-2262, RTM-2269 and RTM-2272, showed the highest mean value for different characters. Among all the traits studied, high GCV and PCV were observed for seed yield per plant and siliqua per plant. Moderate GCV and PCV were recorded for secondary branches per plant, plant height and 1000-seed weight, while a moderate PCV value was observed for chlorophyll content, siliqua length and days to 50 per cent flowering. Low GCV and PCV were recorded for siliqua density, seeds per siliqua, siliqua on main shoot, primary branches per plant and days to maturity. High heritability coupled with high genetic advance as per cent of mean was observed for siliqua per plant, seed yield per plant, 1000-seed weight, plant height and secondary branches per plant, indicating the influence of additive gene action, therefore simple selection would be effective for improvement of these traits. The results from character association indicated that seed yield per plant had significant and positive correlation with plant height, days to maturity, primary branches per plant, secondary branches per plant, siliqua per plant, siliqua density and chlorophyll content. Path coefficient analysis revealed that characters viz., plant height, siliqua per plant, seeds per siliqua, days to maturity,secondary branches per plant, siliqua length, siliqua on main shoot and 1000-seed weight had positive direct effect on seed yield per plant. On the basis of per se performance, germplasm lines viz., RTM-2272, RTM-2271, RTM-2267, RTM-2251, RTM-2262, RTM-2269, RTM-2238, RTM-2265 and RTM-1624 were identified as promising in respect of seed yield and other associated traits.

Keyword: *Correlation coefficient, rocket salad, taramira, variability*

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Genome-wide insights into *CKX* genes driving productivity in *Brassica juncea*

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Indian mustard (*Brassica juncea*) is an important edible oilseed crop whose yield is affected not only by biotic and abiotic stresses but also by the inherently low productivity of its cultivars. Cytokinin oxidase/dehydrogenase (CKX) enzymes, which regulate cytokinin homeostasis, play a crucial role in plant growth, yield, and stress tolerance. Previous studies in other species have shown that manipulating *CKX* genes can enhance these traits. In this study, a genome-wide investigation of the *CKX* gene family was conducted in *B. juncea* cv. Varuna, leading to the identification of 24 *CKX* genes distributed across 36 chromosomes (AABB genome) and classified into seven subgroups based on homology with *Arabidopsis thaliana*. Expression analysis using RT-qPCR revealed that all 24 *CKX* genes were differentially expressed in high- and low-yielding cultivars, with most showing activity in leaves, stems, and developing siliques. Furthermore, the conserved FAD-binding and cytokinin-binding domains essential for *CKX* activity were present across the gene family, highlighting their functional importance. These findings offer insights into the evolutionary dynamics of *CKX* genes in *B. juncea* and lay the groundwork for future functional validation aimed at enhancing yield and stress tolerance in this vital crop.

Keyword: *Brassica juncea, CKX gene, yield enhancement*

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Introgression of white rust resistance in quality mustard varieties through MAS

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White rust, caused by *Albugo candida* (Pers.) Kuntze, is one of the most destructive diseases of cruciferous crops, particularly mustard, where it can lead to severe yield losses ranging from 20 to 90% under favourable conditions. The IARI bread-quality mustard variety PM-30 is widely cultivated and preferred by farmers due to its superior agronomic performance and quality attributes; however, its susceptibility to white rust poses a major limitation to its sustained productivity. To overcome this constraint, a marker-assisted backcross breeding programme was undertaken to introgress white rust resistance–conferring QTL from the resistant donor genotype Donskaja into the genetic background of PM-30. Foreground selection was performed using molecular markers tightly linked to the Donskaja-derived QTL *AcB1-A5.1* associated with white rust resistance. In parallel, markers linked to the *FAE1.1* and *FAE1.2* genes, which regulate erucic acid biosynthesis, were employed to ensure the retention of the low-erucic acid trait in the improved lines. The targeted erucic acid level of less than 2% was further validated through wet-lab analysis using gas chromatography. The confirmed $BC_4F_„$ lines possessing the desired Donskaja resistance QTLs along with mutated *FAE1.1* and *FAE1.2* alleles were subsequently evaluated for yield-related traits and key biochemical parameters. Lines exhibiting yield performance comparable to the recurrent parent PM-30 were identified and advanced for further evaluation. In the subsequent generation, BC_4F_1 lines were assessed for yield potential, oil content, oil quality and maturity duration. Additionally, background selection was conducted using 161 polymorphic markers to accelerate the recovery of the recurrent parent genome. Based on combined phenotypic and molecular analyses, ten BC_4F_1 lines were identified that showed more than 90% recovery of the PM-30 genome. These lines

were morphologically similar to PM-30, exhibited a thousand-seed weight of approximately 6 g, and maintained yield levels at par or more than the recurrent parent. After rigorous evaluation over two consecutive years under station trials, two stable, high-yielding, and white rust–resistant lines were selected and nominated to All India Coordinated Research Project (AICRP) trials for multi-location testing.

Keywords: *Albugo candida, Donskaja QTL, FAE1, marker-assisted backcross breeding, PM-30 introgression, white rust resistance*

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Evaluation of Indian mustard (*Brassica juncea* l.) germplasm for seed yield and attributing traits

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Rapeseed-mustard is an important oilseed crop as it accounts for about 33% supply of total edible oil production in our country. It stands second after Soybean in terms of production. Rajasthan, Madhya Pradesh, Uttar Pradesh, Haryana and West Bengal are major producer of rapeseed-mustard in India. In present investigation 75 germplasm accessions of Indian mustard (*Brassica juncea*) were evaluated for seed yield and attributing traits under timely sown irrigated conditions in augmented block design with six checks (Kranti, NRCHB-101, PM-26, PM-30, Pusa Bold, Radhika) at ICAR–Indian Institute of Rapeseed–Mustard Research (IIRMR), Bharatpur, Rajasthan. The sowing was done in third week of October, 2023. Data were collected for 12 different quantitative traits on each genotype. A very good range of variation was noticed for all the traits assessed. Seed yield/plant varied from 5.2 to 39.6 g with a general mean of 21.47g. 1000-seed weight ranged from 2.04 to 5.75g (mean=4.09g) while Oil content ranged from 36.54% to 42.16% (mean=39.02%). High estimates of genotypic coefficient of variability were noticed for seed yield/plant while medium estimates of GCV was observed for primary branches/plant, main shoot length, 1000-seed weight and seeds/siliqua. High estimates of heritability (BS) and genetic advance (as % of mean) was observed for days to maturity, main shoot length, seed yield/plant, 1000-seed weight and seeds/siliqua. High estimates of heritability and genetic advance is indicating that selection is effective for improvement of these traits. sSeed yield/plant showed significant and positive correlation with days to maturity, siliqua length, 1000-seed weight and main shoot length. Selection based on these correlated traits will be effective for selection of genotypes for high seed yield. In present study promising genotypes of Indian mustard were identified for different yield attributing traits for utilization in breeding programme.

Keywords: *Brassica juncea, correlation, genetic variability, heritability*

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Identification and characterization of resistance gene analogs (RGAs) in *Diplotaxis erucoides*

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Diplotaxis erucoides, a wild relative of cultivated Brassica species, possesses valuable traits such as high resistance to Alternaria blight. However, the genomic organization and evolutionary history of its Resistance Gene Analog (RGA) repertoire remain largely unexplored. Characterizing these resistance

genes is crucial for understanding the innate immune mechanisms and utilizing this species for Brassica crop improvement. The present investigation was undertaken to comprehensively characterize the RGA repertoire in *D. erucoides* and delineate the evolutionary mechanisms driving its gene family expansion. To ensure high-confidence prediction, a within-genome analysis was conducted by reconciling outputs from two complementary pipelines, RGAugury and NLR-Annotator. A custom Python script was employed to filter for conserved NBS domains, establishing a consensus dataset from an initial pool of candidates. For phylogenetic analysis, domains were filtered for a minimum length of 150 amino acids, aligned using MAFFT, and a Maximum Likelihood tree was constructed using FastTree. Gene duplication events were classified using MCScanX. The study identified a total of 1506 RGAs in the genome of *D. erucoides*. Of these, 209 high-confidence common loci NBS were detected from the reconciled datasets. Phylogenetic analysis of these conserved NBS domains revealed subclass abundance of TNLs (90 genes) and CNLs (34 genes). More number of TNLs indicates major involvement of the genes governing EDS1-dependent signalling pathway. Physical clustering organized the identified RGAs into 296 clusters with a massive super-cluster (CL41) on Chromosome 1 containing 24 genes. Synteny analysis revealed tandem duplications for 1,417 genes, of which 861 genes are derived from ancient whole genome duplication. Our study provides a foundation for further analysis on precise identification of genes governing Alternaria Blight resistance in *D. erucoides*.

Keywords: *Alternaria blight, Diplotaxis erucoides, disease resistance, resistance gene analogs*

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Harnessing artificial intelligence for genetic enhancement and productivity gains in oilseed crops

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Artificial intelligence (AI) is redefining the landscape of genetic improvement in oilseed crops by transforming breeding into a predictive, data-driven and highly efficient discipline. Oilseeds such as soybean, rapeseed, groundnut, sunflower and sesame play a critical role in global food security, nutrition and industrial applications. However, their productivity is often constrained by complex quantitative traits, susceptibility to biotic and abiotic stresses, and strong genotype × environment interactions. The integration of AI into plant breeding offers powerful tools to overcome these limitations and to accelerate genetic gains in yield, oil content and quality. One of the most impactful applications of AI in oilseed breeding is genomic selection. Machine learning algorithms, including random forest, gradient boosting and deep neural networks, are capable of capturing non-linear and epistatic interactions among thousands of molecular markers. In soybean, AI-based genomic prediction models have shown improved accuracy in forecasting seed yield and oil content compared to conventional best linear unbiased prediction (BLUP) approaches. Similarly, in rapeseed, deep learning models have been used to predict fatty acid composition, such as oleic and erucic acid content, enabling breeders to select superior genotypes at early stages of development. AI-driven high-throughput phenotyping is another transformative domain. Advanced imaging systems mounted on drones, field platforms, or handheld devices generate large volumes of data related to plant growth, canopy structure, chlorophyll content and stress symptoms. In sunflower and groundnut, AI-based image analysis has been successfully applied to estimate biomass, flowering dynamics, and drought stress tolerance. For example, convolutional neural networks (CNNs) can detect early disease symptoms such as leaf spot or rust from leaf images with high precision, facilitating rapid screening of resistant genotypes. The integration of AI with multi-omics data further strengthens genetic enhancement strategies. Oil biosynthesis is governed by complex regulatory networks involving numerous genes and metabolic

pathways. AI-based integrative models that combine genomics, transcriptomics and metabolomics data have been used to identify key regulatory genes controlling oil accumulation and fatty acid biosynthesis. In soybean, such approaches have enabled the identification of candidate genes associated with higher oleic acid content and improved oil stability. AI also plays a crucial role in predicting genotype × environment interactions, which is essential for improving yield stability across diverse agro-climatic regions. AI-based predictive models can integrate weather data, soil parameters, and genomic information to forecast genotype performance under specific environments. The convergence of AI with genome editing technologies offers a new frontier in oilseed improvement. AI algorithms can assist in identifying optimal target genes, predicting functional consequences of mutations, and designing efficient guide RNAs for CRISPR/Cas-mediated editing. In summary, harnessing artificial intelligence for genetic enhancement and productivity gains in oilseed crops represents a transformative approach to modern plant breeding.

Keywords: *Artificial intelligence, genetic enhancement, productivity, yield*

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Ideotype for high-density planting can aid in yield enhancement in Indian soybean (*Glycine max*, L.)

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Soybean is a major oilseed crop in India predominantly grown under rain-fed conditions. It is cultivated over 12.9 million hectares, with 15.10 million tonnes production and 1170 kg ha^{-1} productivity. Though India ranks fifth in soybean production, its productivity is significantly low compared to the other soybean-growing countries like Brazil, USA, Argentina and China. Breeding for ideal plant type suitable for high-density planting can aid in soybean productivity in India. In this direction, breeding efforts were initiated to develop early maturing genotypes with erect plant type with fewer or no branches, medium to bold seededness and resistant to major diseases viz., anthracnose and Rhizoctonia aerial blight (RAB). During 2024, a total of nineteen such genotypes along with a check variety- NRC 150 were evaluated for yield and attributing under different planting densities viz., 45 cm × 5 cm, 30 cm × 5 cm, 20 cm × 5 cm and 15 cm × 5 cm, at two locations-Indore and Pune. Each planting density experiment was conducted in Randomized Complete Block Design (RCBD) with three replications each in a plot size of 1.8 m^2. The highest mean yield of 30.24 q/ha and 30.50 q/ha was recorded in 15 cm × 5 cm planting density as against 17.84 q/ha and 20.97 q/ha in 45 cm × 5 cm planting in Indore and Pune, respectively. At Indore location, across all the four plating densities, NRC 150 yielded highest (4417 Kg/ha) at 20 cm x 5 cm planting density, followed by the same genotype (4318 Kg/ha) at 30 cm x 5 cm planting density. While at the recommended planting density (45 cm × 5 cm), highest yield was realized by G12 (EC 457254 × JS 95-60) (2849 Kg/ha). Whereas at Pune location, genotype G18 (EC 457254 × JS 95-60) yielded highest (4003 Kg/ha) at 15 cm x 5 cm planting density, followed by the same genotype (3766 Kg/ha) at 20 cm x 5 cm planting density. While at the recommended planting density (45 cm × 5 cm), highest yield was realized by G18 (3033 Kg/ha). Breeding efforts and agronomic interventions plays a vital role in yield enhancement in soybean. The current study integrates ideotype breeding and crop geometry towards enhancing soybean productivity. At Indore location, NRC 150 was found to be promising under high-density planting, while at Pune location, genotype G18 consistently performed superior across all the planting densities. Since the plot size was small, the results will further be validated in larger plots in future experiments. The superior genotypes identified at both the locations will be used as parents to develop stable and wider adaptable high-yielding genotypes under high density planting conditions.

Keywords: *High density planting, Ideotype, Soybean genotype, Yield attributing character*

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Targeted editing of soybean genes via CRISPR/Cas9: Toward improving soybean yield, oil quality, resistance to pests and pod shattering

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Soybean is major oilseed crop of India. The productivity of soybean is stagnated and new approaches including gene editing are being applied for productivity enhancement. The present study focuses on the

targeted gene editing of five key genes, *GmSDP1, GmGA3ox1, GmUGT, Pdh1*, and *FAD2*, to improve different traits in soybean. The primary objectives include improving seed and oil yield in JS 20-98 via targeting *GmSDP1*, enhancing seed yield and photosynthetic efficiency in NRC 150 through targeting *GmGA3ox1*, conferring resistance against *Spodoptera* by targeting *GmUGT* in JS 21-72, improving pod shattering resistance in NRC 130 by targeting *Pdh1*, and increasing oleic acid content in JS 20-98 by editing *FAD2-1A* and *FAD2-1B*. Full-length sequences of all five-target genes and their homologs have been identified in the selected varieties by Sanger sequencing. A total of 12 guide RNAs (gRNAs), were designed and cloned into a shuttle vector (pBlu/gRNA). The gRNA-scaffold cassettes were subsequently sub-cloned into a binary Cas9 expression vector. All 12 gRNA-Cas9 constructs were validated through sequencing and mobilized in *Agrobacterium*. *Agrobacterium*-mediated transformation of soybean cultivars was performed using a genotype-independent rapid transformation method. Following selection, putative transformants for *FAD2 and GA3ox1* constructs were screened, and successful T-DNA integration was confirmed by PCR targeting Cas9, gRNA and the BlpR resistance markers. T• plants with gRNA inserts were successfully achieved, laying the groundwork for improving soybean oil quality and seed yield enhancement. This work lays the foundation for trait-specific genome editing in soybean to improve seed yield and oil quality.

Keywords: *Gene editing, CRISPER/CAS9, RNA, Yield, Oil quality, Pod shattering resistance*

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Harnessing genomics through QTL mapping and candidate gene discovery to improve seed viability in soybean (*Glycine max*.)

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The soybean or 'Golden bean' is the premium oil seed crop of the world. It contains 40-45% high-quality protein and 18-20% healthy oil along with a host of other nutrients vital for human health. However, it consistently endures loss of seed viability during ambient storage challenging maintenance of high-quality seeds for sowing in the next season. It is therefore essential to understand the genetic architect of the trait so that effective measures can be worked out to enhance the viability of the seeds. In this study, we tried to understand the inheritance, mapping of the loci controlling the seed viability and discovery of the candidate genes for seed viability in soybean. A selected group of soybean genotypes with high seed viability viz. EC-1023, EC-105790, G2651, UPSL34, UPSL736 were hybridized pairwise with a set of soybean genotypes with very poor seed viability viz. MACS-565, PK1243, VLS61, and produced the F_1 seeds. The true F_1 plants of the cross EC1023 x VLS61 were advanced to produce $F_{2:3}$ seeds, which were subjected to 72 hours of accelerated ageing (AA) at 41°C and 100% RH, followed by germination test. The germination of the parental genotypes EC1023 and VLS61 were 40% and 14%, respectively, whereas germination of the AA tested $F_{2:3}$ seeds were 4.16-71.42 %. The continuous frequency distribution pattern of germination (%) of the $F_{2:3}$ seeds indicated that the seed viability is governed by polygenes. Parental polymorphism studied with 506 SSR markers indicated it to be 20.35%; however, the distribution of polymorphism across the chromosomes was not uniform, Chr. 15 had 46.15% polymorphism whereas Chr. 3 and 4 had 15.78% only. Through inclusive composite interval mapping approach, 8 QTL for seed viability viz., qSv-6.1 and qSv-6.2, qSv-7.1, qSv-8.1 and qSv-8.2, qSv-10.1, qSv-13.1, and qSv-17.1 were mapped on Chrs. 6, 7, 8, 10, 13 and 17, respectively. The phenotypic variation explained (PVE) by the QTL were 1.97-11.10%. Two QTL viz., qSv-7.1 (PVE=11.10%) and qSv13.1 (PVE=11.08%) appeared to be major QTLs for seed viability and rest minor ones. All QTL except qSv8.2 appeared to be novel. The mapped QTLs were validated in 40 inter-specific RILs with varying level of seed viability. The SSR marker Satt538 linked to the QTL qSv8.2 could successfully (70%) separate the highly viable RILs from the poor-viable RILs. Similarly, SSR markers Sat_316 and Sat_173 were 80-85% successful in separating

the high and poor viable RILs. Based on Protein Analysis through Evolutionary Relationships (PANTHER), gene annotation information, and literature search, more than 700 candidate genes for seed viability underlying the mapped QTL were identified. The mapped QTL and the identified candidate genes will pave the way for marker-assisted breeding of soybean to generate genotypes with improved seed viability.

Keywords: *Accelerated ageing test, Genetics, QTLs, Seed viability, Soybean*

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Multi-trait–based identification of elite soybean germplasm for terminal drought resilience in India

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Soybean (*Glycline max* L. Merrill) is an important oilseed crop with highest protein (42%) and oil (20%) content among grain legumes and is a rich source of essential amino acids which are often deficient in cereals. It is predominantly grown as a rainfed crop which is challenging for achieving higher productivity in India. *Kharif* season terminal drought, which occurs at seed fill stage, is detrimental and reduces soybean productivity up to 80%. The same set of soybean genotypes, comprising 15 introductions (IITA, Nairobi) and 7 Indian cultivars, were screened in a 21-days soil-moisture stress imposed at the pod initiation stage, for the two consecutive seasons, i.e., in a field trial summer 2024 and rainout shelter experiment *kharif* 2025. A range of variation for canopy temperature depression (-17p C – -14p C), chlorophyll retention (SCMR 29 – 43), and delayed leaf senescence (1 – 4 score), indicating efficient physiological adaptation of these germplasm to soil-moisture deficit for breeding drought resilience in soybean. High drought resistance index (DRI) was recorded in tolerant check JS 97-52 (DRI=1.4) and low in sensitive check JS 335 (DRI=0.7). Multiple key drought-tolerance traits evaluation and selection revealed three elite drought resilient germplasm, *i.e.*, TGX 1073-30 A (DRI=1.4), TGX 854-4 E (DRI=1.6) and TGX 814-46 F (DRI=1.5) contributing most effectively to the drought tolerance. These identified drought tolerant accessions will serve as donors in hybridization, a key objective for a successful breeding programme for drought tolerance. Molecular breeding for drought tolerance is also being initiated using markers specific for these traits.

Keywords: *Drought resistance index, soil-moisture deficit, drought resilience, physiological adaptation, delayed leaf senescence, canopy temperature depression, chlorophyll retention*

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Development of food-grade soybean in India

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Unique biochemical composition of grains makes soybean the most sought after vegetarian food source to combat protein deficiency among masses, can keep killer diseases like atherosclerosis, breast cancer, diabetes at bay and geriatric diseases like Parkinson's and Alzheimer's at bay. However, utilization is soybean in food uses is constrained by protein digestibility anti-nutritional factor, Kunitz trypsin inhibitor (KTI) and off-flavour generating lipoxygenases. Further, low level of oleic acid but high concentration of polyunsaturated fatty acids in soybean grains renders the oil fraction prone to rancidity, which industry overcomes by partially hydrogenating the oil. However, this process incurs not only extra cost but also generates trans fats, which are diabetogenic and atherogenic. Therefore, soybeans genotypes free from Kunitz trypsin inhibitor and off-flavour generating lipoxygenase-2, and genotypes bearing high levels of

oleic acid content are sought by the food/oil industry. At ICAR-National Soybean Research, Institute Indore and other institutes/Universities in collaboration with ICAR-NSRI have developed food grade genotypes/varieties and released for different agro climatic zones primarily through Marker Assisted approach. SSR markers Satt 228 and Sattt 509 -which are Ti locus tightly linked markers- were deployed for foreground selection. NRC127 released as the first KTI free variety for Central zone using Marker Assisted Backcrossing with JS97-52 as recipient and PI542044 as donor for null allele of Kunitz trypsin inhibitor. Subsequently, KTI free varieties MACSNRC1667 for Southern zone, NRC181 for Central zone, and NRC197 for Northern Hill zone. NRC132 was the first lipoxygenase-2 free variety of the country. It was released for South zone. NRC150 early maturing lipoxygenase-2 free variety for Central zone. Donor for null allele of lipoxygenase-2 was PI596540 and PI086023 in case of NRC132 and NRC109, respectively. NRC109 is a pre-breeding line developed from Samrat x PI086023. SSR markers linked to Lox2 locus and gene specific marker were deployed for foreground selection in development of liposygnease-2 free varieties/lines. NRC142 was first double null (free from both lipoxygenase-2 and Kunitz trypsin inhibitor) variety released for Central as well as zone. Subsequently, NRC152 an early maturing double null variety was released for Central zone. Yield of the above food grade varieties was significantly higher or at par with the best performing check. Food-grade soybean genotypes, which are double null and have clear hilum, have also been developed through MAS. NRC147, with 37 + 5% oleic acid content a value 2-fold than observed in regular soybean cultivars, is the first high oleic soybean variety released for South zone. Some of the above-mentioned food grade varieties like NRC 150 and NRC142 are very popular among farmers due to their high yield, early/mid duration maturity, disease tolerance, amenable to mechanical harvesting. Some of the above mentioned food grade varieties/lines like NRC109, NRC181, NRC147, NRC101, NRC102 etc. have been commercialized to private companies after signing MoUs. Further, NRC188 is the first vegetable soybean released for Central zone. Tender kernels shelled from green pods picked at R6 stage are suitable for consumed for vegetable purpose. Green pods of this variety can be frozen similar to green pea and stored for marketing. Efforts are underway to develop astringency imparting Group A saponin free soybean.

Keywords: *Food grade soybean, Null KTI, vegetable soybean, marker assisted selection*

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Assessment of genetic variability and yield-contributing traits in soybean through association studies

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Soybean is a major global oilseed crop, ranking just after palm oil in vegetable oil production and plays a vital role in addressing the growing global demand for protein and edible oils. The enhancement of its yield requires a comprehensive understanding of genetic variability and yield-related traits. Accordingly, a field experiment was conducted during the *kharif*, 2021 at the Agricultural Research Station, Ummedganj, Agriculture University, Kota, Rajasthan, where thirty-two soybean genotypes were evaluated in a randomized block design with three replications. ANOVA indicated highly significant differences among genotypes for all the characters, showing good amount of genetic variation. High genotypic and phenotypic coefficients of variation coupled with high heritability and genetic advance as a percentage of mean were recorded for seed yield per plant, biological yield per plant, number of pods per plant, number of branches per plant and 100-seed weight, indicating the predominance of additive gene action additive gene action, making them promising targets for improvement through direct selection. Correlation studies indicated that seed yield per plant had a significant and positive correlation with biological yield per plant, harvest index, pod length, 100-seed weight, number of pods per plant, number of branches per plant and oil

content. Path coefficient analysis also showed that biological yield per plant and harvest index had the highest positive direct effects on seed yield, whereas other traits indirectly affected it. In this study, biological yield per plant, number of pods per plant, number of branches per plant and 100-seed weight was identified as the key traits for effective selection to enhance soybean seed yield. On average performance, genotypes AUKS 213, AUKS 259, AUKS 263, AUKS 262 and AUKS 264 were found as better performing for seed yield and related traits and therefore may be selected to include in the future breeding programs of soybean.

Keywords: *Soybean, seed yield, ANOVA, correlation and path coefficient analysis*

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CRISPR/Cas9-mediated genome editing for the development of long-juvenile soybean genotype

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The long-juvenile trait is a crucial agronomic characteristic that extends the vegetative growth phase and delays flowering in soybean grown under short-day photoperiod conditions. GmFT2a (*Glyma.16g150700*) is a major gene responsible for early flowering under short-day conditions. CRISPR-Cas9-mediated genome editing is the most advanced and rapid process for genome editing, which requires the design and selection of unique gRNA specific to the target gene. For CRISPR-Cas9-mediated editing of the GmFT2a gene, gRNA targeting the first exon was designed using the Cas-Designer component of CRISPR RGEN tools and on-target and off-target score were validated using the CCTop-CRISPR/Cas9 target online predictor website. The gRNA with the on-target score of 0.80, and 11 predicted off-target was selected, annealed, and ligated into the CRISPR/Cas9 expression vector Cas9_MDC123, cloned in the DH5á strain of *E. Coli*, and mobilized into *Agrobacterium tumefaciens* strain EHA105 for transformation. Seeds of the high-yielding, early maturing popular soybean variety NRC150 were used for the *Agrobacterium tumefaciens*-mediated transformation experiment. The infected explants were co-cultivated for 3 days. Following co-cultivation, explants were transferred to shoot induction and shoot elongation under glufosinate selection (3.5 mg/L). Elongated shoots were then transferred to rooting medium. Well-rooted plants were subsequently transferred for hardening. A total number of 102 T• explants were transferred to hardening and screened for Cas9, BLPR and gRNA region using gene-specific primer by PCR. Cotyledons from 5-day-old germinated seeds were infected with *Agrobacterium tumefaciens* containing GmFT2a_Cas9_MDC123 vector and co-cultivated for 3 days, followed by shoot induction, shoot elongation under glufosinate selection (3.5 mg/L), and were subsequently transferred to rooting medium. Well rooted plants were transferred to hardening. A total number of 102 T• explants were transferred to hardening and screened for Cas9, BLPR and gRNA region using gene-specific primer by PCR. Sanger sequencing analysis of one of the T_0 plant confirmed the insertion of adenine at two bases upstream the PAM sequence at the expected target site. In another plant, insertion of a thymine was detected at 62 bases upstream of the PAM sequence and 7 bases downstream of the start codon. Both mutations resulted in the premature stop codon, leading to the truncated protein. Advancement of seeds from these edited T_0 plants to the next generation will lead to the development of a soybean genotype with long juvenile trait.

Keywords: *CRISPR/Cas9, gRNA, glufosinate*

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Influence of photosynthetic traits and canopy light interception in soybean (*Glycine max* (L.) Merill) recombinant inbred lines

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Glycine max L. Merrill is a strategic leguminous crop for global food and nutritional security owing to its high protein and oil content. Enhancing photosynthetic efficiency and radiation-use dynamics is a key breeding objective for developing resilient and high-yielding soybean cultivars under variable agro-climatic conditions. Chlorophyll content, along with absorbed and intercepted photosynthetically active radiation (APAR and IPAR), represents crucial physiological and canopy-level traits that determine biomass accumulation and productivity. The present investigation was undertaken to quantify the genetic variability and interrelationships among chlorophyll content, APAR and IPAR in soybean and to identify promising genotypes for resilient crop breeding. The experiment was conducted during the *Kharif* season of 2022 at the Seed Breeding Farm, Department of Genetics and Plant Breeding, JNKVV, Jabalpur, India, using an augmented block design. A total of 118 soybean genotypes, comprising 115 Recombinant Inbred Lines (RILs) derived from the crosses Cat 3293 × NRC 2 and JS 97-52 × NRC 37, along with three check cultivars *viz*., JS 97-52, NRC 37 and JS 335, were evaluated. Chlorophyll content was estimated non-destructively at 30 and 60 days after sowing (DAS) using a SPAD meter and expressed as Chlorophyll Content Index (CCI). APAR and IPAR were measured at the same stages using a quantum sensor by recording incident, transmitted and reflected photosynthetically active radiation and computing values through standard equations. Statistical analysis was performed using R software, employing the 'agricolae' package for analysis of variance and mean comparisons and the 'corrplot' package for correlation analysis. Significant genetic variability was observed among the genotypes for chlorophyll content, APAR and IPAR at both growth stages, indicating substantial scope for selection and genetic improvement. Chlorophyll content at 30 DAS arrayed between 22.0 to 29.5 µg/cm² and increased markedly by 60 DAS, while APAR and IPAR values showed a consistent increase with crop development. RIL 115-166 emerged as the most superior genotype, exhibiting the highest chlorophyll content and maximum APAR and IPAR at both 30 and 60 DAS, demonstrating enhanced canopy radiation capture and utilization efficiency. The cultivar JS335 also performed comparably well, validating its continued relevance as a standard genotype in breeding programmes. In contrast, RILs such as 115-96, 115-221 and 115-65 consistently recorded lower values for all studied parameters and may serve as contrasting material for physiological and genetic studies. Correlation analysis revealed strong and highly significant positive associations among chlorophyll content, APAR and IPAR at both of the stages. Chlorophyll content at 60 DAS exhibited exceptionally high correlations with APAR and IPAR ($r > 0.97$), highlighting the close physiological linkage between leaf pigment concentration and canopy radiation-use efficiency. Similarly, APAR and IPAR showed near-perfect correlations with each other, confirming that genotypes efficient in absorbing radiation are also highly effective in intercepting incident solar energy. These results emphasize that chlorophyll content, particularly at mid-season stages, can serve as a reliable indirect selection criterion for identifying genotypes with superior photosynthetic efficiency and radiation-use dynamics. Overall, the study demonstrates that combining physiological efficiency *i.e*., high chlorophyll content with canopy efficiency including high APAR and IPAR offers a robust strategy for selecting soybean genotypes with enhanced photosynthetic performance and yield potential. The identified superior RILs, especially RIL115-166, represent valuable genetic resources for breeding resilient soybean cultivars capable of maintaining productivity under diverse and changing environmental conditions, thereby contributing to sustainable and climate-resilient crop improvement programmes.

Keywords: *Genetic variability, chlorophyll content, radiation-use efficiency, photosynthetic efficiency*

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Exploiting genetic variability and yield components for enhancing soybean productivity in temperate agri-ecology of Kashmir

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Advanced photo-insensitive elite lines were used to evaluate genetic diversity, trait interrelationships, and selection indices for grain production in soybean (*Glycine max* L.). In order to measure yield variability and related agromorphological variables, seventeen genotypes of soybeans were assessed using a randomized block design with three replications. Significant genetic diversity was present in the experimental material, as evidenced by the analysis of variance that showed highly significant variations between genotypes for main yield contributing characteristics and grain yield per plot. Grain production per plot, pods per plant, and 100-seed weight all showed substantial phenotypic and genotypic coefficients of variance, according to estimates of genetic variability parameters. These traits' phenotypic and genotypic coefficients of variation closely matched, indicating little environmental impact on their expression. Grain production and pods per plant showed significant broad-sense heritability and high genetic advancement as a percentage of mean, suggesting the dominance of additive gene action and validating the success of direct phenotypic selection for these traits. Grain yield showed weak and non-significant correlations with seeds per pod, but strong positive correlations with pods per plant, plant height at physiological maturity (R8 stage), and 100-seed weight, according to genotypic correlation study. These connections suggest that indirect selection for important component qualities can successfully increase yield. These results were further supported by path coefficient analysis, which found that the most significant characteristic that had the most positive direct impact on grain yield was the number of pods per plant. Plant height primarily affected yield through indirect pathways, although seed weight made a minor direct contribution. Five elite genotypes SKAU-S-15, SKAU-S-29, SKAU-S-16, SKAU-S-3, and SKAU-S-7 were found to be superior based on mean performance and yield stability across replications. SKAU-S-15 and SKAU-S-29 were the best prospects for moving on to multi-location trials because they consistently performed and reported the maximum grain yield per plot. The remaining genotypes can be successfully used as parental material in hybridization programs and demonstrated appropriate combinations of yield and adaptation qualities. Overall, the study shows that the soybean germplasm has exploitable genetic variety and emphasizes the significance of pods per plant and seed weight as trustworthy selection criteria for increasing output. The identified elite genotypes and trait associations provide valuable insights for soybean improvement programs aimed at developing high-yielding and stable cultivars suited to diverse agro-ecological conditions.

Keywords: *Soybean, Kashmir, yield*

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Differential photo-thermo response of soybean genotypes under contrasting seasonal conditions

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Soybean is an important oilseed crop with high protein content (30-45 %) and moderate oil content (15-24 %). Soybean growth is highly sensitive to environmental factors, particularly photoperiod and

temperature. As a quantitative short-day plant, soybean's flowering, morphology, and yield are influenced by day length and thermal regimes, which vary with season and location. This study was conducted at University of Agricultural Sciences, Dharwad to assess the performance of fifteen soybean genotypes for physiological, phenological, yield, and seed quality traits exposed to different seasonal variation (Rainy 2022, post-rainy 2022–23, and summer 2023). The three seasons varied for both photoperiod and temperature regimes. Rainy season had highest day length (12 h 33 minutes) followed by summer (11 h 56 minutes) and post-rainy season (11 h 20 minutes). The maximum temperature in the location also varied during rainy (28.3 ÚC), post-rainy (30.1 ÚC) and summer (33.8 ÚC) seasons. There was significant genetic variability among genotypes for various physiological, phenological, yield, yield components, protein and oil content during different seasons. Across the soybean genotypes under study, the highest (57.2 %) reduction was noted for seed yield followed by plant height (43.6 %), number of pods per plant (39.7 %), chlorophyll 'b' (36.8 %) and chlorophyll 'a' (27.5 %) while, least (2.2 %) was exhibited by number of seeds per pod during post rainy over rainy season. Number of seeds per pod was consistent across seasons implying less effect of photoperiod and temperature on this trait. Reduced photoperiod during *Rabi* caused early flowering which resulted in shorter plants that had lower vegetative growth, fewer pods per plant, smaller seed size and ultimately lower seed yield. During summer, highest per cent reduction was observed for seed yield (76 %) followed by number of pods per plant (44 %), hundred seed weight (28.7 %), plant height (21.3 %) and chlorophyll 'a' (18.9 %) whereas, least (1.1 %) reduction was observed for days to maturity and protein content across genotypes during summer over rainy season. The decrease in seed yield can be ascribed to the prevailing photoperiod (11 h 56 min) and elevated temperatures (average: 33.8 ÚC) between 32 and 37 ÚC during summer, which had a major influence on soybean seed yield. A marked reduction in seed yield was recorded during post-rainy season (up to 57.2%) and summer (up to 76%) when compared to rainy season the normal growing season in India, primarily due to reduced photoperiod and elevated temperatures that shortened the growth cycle and adversely affected pod number, plant height, and seed weight. Notably, MACS 330 showed photoperiod insensitivity for days to maturity, while DSb 34 exhibited yield stability with minimal seasonal reduction for different traits, suggesting their potential for cultivation under variable environments. The study thus indicated differential photo-thermo response of soybean genotypes which underscores the need to screen genotypes under diverse photoperiods to identify stable and high-yielding soybean lines suitable for year-round cultivation.

Keywords: *Seasonal variation, genetic variability, photo-thermo response*

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Designing of guide RNAs for the development of low phytic acid soybean genotype through CRISPR-Cas9-mediated genome editing

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Soybean is a nutritionally important legume widely utilized for food, feed, and industrial purposes due to its high protein and oil content. However, its nutritional quality is compromised by the presence of phytic acid (myo-inositol-1,2,3,4,5,6-hexakisphosphate; IP6), a major antinutritional factor that chelates essential minerals such as iron, zinc, calcium, and magnesium, thereby reducing their bioavailability in monogastric diets causing hidden hunger and also contributing to environmental phosphorus pollution. Conventional breeding approaches for reducing phytic acid have achieved limited success. Recent advances in CRISPR-Cas9 genome editing provide a precise and efficient platform for targeted manipulation of genes involved in phytic acid biosynthesis. Inositol phosphate kinase 1 (*IPK1*) catalyzes the terminal step of phytic acid biosynthesis by converting inositol-1,3,4,5,6-pentakisphosphate (IP5) into IP6, making it a strategic target for phytic acid reduction without disrupting upstream inositol metabolism essential for seed development.

The soybean genome contains three *IPK1* homologs located on chromosome 14, 6 and 4 (*Glyma14g07880, Glyma06g03310* and *Glyma04g03240*). Among these, *Glyma06g03310* and *Glyma04g03240* exhibit very high nucleotide sequence identity (96.65%), enabling the design of a single guide RNA to simultaneously target both homologs. For CRISPR-Cas9-mediated genome editing, guide RNAs were designed using the CRISPR-P 2.0 (a web-based tool) to target the selected genes. For editing of *Glyma14g07880*, a total of 261 guide RNAs were generated, of which 98 targeted exon regions. Based on off-target analysis, 11 guide RNAs exhibited low off-target score potential (off-target score d" 31) and high predicted efficiency scores (e"0.69). From these, three optimal guide RNAs were selected. Similarly, out of a total of ten guide RNAs designed to simultaneously target exon regions of the *IPK1* homologs on chromosomes 4(*Glyma04g03240*) and 6(*Glyma06g03310*), three guide RNAs were selected based on their predicted on-target score ranging from 0.35 to 0.60. These six guide RNAs will be cloned into a CRISPR/Cas9 expression vector for targeted mutagenesis of *IPK1* genes, aiming to develop low-phytic-acid soybean genotypes with improved nutritional quality.

Keywords: *Genome editing, CRISPR/Cas9, RNAs, phytic acid*

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Screening, identification and evaluation of waterlogged tolerant soybean (*Glycine max* L. Merrill) genotypes

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Soybean (*Glycine max* (L.) Merril) has a prominent place among modern agricultural commodities, as the world's most important seed legume, which contributes about 25% to the global edible oil production, about two thirds of the world's protein concentrate for livestock feeding and is a valuable ingredient in formulated feeds for poultry and fish. Soil waterlogging is a common abiotic stress affecting production and productivity of soybean. It is a major problem after drought as the main soybean growing regions in India have heavy soils, low penetration rates and receive high rainfall. The waterlogging condition is an apparent challenge to soybean production; therefore, it is essential to evolve varieties which can withstand waterlogged conditions. Keeping the above facts in mind an experiment was conducted to identify soybean genotypes tolerant to waterlogged condition and to evaluate the extent of genetic variability present among the soybean genotypes under waterlogged condition. Seventeen soybean genotypes including two checks were evaluated under control and waterlogged conditions at CAU Research Farm, Andro during *kharif* 2022. Foliar damage scale, Plant survival rate and maximin-minimax approach were employed for classifying genotypes as resistant, tolerant and susceptible to waterlogging. Statistical analysis showed significant differences between the tested genotypes. Phenotypic coefficient of variation (PCV) was observed to be higher than the genotypic coefficient of variation (GCV) for all the traits under study. Seed yield per plant showed a high heritability of 86% accompanied by the highest genetic advance as percent of mean of 74.04%. The traits that found a positive and significant correlation with seed yield per plant were number of clusters per plant, number of pods per plant, number of pods per cluster, pod length, seeds per pod and days to 50% flowering. Path analysis revealed a highest direct positive effect for seed weight and number of clusters per plant followed by number of pods per plant, seeds per pod, pod length, harvest index, which were the main contributing characters to seed yield per plant indicating the selection of these characters for efficient crop improvement. Out of 17 genotypes studied, four genotypes viz., NRC 189, NRC 256, NRC 257 and EC 457464 were found to be tolerant under waterlogged conditions. Although these cultivars had lesser yield compared to control conditions, after 15 days of waterlogging their yield was still overall higher than other genotypes under waterlogging. These were also identified as tolerant genotypes; this was found to be in accordance with the flooding tolerance definition given by Van Toa *et al.* (1994).

Among the four tolerant genotypes identified, NRC 189 showed significantly less percent yield loss under waterlogging compared to control. These identified genotypes can be included in hybridization programs but appraisal at molecular level would be suggested for accurate assessment of their performance.

Keywords: *Soybean, water logging, yield*

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Genetic evaluation and trait association analysis for yeld enhancement in soybean (*Glycine max* L. Merrill)

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Glycine max [L.] Merrill is an internationally significant leguminous crop, appreciated for its high protein (~40%) and oil (~20%) content. Enhancing seed yield, a polygenic trait influenced by multiple agronomic characters, remains a major breeding objective. Present investigation was conducted during Kharif, 2024 at the Research Farm, Zonal Agricultural Research Station, Morena, RVSKVV, Gwalior, M. P., India, using 60 genetically diverse genotypes laid out in a Randomized Block Design with two replications. Substantial genetic variability was observed for main yield attributing traits. Phenotypic coefficients of variation (PCV) exceeded genotypic coefficients (GCV), indicating environmental influence; however, small PCV-GCV differences for many traits suggested existence of a strong genetic basis. High heritability (>99%) and genetic advance as percentage of mean (GAM) were investigated for numbers of seeds per plant, biological and seed yield per plant signified that traits governed largely by additive gene action. Correlation analysis revealed significant positive associations of seed yield with numbers of seeds and pods per plant, biological yield, harvest index and hundred-seed weight. Path coefficient analysis identified biological yield as having the highest direct positive effect on seed yield, tracked by harvest index and numbers of seeds per plant. Whereas, negative direct effects of some traits were offset by strong indirect contributions via key yield contributing components. These findings highlighted that traits of high breeding value, offering essential guidance for selection indices in soybean improvement. Integrating these findings with molecular tools could accelerate the development of high-yielding, climate-resilient cultivars suitable to diverse agro-ecological zones.

Keywords: *Genetic evaluation, GCV. PCV, soybean, yield enhancement*

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Role of photoinsensitivity in the adaptation of soybean (*Glycine max* (L.) Merr.) to Indian environments

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Soybean (*Glycine max* (L.) Merr.) is a facultative short-day, photoperiod-sensitive crop whose global adaptation is largely regulated by maturity and photoperiod genes. While photoinsensitive alleles at major maturity loci (E1, E2, E3 and E4) are well known for conferring adaptation to higher latitudes by enabling flowering under long-day conditions, their role in lower latitudes has remained poorly understood. India represents a unique soybean-growing environment spanning a wide latitudinal range (8°–37°N), where

cultivation is predominantly rainfed and crop duration is frequently constrained by terminal drought and heat stress. The present study investigated the allelic status of major photoperiodic genes in 101 Indian soybean varieties and evaluated their photosensitivity, phenological response, and adaptive significance. Molecular genotyping revealed that most varieties carried dominant photoperiod-sensitive alleles, while only a small proportion possessed recessive photoinsensitive alleles. Photosensitivity varied widely among varieties, and those carrying e1-as or e2 alleles exhibited significantly reduced photosensitivity, earlier flowering, and earlier maturity. Recessive e3 alleles showed no significant effect under Indian conditions. Genetic validation using an F, population confirmed that e1-as primarily reduced days to flowering, whereas e2 reduced days to maturity. The adaptive value of photoinsensitivity was further demonstrated through analysis of 35 years of breeder seed demand data, which showed that photoinsensitive varieties, despite being fewer in number, had a significantly higher weighted mean seed demand, indicating superior farmer acceptance and adaptation. The results demonstrate a novel role of photoinsensitive alleles in lower latitudes, where they contribute to soybean adaptation primarily by conferring earliness rather than enabling flowering under long days. Strategic deployment of photoinsensitive alleles in breeding programs can facilitate the development of early-maturing, climate-resilient soybean varieties suited to rainfed and short-season environments of India.

Keywords: *photoinsensitive, terminal drought, soybean*

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Assessment of genetic divergence in mini core collection of peanut (*Arachis hypogaea* L.)

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Groundnut (*Arachis hypogaea* L.) is an important oilseed crop where kernel yield is the ultimate economic trait influenced by multiple yield-contributing characters. Due to the narrow genetic base of existing groundnut cultivars, the incorporation of novel gene sources is imperative for enhancing genetic variability and identifying yield-associated alleles. In this context, the present study assessed the genetic divergence among 144 groundnut mini core collections, including five standard checks (K-6, Dh-256, TMV-2, K-9 and ICRC-1), obtained from ICRISAT during *Kharif* 2024. Genetic divergence among the genotypes was quantified using Ward.D^2 method based on Euclidean distance. The genotypes were grouped into eight clusters. Cluster I had the maximum number of genotypes (31) whereas, Cluster VI had the minimum (3). Harvest index contributed the maximum (18.24%) due to wide variation in biomass partitioning and hundred kernel weight the minimum (1.26%) because of its relative stability across genotypes towards genetic divergence. Among clusters, the highest intra-cluster distance in Cluster VI (6.06) indicates the presence of greater genetic variability among its genotypes, arising from wider differences in trait expression. While the lowest intra-cluster distance in Cluster II (2.46) suggests close genetic relatedness, with genotypes exhibiting more uniform trait performance and narrower genetic variation. The maximum inter-cluster distance occurred between Cluster I and Cluster VII (5.82), while minimum inter-cluster distance (1.34) was found between Cluster II and Cluster III, implying a strong genetic resemblance among the genotypes within these clusters. For high pod yield and kernel yield, ICG 76 (Cluster VII) and ICG 14118 (Cluster VIII) were exceptional choices respectively. This study demonstrated considerable genetic divergence among groundnut genotypes, indicating that hybridization between superior lines from distantly related clusters could effectively broaden variability and accelerate yield-oriented genetic improvement.

Keywords: *Groundnut, genetic variability, genotypes, hybridization, oilseed*

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Character association and genetic diversity in groundnut (*Arachis hypogaea* L.)

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A biometrical investigation on "Character association and genetic diversity in groundnut *(Arachis hypogaea* L.)*"* for twenty-two groundnut genotypes with three replications was conducted at AICRP on Groundnut, OUAT, Bhubaneswar during *Rabi*-summer, 2024-25 for fourteen yield attributing traits to study the genetic variability, nature of association of characters and genetic divergence to find out the ways and means for making judicious selection of parents in order to get meaningful recombination. Analysis of variance for all fourteen characters indicated the existence of genetic variability of twenty-two groundnut genotypes. High heritability coupled with high genotypic advance was found in pods/plant, pod yield/plant(g), 100 kernel-weight and shelling % indicating the role of additive gene action providing thereby ample scope for selection. Pod yield/plant (g) showed a significant strong positive correlation with pod yield (kg/ha), kernel yield/plant, kernel yield (kg/ha) and 100-kernel weight at both phenotypic and genotypic levels.

The studies on multivariate analysis of twenty-two genotypes led to the construction of six clusters signifying that geographical diversity is not a reliable index for genetic diversity. Cluster II contained the largest number of genotypes (7), followed by clusters III (5). Highest inter-cluster distance was observed between cluster V and VI (37.82) followed by cluster I and VI (35.44). Kernel yield/ plant contributed most to genetic divergence. From the above study, it became apparent that judicious selection of parents from cluster V and VI in normal cross and cluster combination of (VxVI) x I would be useful for hybridization in order to obtain superior recombinants.

Keywords: *Arachis hypogaea, genotype, genetic variability, phenotypic*

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Genetic stability analysis of climate resilient groundnut genotypes using AMMI model

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The present investigation entitled "Stability analysis of climate resilient groundnut genotypes (*Arachis hypogeal* (L.)) for yield and yield components" was carried out during *Kharif* 2024 using sixteen genotypes in a randomized complete block design with three replications at seven locations of Zone 3 and Zone 8, Karnataka i.e Dharwad, Bailhongal, Hanamanamatti, Nippani, Annigeri, Vijayapur and Bagalkot. The objective was to identify stable and high-yielding genotypes across different environments. Based on AMMI analysis, genotypes Dh 291, Dh 311 and Dh 319 were identified as the most stable across environments, as they were positioned close to the origin in both AMMI1 and AMMI2 biplots, indicating minimal genotype × environment interaction along with consistent performance. Among the tested genotypes, Dh 318 followed by Dh 257 and Dh 316 combined above-average mean yield with low to moderate interaction effects, suggesting wider adaptation along with higher yield . Overall, Dh 291 emerged as the most stable genotype, while Dh 318 was the most desirable genotype combining high yield and stability across different environments. The genotypes that are stable, high-yielding are suitable for cultivation which contribute for enhancing productivity under diverse agro-climatic conditions.

Keywords: *Arachis hypogaea, agro-climate, genetic, stability genotypes, yield*

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Assessment of stable groundnut (*Archais hypogaea* L.) genotypes in central India zone for pod and kernel yield using AMMI and GGE biplot

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Thirty two elite groundnut genotypes were examined in 4 environments to analyze stability of genotypes, and identify mega-environments if they exist. Additive main effect and multiplicative interaction (AMMI) model, cultivar-superiority measure, and genotype plus genotype-by-environment (GGE) biplot analysis were used for data analysis. The analyses of variance for pod yield per plant revealed that genotype, environment and genotype x environment interaction were accounting for 16.59%, 43.09% and 40.32% of the total variation, respectively whereas for kernel yields per plant showed that genotype, environment and genotype x environment interaction were accounting for 13.77%, 21.06% and 65.15% of the total variation, respectively. In AMMI analysis, the pattern portion of both pod yield and kernel yield were (94.99%) and (85.84%), respectively, in the interaction effect was concentrated in the first two IPCA scores explaining the magnitude of interaction effect on yield. Hence, Genotype G6 (ICGS-44), G17 (ICGV-13299) and G25 (ICG-X-140068) had the highest mean pod yield over all environments. Whereas, G12 (ICGV-13227) and G19 (ICGV-8098) had the highest mean kernel yield over all environments, but

not stable (inconsistent yield) compared to other genotypes G1 (KDG 128), G5 (TG-26), G7 (ICGV-3043),G13 (ICGV-13262), G15 (ICGV-13244), G17 (ICGV-13299), G18 (ICGV-13232), G22 (NRCG-13574), G23 (ICGV-2890), G27 (ICGV-13542), G29 (ICGV-9023), G30 (ICGV-13572) and G31 (ICGV-6258). On the other hand, while these genotypes were stable, they had low pod yield and kernel yield compared to the G6 (ICGS-44), G12 (ICGV-13227), G17 (ICGV-13299) G19 (ICGV-8098) and G25 (ICG-X-140068).

Keywords**:** *Groundnut, pod and kernel yield, additive main effects and multiplicative interaction, GGE biplot*

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Assessment of genetic variability for selection of elite lines in groundnut (*Arachis hypogaea* L.)

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The present investigation was conducted during *Kharif* 2025 at the Regional Research Sub-Station, Jalagarh, Purnea to assess genetic variability for yield and yield-attributing traits in groundnut (*Arachis hypogaea* L.). The experiment was laid out in a randomized block design (RBD) with four replications. Row to row and plant to plant distance was maintained at 30 and 10 cm respectively. Analysis of variance revealed significant differences among genotypes for all the studied traits, namely initial plant population, final plant population, shelling percentage, kernel yield and pod yield per plot, indicating the presence of substantial genetic variability. High heritability coupled with high genetic advance was recorded for traits *viz.;* kernel yield and pod yield per plot suggesting the predominance of additive gene action and indicating that selection would be effective in early generations. Maximum inter cluster distance was recorded between cluster I and Cluster V followed by cluster III and V. Besides these maximum number of genotypes falls under cluster V(8) followed by cluster IV(4). It indicated that these genotypes are divers to each other. So, it might be useful in further breeding progamme.

Keywords*: Groundnut, genetic variability, heritability, genetic advance, yield*

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Genetics of quantitative traits among the inter-specific BC_1F_4 populations of groundnut (*Arachis hypogaea* L.)

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The diploid wild Arachis species belonging to the section Arachis *viz*., *Arachis duranensis* (2n=2x=20) is a potential source of desirable genes for resistance to biotic stresses. The cultivated groundnut *Arachis hypogaea* L is a segmental allopolyploid species (2n=4x=40) has limited genetic variability which hinders rapid genetic improvement. To overcome the crossability barrier which arises due to ploidy level differences, synthetic tetraploid of *Arachis duranensis* (2n=4x=40) has been evolved by colchicine treatment. Crosses were made between *Arachis hypogaea* cv. JL 24 X *Arachis duranensis*^{4x}. The resultant F_1 hybrids were backcrossed with *Arachis hypogaea* cv. VRI 2 to accumulate favourable genes distributed in the cultivars. Altogether, 141 progenies belonging to BC_1F_4 generations were evaluated in a RCBD with two replications during *Rabi*/summer 2024-25 at the Regional Research Station, Vridhachalam. Biometrical observations were recorded from each plant in a progeny-row for various economic traits *viz*., leaflet

length, leaflet width, number of primary branches per plant, number of secondary branches per plant, number of mature pods per plant and pod yield per plant. The ANOVA exhibited highly significant differences for all the traits observed among the progenies. Leaflet length ranged from 1.95 to 5.7cm with a mean value of 3.962cm. The range for leaflet width was from 0.95 to 2.35cm with a mean of 1.795cm. Number of primary branches per plant registered a mean value of 5.09 and observed a range of 3.5 to 9.75. Number of secondary branches per plant varied from 3.5 to 34.0 with a mean value of 13.74. The overall mean number of mature pods per plant was 13.587 and reported a wide range of 5.5 to 30.0. Pod yield per plant swings from 2.0 to 23.0g with a mean value of 11.661g. Wide range of variability for the traits indicated the role of interspecific hybridization in bringing the desirable recombinants in a positive direction. PCV and GCV were higher for number of secondary branches per plant (49.39, 32.92), number of mature pods per plant (42.27, 32.43) and pod yield per plant (40.09, 29.28). However, the leaflet length (19.86, 16.23), leaflet width (17.48, 12.54) and number of primary branches per plant (23.41, 17.70) exhibited moderate PCV and GCV values. In general, PCV was invariably higher than the corresponding GCV indicating the presence of environmental influence to some extent, in the overall expression of all the traits observed. High heritability in broad sense were reported only for leaflet length (66.7 per cent), while the remaining traits noticed moderate heritability estimates, indicating probable role of additive gene action in the expression traits. Moderate estimates of heritability coupled with high genetic advance observed for number of secondary branches per plant (44.43, 41.91), number of mature pods per plant (58.87, 40.08) and pod yield per plant (53.33, 24.17) indicated the role of additive gene action and such traits can be relied upon for rapid genetic improvement through simple selection.

Keywords: *Arachis hypogaea, genetic improvement, interspecific hybridization, yield*

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Evaluation of promising and advanced groundnut genotypes for yield and yield associated traits under rainfed conditions

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Groundnut (*Arachis hypogaea*) is an important oil seed crop cum food legume crop highly valued for its oil, protein, and carbohydrate content. In India groundnut is grown in 47.07 lakh hectares, producing 101.80 lakh tonnes. In Andhra Pradesh, after rice groundnut is the second most significant edible oilseed crop in terms of both economy and acreage. The low yield in groundnut is contributed by growing the crop in marginal lands under rainfed situation with deficit rainfall and improper management practices. Drought is one of the most abiotic stresses affecting pod yield, especially in semi-arid and arid regions where water availability is unpredictable. Groundnut is sensitive to drought stress particularly during critical stages such as flowering, pegging and pod-filling. To overcome the existing yield gap, genotypes with drought tolerance is need to be identified which can significantly manage drought effects and provide a better solution to rainfed farmers. In the present study the main objective was to assess the promising advanced groundnut genotypes for yield and yield associated traits along with drought tolerance under rainfed conditions. The experiment was conducted during Kharif 2024 at Agricultural Research Station, Kadiri with twenty elite and advanced groundnut genotypes. The 24 genotypes were developed at ARS, Kadiri from the breeding material generated by involving drought tolerant parents in the crossing programme. In total 24 genotypes including four checks (Kadiri Lepakshi, Kadiri 9, Kadiri 6 and Visista) were evaluated in a replicated row yield trial. Observations were recorded for days to 50 per cent flowering, Shelling percentage, 100 pod weight, 100 kernel weight, SMK Percentage, dry pod yield and Kernel yield. The analysis of variance for 24 groundnut genotypes with regards to yield and yield component traits revealed that the existence of significant differences among the genotypes studied for all the traits in the rainfed conditions indicating that good amount of variation in the genotypes for effective selection. Out of 24 entries tested, three entries RRYT 24 K - 031 (5254 kg/ha dry pod yield and 3538 kg/ha kernel yield), RRYT 24 K - 033 (4386 kg/ha dry pod yield and 2851 kg/ha kernel yield) and RRYT 24 K - 031 (4120 kg/ha dry pod yield and 2983 kg/ha kernel yield) recorded significantly

higher dry pod and kernel yields against the best check Kadiri Lepakshi (dry pod yield 3831 kg/ha and kernel yield 2607 kg/ha). A perusal of the results of the present investigation revealed the identification of three superior drought tolerant groundnut genotypes from the twenty promising advanced lines assessed under rainfed conditions. These three genotypes could be promoted for multi-location testing for further adoptability studies. These genotypes may be offering potential solution for improving productivity in regions affected by drought stress.

Keywords: *Groundnut, Yield traits and Drought*

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Phenotypic characterization of groundnut germplasm lines

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Groundnut (*Arachis hypogaea* L.) is an allotetraploid, self-pollinating species within the Fabaceae family, characterized by a chromosome number of 2n = 4x = 40 and native to South America. It is a major oilseed crop and grain legume, cultivated annually in tropical and subtropical regions worldwide. It is a good source of high-quality edible oil (44-56%), protein (22-30%) on a dry seed basis, carbohydrates (10-25%), vitamins (E, K, and B complex), minerals (Ca, P, Mg, Zn and Fe) and fiber because of this nutritional value groundnut is also popular as a poor man's Cashew. India is the world's second-largest producer of groundnut and recorded average productivity varies between 1850 to 1900 kg/hectare and in Karnataka it varies between 1100 to 1260 kg per hectare but, actual potential of improved varieties varies between 2600 to 3200 kg per hectare. To full fill this huge yield gap development of improved and suitable variety to local regions is need of ours. With this background information present investigation on phenotypic characterization of 200 groundnut germplasm lines was carried out at AICRP on groundnut, Zonal Agricultural and Horticultural research Station, Babbur Farm, Hiriyur, during *Kharif* 2025. These evaluated 200 germplasm lines maintained at AICRP groundnut showed huge variation for pod yield (5.58 to 34.33 q/ha), Plant height (22 to 44 cm), Branches per plant (5 to 30 numbers), Days to maturity (98 to 121days), Sound matured kernels (45.87 to 90.54 %) and 100 seed weight (22.5 to 50 g). Out of these 200 lines, 37 lines measures 40 to 50g for 100 seed weight, 78 lines measures 35 to 40g for 100 seed weight, 77 lines measures 30 to 35g for 100 seed weight and 8 lines measures less than 30g for 100 seed weight. There are ten lines produced more than 25q dry pod yield per hectare. Therefore, these germplasm lines can be used for selection of high yield genotype as well as parents for further improvement since they showed huge variations for all the observations recorded.

Keywords: *Germplasm lines, groundnut, variety and variation*

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Assessment of genetic diversity in spanish bunch groundnut (*Arachis hypogaea* L.) via integrated morphological and molecular markers

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Groundnut (*Arachis hypogaea* L.) remains a primary, albeit physiologically complex, oilseed legume. The present investigation was undertaken using 83 genotypes of Spanish bunch groundnut to evaluate variability, genetic parameters, genetic divergence, character association and path analysis. The high values of genotypic and phenotypic coefficient of variation were observed for mature pods per plant,

immature pods per plant, total number of pods per plant, pod yield per plant, kernel yield per plant, fodder yield per plant, biological yield per plant and harvest index% indicating that sufficient variability existed in the experimental material for these traits. High heritability coupled with high genetic advance as percent of mean was observed for morphological characters viz., mature pods per plant, immature pods per plant, total number of pods per plant, pod yield per plant, 100 pod weight, kernel yield per plant, 100 kernel weight, fodder yield per plant, biological yield per plant, harvest index%. These characters were governed by additive gene action. Hence, direct selection could be made from these traits for improvement of the crop. Based on the integrated results of genetic divergence and path analysis, genotypes characterized by high harvest indices and kernel weights should be prioritized as parents in hybridization programs. The divergence analysis indicates that crossing genotypes from distinct clusters will likely result in transgressive segregants with superior heterotic vigor for oilseed productivity.

Keywords*: Arachis hypogaea* L., *genetic variability, heritability, additive gene action, path coefficient analysis, character association*

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Assessment of divergence and genetic parameters governing yield and its attributing traits in groundnut (*Arachis hypogaea* L.) germplasm lines

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Groundnut is an allotetraploid oilseed as well as legume crop. It ranks among the five major oilseed crops in India. It is an important source of edible oil, high-quality protein, minerals and vitamins. Owing to its high caloric value, groundnut serves as an energy-dense food crop. Evaluation of 65 groundnut germplasm was conducted to quantify divergence and genetic parameters for yield and associated traits at the Research Farm, Department of Genetics and Plant Breeding, Rajmata Vijayaraje Scindhia Krishi Vishwavidyalaya (RVSKVV), College of Agriculture, Gwalior (M.P.) during *kharif* 2024 in a Randomized Block Design with three replications. Analysis of variance revealed highly significant differences among genotypes for all the traits studied, indicating the presence of substantial genetic variability. High estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were observed for kernel yield per plant followed by number of pods per plant pod yield per plant and harvest index suggesting the predominance of additive genetic effects and greater scope for effective selection. High heritability and genetic advance as percent of mean (GAM) was found for 100 kernel weight followed by shell outturn, kernel yield per plant, plant height, number of pods per plant, pod yield per plant, biological yield per plant, sound mature kernel, harvest index, days to maturity and number of branches per plant. According to Tocher's method these germplasms were grouped into three distinct clusters. The studied groundnut germplasm can further serve as a valuable genetic resource as parent in future breeding program, genetic base broadening and development of high-yielding, resilient varieties through conventional and molecular breeding approaches.

Keywords: *Groundnut, diversity, variability, heritability and genetic advance*

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Screening of groundnut (*Arachis hypogaea* L.) genotypes for major foliar diseases under natural epiphytotic conditions

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Groundnut (*Arachis hypogaea* L.) is the fourth most important oil seed crop in the world. The early and late spots are foliage disease more common and more destructive of groundnut which cause severe yield losses up to 70% and reduces the quality of the pod and fodder. Recent efforts have targeted on developing resistant source against leaf spots and rust diseases which are helpful for discarding the hazardous toxic chemical compounds used for controlling the disease. The current study aimed to identify the sources of resistance to leaf spots and rust from the newly identified genotypes as well as from wild species and to study the way in which these were responding to the to the disease development. Methods: Twenty four groundnut genotypes were screened for Early Leaf Spot, Late Leaf Spot, Rust & Alternaria leaf spot diseases of groundnut under natural epiphytotic conditions in field at AICRP on Groundnut, CRS,Aliyarnagar during Rabi 2024-2025, Screening was carried out using infector row technique and the observations of disease intensity and rate of infection were recorded using 0-9 scale. Result: Among the AVT-I entries screened for major diseases of groundnut, four entries viz., AIS-2024-7,AIS-2024-8, AIS-2024-9 and AIS-2024-11 showed resistance to both leaf spots and rust diseases. AIS-2024-3, AIS-2024-4 & AIS-1-2024-3 are resistant to ELS, AIS-2024-7 found to be resistant to LLS, AIS-2024-1, AIS-1-2024-3, AIS-1-2024-7 are found to be resistant to Rust. Except 6 entries all the entries were resistant to Alternaria leaf spot disease. The susceptible check Co2 recorded maximum leaf spots and rust disease grade of 5-7. The resistant lines will be useful to develop introgression lines using marker-assisted backcrossing approach to improve foliar fungal disease resistance in popular groundnut varieties.

Keywords: *Arachis hypogaea, breeding, leaf spot disease, resistant genotypes, screening*

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Study of mutagenic effect of EMS and sodium azide in groundnut (*Arachis hypogeae* L)

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As the requirement of groundnut for various purposes continues to increase, there is need to breed new groundnut varieties with high yield and quality, in addition to resistance to biotic and abiotic stress factors. However, cultivated groundnut is an allotetraploid species that shows very low genetic variability. Therefore, Induced mutation may be one of the approaches for broadening crop genetic variability to overcome the limitations associated with narrow genetic basis. In the current study, two varieties in groundnut namely ICGS-76 and Rajashree were used in the present studies. The mutagens used in this study include chemical mutagens ethyl methane sulphonate (EMS) and sodium azide (NaN_3). The highest mutation frequency was recorded from 0.6% NaN_3 . The mutagenic effectiveness was observed to be highest for 0.2 % NaN_3 . Mutagenic efficiency, in terms of lethality was highest for 0.2% NaN_3 and 0.4% EMS. In terms of injury the mutagenic efficiency was highest for 0.4% EMS. Wide spectrum of chlorophyll and morphological mutants were induced by these chemical mutagens. Two types of chlorophyll mutants were observed in the order of viridis>variegated. A number of visible mutants were isolated for some morphological traits viz., dwarf

fertile, dwarf sterile and spreading canopy mutant. A total of 14 and 11 dwarf fertile mutants were isolated from ICGS-76 and Rajashree respectively. The dwarf fertile mutants attained the height of only 11.00-14.00 cm while the parents attained the height of 23.89 cm (ICGS-76) and 24.82 cm(Rajashree) at maturity. Thus, the efficiency of mutagen in causing micro mutants in M_2 and later generations can be judged by the change in mean value observed in a mutant population as compared with the parent populations. It was observed in the present investigation that the mean shifted both in positive and negative directions.

Keywords: *Mutagen, EMS, sodium azide*

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Studies on genetic variability and character association for yield, kernal iron and zinc content in groundnut genotypes (*Arachis hypogeal* L.)

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Groundnut is one of the major oilseed crops in the world including India. Kernels of ground nut serve as a rich source of edible oil (47-53%) and quality protein (25-36%) and also minerals and vitamins. Iron and zinc are the important micronutrients for human health and play vital role in overcoming hidden hunger. Low genetic variability has been a major bottleneck in genetic enhancement of the nutritional status of food crops and/or cultivars. In crop improvement programme, availability of sufficient genetic variability is of immense importance for both yield and nutritional parameters. The knowledge of nature and magnitude of genetic variance controlling yield and yield components and character association is a prerequisite for improvement of yield and nutrient content in any crop. Therefore, the present investigation was undertaken to assess the genetic variability and character association for pod yield and kernel iron and zinc content in 27 diverse groundnut genotypes. The field experiment was carried out in randomized complete block design with two replications during *Kharif* 2022 at University of Agricultural Sciences, Dharwad. The analysis of variance revealed significant differences among the genotypes for all the characters studied indicating presence of wide genetic variation for different characters among 27 genotypes. The phenotypic coefficients of variation values were higher than genotypic coefficients of variation values. The traits viz., plant height, pods per plant, 100 seed weight and pod yield recorded high phenotypic coefficient of variation and genotypic coefficient of variation suggesting that there is considerable genetic variability among the genotypes studied for the evaluated traits and these traits possessed high selective value. High heritability couples with high to moderate genetic advance over mean was recorded for all the traits studied except days to 50 percent flowering indicating that additive gene action operates for these traits and has potential for improvement through direct selection methods. Character association studies revealed that pod yield showed positive association with 100 kernel weight, shelling percent, number of pods, Zinc content. Fe content showed significant and positive correlation with zinc content, shelling percent and 100 kernal weight. Fe content showed negative correlation with pod yield. Groundnut genotypes DBG-4, Dharwad local-1 and Dhrawad local-2 recorded high Fe and zinc content. The data generated in study provide useful resources for its quality development in groundnut breeding programme.

Keywords: *Groundnut, genetic variability, genetic advance, heritability, correlation*

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Opportunities of groundnut (*Arachis hypogaea* L.) cultivation for crop diversification and income enhancement in Tripura through integrated nutrient management (INM)

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An annual legume, Groundnuts (*Arachis hypogaea* L.) are also known as peanuts, earthnuts, monkey nuts, and goobers. It is one of the most significant oilseed crops in the world, ranking as the fourth most important oilseed crop and the thirteenth most important food crop. In addition to being high in vitamin E, niacin, riboflavin, thiamine, folacin, calcium, phosphorus, magnesium, zinc, iron, and potassium, groundnut kernels have 40%–50% fat, 20%–50% protein, and 10%–20% carbohydrates. Groundnut cultivation offers significant potential for Tripura farmers due to its adaptability to diverse land types, ability to improve soil health, versatile growing & suitability for Intercropping, water efficiency and Economic Returns**.** Although the agro-climatic conditions of Tripura are conducive to oilseed production, groundnut is seriously underutilized due to poor varietal evaluation and low adoption rate of (INM) system, thus providing low yields leading to soil exhaustion as well deterioration in farm income. There is hardly any scientific information on the interactions of improved groundnut varieties and INM in Tripura, which reflects a significant knowledge gap to encourage groundnut as an alternative diversification crop. Filling in this gap, the performance of improved groundnut lines (TAG 24, GJG 22, Girnar 5) was studied against integrated nutrient management taking into account organic, inorganic and biological sources of nutrients. Introduction The cultivation of improved groundnut cultivars (TAG TAG 24, GJG 22 and Girnar 5 etc), high yielding hybrids (ICGV-308, JL 24 etc.) along with judicious use of organic and inorganic nutrient sources provides a viable option for improving productivity, profitability and sustainability in semiarid tropics.On farm trials under Tripura like agro-climatic situations reveal that the improved varieties respond positively to INM practices. Recommended doses of N-P-K along with farmyard manure (5–10 t/ha), biofertilizers (Rhizobium and phosphate-solubilizing bacteria), and micronutrients (particularly calcium and boron) resulted in significant improvements in growth and yield parameters. Pod yield increases of 18–32% were recorded under INM compared to sole chemical fertilizer application, with TAG 24 and GJG 22 consistently producing higher pod yields (2.2–2.6 t/ha) and superior shelling percentages (68–72%). Girnar 5 demonstrated stable performance under moderate moisture stress, maintaining yields above 2.0 t/ha with improved nutrient-use efficiency. Soil organic carbon increased by 0.12–0.25%, while available nitrogen and phosphorus improved by 10–18% and 8–15%, respectively, over initial levels. Enhanced nodulation (25–35 nodules/plant) and higher nitrogen fixation rates contributed to reduced external nitrogen requirements and improved residual soil fertility for subsequent crops. Nutrient uptake analysis showed higher N, P, and K absorption in INM plots, directly correlating with increased biomass and pod yield. Economic analysis further highlighted the income-enhancing potential of INM-based groundnut systems. Net returns increased by 25–40%, with benefit–cost (BC) ratios ranging from 1.9-2.4, compared to 1.4–1.6 under conventional fertilization. Additional income from groundnut haulms, valued as quality fodder, further improved farm profitability. Varieties such as TAG 24 and GJG 22 were particularly suitable for market oriented production due to better kernel quality and consumer preference.

Keywords: *Biofertilizers, farmyard manure, groundnut, Rhizobium*

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Stability and adaptability of castor genotypes for yield and its components across environments using AMMI and GGE Biplot models

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Castor (*Ricinus communis* L.) is a strategic non-edible oilseed crop of global importance, valued for its exceptionally high ricinoleic acid content (>80%), which confers unique chemical properties for applications in lubricants, cosmetics, coatings, pharmaceuticals, and biodiesel industries. Despite its industrial potential, productivity in castor remains constrained by genotype × environment interactions (GEI), which obscure the true genetic potential of hybrids across variable production ecologies. The present investigation sought to elucidate the magnitude and pattern of GEI and to identify stable, high-performing hybrids for yield and yield-contributing traits across diverse agro-climatic conditions (three locations) of Telangana, India. Eight elite castor hybrids were evaluated across multi-environment trials using AMMI (Additive Main Effects and Multiplicative Interaction) and GGE (Genotype and Genotype × Environment) biplot models to dissect stability, adaptability, and environmental representativeness. Highly significant GEI effects were detected for seed yield, days to 50% flowering, number of nodes, and hundred-seed weight, underscoring the differential response of genotypes across environments. The AMMI biplot effectively captured interaction patterns, identifying E1 (Palem) as the most representative and least interactive environment for yield performance. "Which-won-where" analysis of the GGE biplot delineated mega-environment groupings, with PCH-596 excelling under E2 (Tandur) and E3, while ICH-5 demonstrated superior adaptability to E1. The Average Environment Coordinate (AEC) view identified E2 and E1 as the most discriminative and representative sites, providing critical insight into site selection for future testing. Yield Stability Index (YSI) and GGE ranking analyses consistently recognized PCH-596 (G2) and ICH-5 (G6) as the most stable and high-yielding hybrids across environments, with PCH-111 (G5) showing specific adaptability. The integration of AMMI and GGE biplot methodologies proved highly effective in unravelling complex GEI patterns, facilitating the identification of genotypes with broad and specific adaptability. These findings provide a quantitative basis for environment-specific hybrid recommendations and contribute to accelerating genetic gains in castor breeding programs targeting enhanced productivity and resilience.

Keywords**:** *AMMI, Castor, genotype x environment interaction, GGE biplot, yield*

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Evaluation of castor varieties with yield potential comparable to hybrids for Telangana agro-climatic conditions

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Castor (*Ricinus communis* L.) is an important industrial oilseed crop and a monotypic species belonging to the family Euphorbiaceae. It is believed to have originated in the Ethiopian and Eastern African regions, as evidenced by the high genetic diversity observed in these areas. The crop is primarily valued for its oil, which has immense industrial significance due to the presence of ricinoleic acid. Castor oil is widely used as an efficient lubricant for high-speed engines and as a key ingredient in products such as soaps, shampoos,

shoe polish, candles, ointments, and several other industrial applications. Being a predominantly cross-pollinated crop, hybrids are widely cultivated in castor. However, owing to the relatively low inbreeding depression in castor, varieties can also exhibit yield potential comparable to that of hybrids. Hence, development of such varieties with high yield potential will reduce the cost of seed compared to the hybrids. An experiment was conducted at the Regional Agricultural Research Station (RARS), Palem, to identify high-yielding castor varieties. Fourteen advanced lines, namely PCS-438, PCS-520, PCS-536, PCS-464, PCS-518, PCS-494, PCS-471, PCS-498, PCS-437, PL-111, PCS-468, PCS-463, PCS-527, and PCS-519, along with the check variety Pragathi (PCS-262), were evaluated in a Randomized Block Design (RBD) with two replications during *kharif*, 2024. The results revealed that PCS-438 (1213 kg/ha), PCS-494 (1223 kg/ha), and PCS-468 (1197 kg/ha) recorded significantly higher seed yield compared to the check PCS-262 (1023 kg/ha). Further, oil content analysis indicated that PCS-468 recorded the highest oil yield (482 kg/ha), followed by PCS-438 (448 kg/ha), which were superior to the check variety PCS-262 (389 kg/ha). Thus, the superior performing varieties can be further evaluated in yield trial to identify potential superior varieties in castor.

Keywords: *Castor, hybrids, oilseed, oil content, varieties, yield*

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Deciphering genetic mechanisms and environmental modulation of sex expression in castor hybrid GCH-7

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Stability of sex expression is a critical prerequisite for successful hybrid seed production and yield consistency in castor (*Ricinus communis* L.), an economically important industrial oilseed crop of India. The present investigation was conducted during the *kharif* seasons of 2022 and 2023 at the Centre for Oilseeds Research, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat with the objective of elucidating the genetic basis of reversion and sex expression in castor hybrid GCH-7 and to assess its stability and adaptability across diverse agro-climatic environments. The experimental material consisted of four parental lines, namely SKP 84, SKP 84 (M), SKI 215, and SKI 215 (M), and four derived hybrids: SKP 84 × SKI 215, SKP 84 × SKI 215 (M), SKP 84 (M) × SKI 215, and SKP 84 (M) × SKI 215 (M). These genotypes were evaluated under three contrasting environments following a randomized block design with appropriate replications. Observations were recorded on sex expression traits, including the frequency of interspersed staminate flower (ISF) types, monoecious plants, and consistency of floral expression across primary, secondary, and subsequent raceme orders. Genetic control of sex expression was examined through segregation analysis using chi-square (÷²) tests. The results revealed the involvement of diverse gene actions, including dominant epistasis, recessive epistasis, and polymeric gene interactions, across different crosses and environments. Importantly, ÷² values were non-significant in all cases, indicating conformity to Mendelian segregation and suggesting genetic stability in the inheritance of sex expression traits. These findings confirm that sex expression in castor is governed by complex but predictable genetic mechanisms. Marked variation was observed among the F• hybrids for sex expression. Cross I (SKP 84 × SKI 215) exhibited exceptionally high genetic conformity, with more than 99% plants expressing the desirable ISF type across all environments, indicating superior true-to-type maintenance. Cross II [SKP 84 × SKI 215 (M)] recorded nearly 50% monoecious plants, while Cross III [SKP 84 (M) × SKI 215] showed 37% monoecious expression. Cross IV [SKP 84 (M) × SKI 215 (M)] exhibited the highest deviation, with approximately 70% monoecious and 30% ISF-type plants,

reflecting greater genetic instability. Environmental influence on sex expression was evident across raceme orders. ISF expression increased in later racemes in most hybrids; however, SKP 84 × SKI 215 consistently maintained lower deviations across environments, demonstrating strong phenotypic stability and reduced environmental sensitivity. Yield performance analysis further identified this hybrid as the most stable and widely adapted genotype, exhibiting consistent seed yield per plant across environments. Overall, the study highlights the importance of genetic background and parental combinations in determining sex expression stability in castor. The identification of a stable, true-to-type hybrid such as SKP 84 × SKI 215 offers significant potential for commercial exploitation and provides valuable insights for hybrid breeding and seed production programs under diverse agro-climatic conditions.

Keywords: *Castor, genetic basis of reversion, hybrid breeding, sex expression, stability*

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Effects of crop resistance on tritrophic interactions among castor genotypes, capsule borer (*Conogethes punctiferalis*), and its larval parasitoid (*Eriborus trochanteratus*)

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Castor (*Ricinus communis* L.) is one of the important non-edible oilseed crops with immense industrial and medicinal value. Among the various constraints limiting castor productivity, damage caused by the capsule borer, *Conogethes* (=*Dichocrocis*) *punctiferalis* Guenée (Crambidae: Lepidoptera), is the most serious, with yield losses of about 48.6–52% reported in castor. The cryptic habit and concealed feeding behavior of the pest make its management difficult, and farmers often notice infestation only after capsule damage has already occurred. Host plant resistance and biological control are considered efficient and environmentally friendly approaches for sustainable pest management. In the present study, tritrophic interactions among castor genotypes, the capsule borer (*Conogethes punctiferalis*), and its larval parasitoid (*Eriborus trochanteratus*) were investigated under field conditions. The role of biophysical resistance factors in castor genotypes with diverse morphological characters against the capsule borer and their mediational effect on the functional response of the larval parasitoid (*Eriborus trochanteratus*) was studied. Screening was carried out using the infester row technique, along with resistant and susceptible checks, in a randomized block design with two replications. The results revealed that nine castor genotypes were resistant, recording less than 10% capsule damage. Genotypes with brown-colored capsules, absence of waxy bloom, non-spiny and loose spikes, and greater capsule pericarp thickness exhibited lower capsule borer infestation. Compactness of spike showed significant positive correlation with capsule borer infestation (r = 0.956*), while pericarp thickness resulted significant negative correlation with capsule borer infestation (r = -0.666*). Parasitisation of capsule borer larvae by *Eriborus trochanteratus* (Ichneumonidae: Hymenoptera) was recorded in all genotypes and ranged from 3.1% to 35.6% with an average of 18.9%. Parasitisation showed a strong positive correlation with percent capsule borer infestation (r = 0.942*). However, parasitisation did not correlate significantly with most biophysical characters of castor genotypes, except pericarp thickness, which showed a negative correlation (r = “0.439*). Biophysical plant characters play a crucial role in conferring resistance or susceptibility to insect pests, and quantifying the contribution of these traits is essential for developing pest-resistant or tolerant cultivars under field conditions. The resistant sources and associated biophysical traits identified in the present study can be effectively utilized in breeding programs aimed at developing castor cultivars tolerant to capsule borer. Overall, the findings on tritrophic interactions among the host plant, pest, and natural enemy provide valuable insights for integrating host plant resistance with biological control strategies for sustainable pest management.

Keywords: *Castor, capsule borer, genotypes, host plant resistance, larval parasitoid, tritrophic interactions*

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Genetic improvement of monoecious castor (*Ricinus communis* L.) for enhanced seed yield and productivity

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Castor (*Ricinus communis* L.) is an important oilseed crop of India. Castor is monotypic with only one cultivated species and it is highly cross-pollinated crop. Hence proper utilization of available diversity is important to generate Monoecious castor for enhanced seed yield and productivity. The breeding programme emphasized improvement of key agronomic and adaptive traits, including earliness, seed yield, yield components, compact plant type, drought tolerance, resistance to *Fusarium* wilt, non-spiny capsules, and tolerance to sucking pests. Breeding materials were developed through pedigree and backcross breeding methods using diverse germplasm comprising monoecious, pistillate, and disease-resistant lines. Selection criteria for monoecious progenies were based on flowering duration, branching pattern, spike architecture, effective spike length, seed weight, and resistance to biotic stresses. A field experiment was conducted with 55 advanced selections at Tapioca and Castor Research Station during *kharif* 2021-25 under rainfed conditions. All the 55 monoecious lines were generated utilizing the Monoecious x Germplasm, Monoecious x Monoecious and Germplasm Collections. The ideal plant type proposed for rainfed situations indicates selection for dwarf to medium plant height (50-60 cm), short to medium duration (120-150 days), 2 to 3 secondary and tertiary branches with better orientation of leaves and branches for efficient utilization of light, 35 to 40 medium size leaves with LAI of 3 to 3.5, long productive spikes with bold capsules and seeds, and 30 to 40% harvest index would be effective. Among them one stabilised monoecious line namely YRCS 1904 performed consistently superior for three seasons in station trials and subsequently tested for wilt screening in national screening nursery against wilt disease under sick plot conditions. The monoecious line YRCS 1904 is medium tall with spreading type with 17 nodes having red stem colour. The monoecious line recorded 50 days of 50% flowering and having of 100 seed weight of 30 g with seed yield of 1625 kg/ha against best check YTP 1 with seed yield of 1450 kg/ha in station trails.

Keywords: *Castor, genetic improvement, monoecious, seed yield, wilt*

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Combining ability, heterosis and stability studies in linseed (*Linum usitatissimum* L.)

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The present investigation was undertaken in six environments comprising of early, normal and late sown condition along with rainfed and irrigation conditions. Eight parents and their 28 F_1's (generated in diallel fashion excluding reciprocals) evaluated in randomized block design with three replications at Agricultural Research Station, Ummedganj, Kota. Observations were recorded for twelve the characters namely, days to 50 per cent flowering, days to maturity, plant height, number of primary branches, number of secondary branches, number of capsules per plant, number of seeds per capsule, test weight, oil content, biological yield, seed yield and harvest index in each environment. The pooled analysis of variance revealed that genotype, environment and genotype × environment interaction were significant for all the characters. The environment wise combining ability analysis revealed significant differences for GCA and SCA variances for all the characters indicating importance of both additive and non-additive gene effects in the genetic control of all the characters studied. The GCA/SCA showed preponderance of non-additive gene action for most of the characters. As regards general combining ability effects and *per se* performance,

the parents RL 15583 emerged as good general combiner for yield and most of the contributing characters. Out of 28 crosses studied, crosses *viz*., RL13161 x PA2, Meera xRL13161 and Meera x RL15582 had high *per se* performance, SCA effects and significant heterotic effect in desirable direction for yield and most of the associated traits. The crosses exhibiting the highest heterosis and heterobeltiosis for seed yield and most of the other yield contributing characters were RL15582 x KBA4 and RL13161 x KBA3. These crosses were considered promising for their use for yield improvement in linseed. A close perusal of all the experiment results revealed that parents *viz.*, PA2, KBA3 and RL15583 were most desirable for all the characters and they could be utilizing in future breeding programme for the development of high yielding and early maturing genotype. While among the hybrids RL15583 x KBA3, RL15582 x KBA4 and RL 15582 x PA 2 were identified as ideal cross combinations as they depicted higher *per se* performance, SCA effects and magnitude of heterosis for yield, yield contributing characters and quality parameters. Conclusively, it has been suggested that heterosis breeding could be useful breeding approach for developing of early and high yielding genotypes from potent breeding material evaluated in the present experiment and further amelioration of seed yield and quality can be achieved in linseed.

Keywords: *Combining ability, heterosis, linseed, seed yield, stability*

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Development of wilt resistant and climate resilient linseed genotype DLV 22

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In the present study induced mutation using gamma irradiation to enhance genetic variability for desired agronomic and stress-resistance traits was carried out. Field experiments were conducted over nine years (2013–2022) at the Main Agricultural Research Station (MARS), University of Agricultural Sciences, Dharwad. Two linseed varieties were subjected to 20 kR gamma irradiation. The M_1 generation was raised during *Rabi* 2013 and bulk harvested, while individual plant selection was carried out in the M, generation during *Rabi* 2014. Mutant families were advanced through successive generations during *Rabi* 2015 and *Rabi* 2016. In the M„ generation, mutants were screened for their reaction to wilt using susceptible and resistant checks in the hotspot location. The mutants with desirable agronomic characters and wilt resistance were stabilized through the selfing generations and contributed to IVT through AICRP on linseed and tested across Zone I and II during 2020-21 along with 18 test entries and 1 zonal check (RLC 92). Note-worthy among them were DLV-22 which recorded high seed yield, more branches, high capsules number and exhibited resistance to wilt disease. SLS 136 and DLV-22 which recorded higher (>10%) seed yield over the best check LMS 9-2-K (40.3) DLV 22 also recorded higher oil content (42.3 %). The station trials conducted during *Rabi* 2022 with three dates of sowing spanned from September 15th to November 15th revealed that statistically on par yields were obtained across the three sowing windows indicating their resilience.

Keywords: *Mutation breeding, linseed, wilt resistance, yield*

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GNNIG-5 (Aarohi): A high yielding niger variety identified for tribal India

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Niger [*Guizotia abyssinica* (L.f.) Cass], grown mostly by tribal farmers as livelihood crop is one of the important minor oilseed crops of India which mainly cultivated in tribal pockets of Madhya Pradesh, Orissa, Maharashtra, Bihar, Gujarat, Karnataka and Andhra Pradesh. In Gujarat, it is traditionally grown in *kharif* season crop in South Gujarat region particularly in Kaprada and Dharampur talukas of Valsad districts, Vansda and some parts of Chikhali taluka of Navsari district, parts of Vyara and Songhadh talukas of Tapi district and in whole of The Dangs. Though an importance of niger seed oil for tribal farmers of hilly area of south Gujarat, its area under this region is being drastically reduced year by year due to lack of high yielding cultivars, lack of improved packages of practices and erratic rainfall. Hence, a suitable high yielding with high oil containing and resistance to major pests and diseases was in demand for south Gujarat region. In this context, Niger Research Station, Navsari Agricultural University, Vanarasi made an attempt to create variability through desirable selections made in the various niger populations developed by several polycrosses which resulted in development of an existing genotype NPR-11. The proposed genotype NPR-11 was evaluated in various categories of trial from 2018-19 to 2023-24 in the Gujarat state trials and also in Co-ordinated varietal trials at national level AND was also nominated in AICRP trial during *Kharif*, 2021 for IVT and further advanced to AVT-I & II where recorded (over 10 locations) 16.80% and 17.88% higher seed yield over the national checks JNS-9 and IGPN-2004-1, respectively. It also, showed highest oil yield (208 kg/ha) which is 16.85% and 22.92% increase over both national checks. The identified variety also performed well under all agronomic practices across the locations and recorded an average seed yield of 665 kg/ha with seed yield increment of 16.46% and 31.42% over the local and national checks under large scale demonstration trial in Gujarat region. The identified genotype was also resistant to Alternaria leaf spot and stem/root rot diseases and pests like niger caterpillar, whitefly and leafhopper. Looking to the overall performance of seed yield, oil yield and disease reaction, NPR-11 was identified by CVRC Meet for released at National level under the name GNNIG-5 (Aarohi).

Keywords: *Aarohi, Gujarat, GNNIG-5, high yield, NPR-11, niger variety*

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Assessment of genetic variability and character association in niger genotypes through PCA and cluster analysis

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Genetic variability and interrelationship among yield and its contributing traits are crucial for effective selection and genetic improvement in niger (*Guizotia abyssinica* Cass.). The present investigation was undertaken to assess genetic variability, character association, and genetic divergence among fifty-nine niger genotypes at AICRP on Niger, ZARS, Igatpuri using analysis of variance (ANOVA), genetic parameters, principal component analysis (PCA), correlation analysis and hierarchical cluster analysis. Eight quantitative characters *viz*., days to 50% flowering, days to maturity, plant height, number of branches per plant, number of capitula per plant, number of seeds per capitulum, thousand seed weight, and yield per plot were evaluated. ANOVA revealed highly significant differences among genotypes for all the

traits studied, indicating the presence of substantial genetic variability. Estimates of phenotypic coefficient of variation (PCV) were marginally higher than genotypic coefficient of variation (GCV) for all traits, suggesting limited environmental influence. High GCV and PCV were observed for yield per plot and number of seeds per capitulum. High heritability coupled with high genetic advance as per cent of mean was recorded for yield per plot, number of seeds per capitulum, thousand seed weight, and number of branches per plant, indicating the predominance of additive gene action and effectiveness of selection for these traits. Correlation analysis revealed that yield per plot exhibited positive and significant associations with number of seeds per capitulum, test weight, plant height and number of capitula per plant, suggesting their importance as selection criteria for yield improvement. Days to maturity showed a negative association with yield, indicating the advantage of early maturing genotypes. Principal component analysis showed that the first two principal components accounted for a substantial proportion of total variation, with yield per plot, test weight, number of seeds per capitulum and days to maturity contributing maximum to genetic divergence. The PCA biplot effectively separated genotypes based on yield potential and maturity duration. High-yielding and divergent genotypes such as NSS-5554, SP-51, KMS-36, JN-121, EC-158670, N-12, and 87-14 were distinctly positioned in favorable quadrants, indicating their superiority for yield and associated traits. Hierarchical cluster analysis grouped the genotypes into distinct clusters, indicating wide genetic diversity among the evaluated material. Genotypes occupying distant clusters, particularly NSS-5554, SP-51, KMS-36, JN-121, and EC-158670, exhibited superior yield performance and desirable trait combinations, making them suitable candidates for utilization in hybridization and selection programmes. Genotypes belonging to different clusters exhibited considerable divergence and could be exploited in hybridization programmes to generate desirable recombinants. The study concluded that selection based on yield per plot, number of seeds per capitulum, thousand seed weight, and number of capitula per plant would be most effective and the identified superior genotypes can be exploited as promising parental material for future breeding programmes aimed at enhancing yield in niger.

Keywords: *Character association, cluster analysis, genetic variability, genotypes, niger, PCA*

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Estimation of genetic variability for quantitative traits in niger (*Guizotia abyssinica* L. f. Cass) genotypes

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Niger (*Guizotia abyssinica* L.f. Cass) is an annual dicotyledonous herb commonly group for its seed and oil. Niger is named after the French historian Guizot. Niger belongs to family Compositae/Asteraceae, tribe Helianthoides and Sub tribe Verbeninae. It is completely self-incompatible crop having diploid chromosome number 2n=30. It is native of high lands of Ethiopia and originated from *G. scabre* sub spp. Wild form of niger has low oil content (24-35%) than the cultivated niger (36-42%). Indian niger oil reported higher in oleic acid (25%) and lower in linoleic acid (55%). It has protein content about 10-30%. Niger is mostly grown in marginal and sub marginal lands. The study was laid out in a Randomized Block Design with three replications experimental area of Zonal Agricultural Research Station, AICRP on Niger, Chhindwara, Madhya Pradesh, during the *Kharif* season 2022. The experiment materials were comprised of twelve niger promising genotypes including one Check JNS 28. In the present studies the days to fifty percent flowering ranged from 64 to 69 with mean value 66, variation for plant height ranged from 105-135cm with mean an average value of 128cm. the observation data of number of branches per plant ranged between 9 to 13 with a general mean 10. The data of number of capitula per plant ranged from 20 to 41 with an average 33. The 1000 seed weight ranged between 3.8 to 4.4g with mean value 4.0g. the seed yield (kg/ha) 242 to 718 with a mean value 544 Kg/ha. The days to maturity variation ranged from 99 to 104 days with mean value 101 days and plant population ranged from 270 to 333 with

mean value of 303. Those traits which showed less variation between PCV and GCV can be directly selected for further breeding programmes. Heritability is conjunction with genetic advance would give a more reliable index of selection value. Present study revealed that all the traits under study showed low genetic advance ranging from 0.30 to 11.81 except high genetic advance in seed yield was 191.70. High heritability with high genetic advance over mean were recorded for seed yield. It shows genotypic variance for this character due to high additive gene effect. High heritability coupled with low genetic advance indicates non additive gene action.

Keywords: *Genetic variability, genotypes, quantitative traits, niger*

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Evaluation of Indian and exotic niger cultivars suitable for high altitude and tribal zone in Andhra Pradesh

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Niger (*Guizotia abyssinica*) is a vital traditional oilseed crop for the tribal communities of the High Altitude and Tribal (HAT) Zone of Andhra Pradesh. However, regional productivity is often limited by the use of local landraces and non-scientific cultivation practices. The evaluation of Indian and Exotic Niger cultivars was conducted to evaluate and identify high-yielding niger varieties suitable for the specific agro-climatic conditions of the HAT Zone to enhance the economic security of tribal farmers. The experiment was conducted at Regional Agricultural Research station, Chintapalle, ASR District, Andhra Pradesh during 2022-23, 2023-24 and 2024-25 using Randomized Block Design (RBD) and replicated three times. The Indian and Exotic Niger cultivars selected were JNS-9, GN-1, GN-2, GN-3, Deomali, JNS-28, JNS-30, IGPN-2004-1, Utkal Niger 150, KBN-2, KGN-2 and Exotic Niger cultivars selected were IIOR-3409, IIOR-3410, IIOR-3411 and IIOR-3412. The Indian and Exotic Niger cultivars were collected from ICAR-IIOR and ICAR-AICRP on Sesame and Niger, JNKVV, Jabalpur. Various characters studied were days to 50% flowering, days to maturity, plant height, number of branches per plant, number of capitula per plant, 1000 seed weight, seed yield per plot and seed yield per hectare. There was no significant difference for the characters like plant height, number of branches per plant and 1000 seed weight, but significant differences were observed for the remaining characters. Utkal Niger 150 recorded highest seed yield per plot (406.6g) and seed yield per hectare (450.49 kg) followed by IGPN-2004-1 370.72 and 413.98 respectively. GN-3 recorded less number of days for 50% flowering (42.67 days) and maturity (89.33 days) shows its earliness, but is having high 1000 seed weight (4.07 g). IIOR-3410 recorded highest plant height (135.04 cm) and more number of capitula per plant (46.28), whereas IIOR-3411 recorded more number of branches per plant (10). The study concludes that for farmers and stakeholders in the High Altitude and Tribal Zone of Andhra Pradesh, Utkal Niger 150 and IGPN-2004-1 are the most suitable varieties due to their superior yield performance.

Keywords: *High altitude and tribal (HAT) zone, high-yielding varieties, Indian and exotic cultivars, niger*

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Assessment of genetic variability, heritability, genetic advance and diversity in niger (*Guizotia abyssinica* L.) germplasm

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Niger (*Guizotia abyssinica* Cass.) is an important minor oilseed crop cultivated mainly under marginal environments; however, its yield potential remains low due to limited systematic utilization of available genetic variability. Improvement of seed yield in niger largely depends on the assessment of genetic variability, heritability and identification of genetically diverse parents for effective breeding programmes. The present investigation was undertaken to assess genetic variability, heritability, genetic advance and genetic divergence for yield and its contributing traits in 33 niger accessions, including three checks. Field experiment was conducted at Project Coordinating Unit (Sesame and Niger) Research Farm, JNKVV, Jabalpur, Madhya Pradesh during *kharif* 2022 and 2023 in Randomized Complete block design replicated thrice. The results of the statistical analysis of variance (ANOVA) on the data from the ten characters showed that there were significant genotype differences for all the characters under study. The highest phenotypic and genotypic coefficient of variation was recorded for number of seeds per capitula followed by number of capitula per plant, number of branches per pant and seed yield per plant. High heritability coupled with high genetic advance was recorded by number of capitula per plant followed by biological yield per plant, plant height and seed yield per plant indicating the presence of sufficient variability in the existing collection and selection based on these traits may be effective. The genetic divergence determined by Tocher's method grouped 33 niger accessions into 07 clusters with Cluster II being the largest including nineteen accessions, cluster IV included six accessions, cluster I included 03 accessions and the cluster VI included 02 accessions, and the cluster III, V and VII were solitary. Cluster V recorded high mean value for number of branches per plant, number of capitula per plant, biological yield per plant and seed yield per plant. Cluster IV recorded high mean for plant height, number of seeds per capitula and 1000 seed weight (g), cluster I for days to 50% flowering and cluster V with high mean value of days to maturity. Maximum inter cluster distance was observed between cluster I and cluster VII followed by clusters IV and VII while, lowest divergence was noticed between cluster III and V. Maximum intra cluster distance observed within cluster IV while lowest intra cluster distance was observed within cluster III. Thus, on the basis of present findings it is evident that a lot of variability exists for the yield parameters among the niger accessions available. Hybridization between accessions of cluster I and cluster VII followed by clusters IV and VII will result in creation of wide spectrum of variability for further use in breeding programmes.

Keywords: *Genetic variability, genetic advance, genetic diversity, heritability, niger*

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Genetic variability, heritability and trait association for seed and petal yield in safflower (*Carthamus tinctorius* L.) across multi-environments

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Safflower (*Carthamus tinctorius* L.) is an important oilseed and industrial crop valued for its edible oil and petal yield. An investigation was undertaken to assess genetic variability, heritability, genetic advance, character association and the direct and indirect effects of yield-contributing traits in safflower with the objective of identifying effective selection criteria for yield improvement. The experimental material comprised sixty diverse safflower germplasm lines evaluated across six different environmental conditions. The pooled mean performance across environments revealed substantial variation for seed yield and its component traits. Genotype GMU-2551 ranked first for higher number of capitula per plant along with early flowering and early maturity, indicating its suitability for short-duration environments. GMU-3098 was superior for seed yield per plant and length of the longest primary branch, while GMU-3326 recorded the lowest height of insertion of the first branch. Genotype GMU-4093 was superior for height up to the main capitulum, whereas GMU-704 recorded maximum plant height. GMU-2968 and GMU-900 exhibited the highest number of primary and secondary branches per plant, respectively. Genotype GMU-7666 was superior for capitulum diameter, GMU-184 for number of seeds per capitulum, GMU-3965 for hundred seed weight and GMU-4814 for petal yield per plant. Genetic parameter estimates revealed considerable variability for all traits studied, with phenotypic coefficients of variation exceeding genotypic coefficients of variation, indicating environmental influence. High heritability coupled with high genetic advance as percentage of mean was observed for height of insertion of first branch, height up to main capitulum, number of branches per plant, number of capitula per plant, number of seeds per capitulum, hundred seed weight, seed yield per plant and petal yield per plant, suggesting the predominance of additive gene action. Correlation analysis revealed that seed yield per plant was positively and significantly associated with number of capitula per plant, number of seeds per capitulum, hundred seed weight, capitulum diameter, plant height and height up to main capitulum. Path coefficient analysis indicated that number of capitula per plant exerted the highest positive direct effect on seed yield. Hence, direct selection for these traits would be effective in developing high-yielding safflower genotypes.

Keywords: *Correlation analysis, genetic variability, path coefficient analysis, safflower*

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Trait-based screening of sesame genotypes under drought and waterlogging stress

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A set of 53 sesame genotypes, including advanced breeding lines, was evaluated under soil moisture deficit conditions to characterize variation in morpho-physiological traits associated with drought tolerance. Continuous monitoring using real-time soil moisture sensors confirmed the persistence of stress throughout the experimental period. Significant genotypic differences were observed for gas-exchange parameters

and growth indices, including crop growth rate, net assimilation rate, relative growth rate, specific leaf weight, and leaf area index. Moisture stress significantly reduced growth and yield attributes; however, genotypes IIOS-1103, MC-552, MC-827, MC-970, and MC-1037 consistently maintained higher seed yield across both years. These genotypes exhibited higher SPAD chlorophyll values, greater leaf area, improved relative water content, enhanced photosynthetic rates, increased capsule number, and superior seed yield under stress, indicating efficient physiological adjustment to limited soil moisture. Seed oil content and fatty acid composition were comparatively stable in these genotypes under stress, highlighting their suitability for drought-prone environments and their potential use in sesame breeding programmes. In a complementary experiment, 30 sesame genotypes were screened for tolerance to waterlogging stress imposed at both seedling and flowering stages under field conditions. At the seedling stage, 10-day-old plants were subjected to waterlogging (7 cm water above soil surface) for 72 h, resulting in mortality of most genotypes. Six surviving genotypes were subsequently exposed to a second 72-h waterlogging event at flowering. Genotypes IC-132171, IC-500325, JCS-DT-26, IC-500491, IIOS-3, and GT-10 showed superior recovery and yield performance. These genotypes developed extensive surface roots, enhanced root biomass, and prominent stem and root aerenchyma, which were associated with higher leaf area, plant height, SPAD chlorophyll values, and seed yield. The results demonstrate the existence of exploitable genetic variability for tolerance to both drought and waterlogging stresses in sesame.

Keywords: *Drought tolerance, genotypes, morpho-physiological traits, sesame*

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Epistatic control and gene-effect estimation for phenology, yield and oil content in sesame using joint-scaling and six-parameter models

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Generation-mean and scaling analyses were used to dissect the genetic control of phenology, yield components and oil content in sesame (*Sesamum indicum* L.). We focused on a detailed analysis of Cross: Thilarani × TKG 55, evaluated across six generations (P_1, P_2, F_1, F_2, BC_1, BC_2) in a compact family block design under irrigated medium black soil at Bilaspur, India. Simple scaling tests (A–D), Cavalli's joint-scaling test, and Hayman's six-parameter model were applied to detect epistasis and estimate additive, dominance and epistatic components. Variance components (D, H, E), degree of dominance, potence ratio, effective factor estimates (Burton; Castle–Wright), heterosis and inbreeding depression were also computed. For many traits (days to 50% flowering, days to maturity, biological yield, seed yield), scaling tests and joint-scaling ÷² indicated significant epistatic interactions; six-parameter estimates often revealed duplicate-type epistasis with dominance (h) and dominance × dominance (l) components opposing in sign. Traits such as plant height and capsules per plant showed complementary epistasis for some components. Heterosis and inbreeding depression varied by trait: yield-related traits frequently exhibited substantial heterosis and high inbreeding depression, consistent with overdominance or non-allelic interactions, whereas oil content displayed predominantly additive control. The findings underscore the importance of epistasis in sesame genetic architecture and suggest that selection strategies should consider non-additive interactions for effective exploitation of heterosis and for trait improvement.

Keywords:*Epistasis, generation-mean analysis, heterosis, hayman six-parameter model, joint-scaling test, sesame*

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A high yielding, high oil content and bold seeded variety of sesame (*Sesamum indicum* L.) recommended for Gujarat state

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Sesame (*Sesamum indicum* L.), a member of the *Pedaliaceae* family is one of the oldest cultivated oilseed crops known to humankind. Sesame is often referred to as the "queen of oilseeds" due to its exceptionally high oil content and stabilized keeping quality contributed by high degree of resistance to oxidation and rancidity. India is the second largest producer of sesame in the world. It was cultivated in an area of 15.30 lakh ha in India with an annual production of 8.47 lakh tonnes and productivity of 553 kg/ha (2023-24). In Gujarat during 2023-24, the crop covered 1.73 lakh ha with annual production of 1.43 lakh tonnes and productivity of 831 kg/ha (oilseeds.dac.gov.in). At present for *Kharif* season, varieties GT 3, GT 4, GT 6 and GT 10 are under seed production chain and covering major area of Gujarat state. Low productivity of sesame in India is mainly due to cultivation of varieties with poor yield potential and inconsistent yield performance under varied environmental conditions. Hence, there is a need to augment the productivity of crop through crop improvement programmes. Keeping this objective in view, breeding efforts was initiated to evolve new high yielding variety of sesame suitable in different agro-climatic conditions of Gujarat. In this context, sesame genotype SKT 1501 was evolved from cross between RT 334 and GT 3 at Centre for Oilseeds Research, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. It was evaluated in multilocation state trials from *Kharif* 2016 to *kharif* 2020, while it was tested in Initial Varietal Trial at different five centres of zone I in the *kharif* 2019. The results revealed that the genotype SKT 1501 exhibited wider adaptability and consistent superiority for seed and oil yields in Gujarat state as compared to check varieties during the five-year testing. On the basis of overall mean (17 locations) it yielded 957 kg/ha seed yield with a tune of 25.92, 18.73, 8.87, 21.49 and 18.16 per cent higher than check varieties GT 2, GT 3, GT 4, GT 6 (local checks) and GT 10 (National check), respectively. The same genotype is also containing 49.06 % oil content in its seed and gave on an average 470 kg/ha oil yield which was 28.77, 19.29, 11.11, 26.00 and 32.39 per cent higher as compared to the check varieties GT 2, GT 3, GT 4, GT 6 and GT 10, correspondingly. This genotype is matured in 90 days and having profuse branching and long capsules. Seeds are of white colour with high 1000 seed weight (3.48 g) as compared to the check varieties. Under field condition, it was found resistant to phyllody, moderately resistant to powdery mildew and *cercospora* leaf spot, while moderately susceptible to *phytopthora* blight and *macrophomina* stem rot. Similarly, it was resistant to leaf webber, while moderately resistant to mite. Considering the superior performance, SKT 1501 has been accepted by 53rd State Seed Sub-Committee Meeting held at Krushi Bhavan, Gandhinagar (Gujarat) on August 27, 2021 and released as Gujarat Til 7 (Banas Gaurav) for commercial cultivation in sesame growing areas of Gujarat State. GT 7 has been registered with national identity number (IC 638673) and conserved under long term storage at NBPGR, New Delhi. It has also been notified in the Gazette of India, Ministry of Agriculture and Farmer Welfare (Department of Agriculture and Farmers Welfare), New Delhi with notification number S.O. 4222(E) dated September 25, 2023. Thus, this variety will helpful in enhancing and stabilize the income of sesame growing farmers of Gujarat State.

Keywords: *Bold seed, high oil content, high seed yield, sesame*

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Agronomic traits governing yield enhancement for effective selection in sesame (*Sesamum indicum* L.)

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Sesame (*Sesamum indicum* L., 2n = 26), a member of the Pedaliaceae family, is recognised as one of the earliest domesticated oilseed crops. It is primarily cultivated for its nutrient rich seeds, which contain 40 to 64% oil and 20–25% protein and abundant in amino acids, vitamin B, E, minerals, and antioxidants including sesamin, sesamolin and ã-tocopherol. Despite its nutritional superiority and wide adaptability, sesame productivity remains relatively low compared to other oilseed crops due to narrow genetic base of cultivated varieties, indeterminate growth habit, susceptibility to biotic and abiotic stresses and limited exploitation of available genetic resources. The success of any crop improvement programme largely depends on the extent of genetic variability present in the germplasm for economically important traits. Estimates of genetic parameters such as genotypic and phenotypic coefficients of variation (GCV and PCV), heritability, and genetic advance provide valuable information on the nature and extent of variability. A study was conducted in 60 sesame accessions at Regional Agricultural Research Station (RARS), Tirupati, during Rabi 2024–25 to assess the variability and association for 13 seed yield and yield-contributing traits in 60 genotypes. Based on genetic parameters, higher values of GCV and PCV were observed for seed yield per plant, thousand seed weight, number of capsules per plant, number of primary branches per plant and height of the first capsule. High heritability is observed for all the studied traits. Out of 13 traits, 11 traits showed high genetic advance per mean except days to flowering and days to maturity. High PCV, GCV and high heritability coupled with high genetic advance as percent of mean were observed for seed yield per plant, thousand seed weight, number of capsules per plant, number of primary branches per plant and height of the first capsule indicating that the variation in the above characters most likely due to additive gene effect Genetic variability serves a critical role in the utilization of available germplasm in breeding programs and is a prerequisite for genetic advancements in plant breeding. Hence, simple directional selection may be effective to improve these characters. Correlation analysis revealed that seed yield per plant exhibited a significant and positive association with days to 50% flowering, number of internodes, number of primary branches per plant, number of capsules per plant, number of seeds per capsule, and 1000-seed weight, indicating the importance of these traits in yield improvement. The positive interrelationships among these characters suggest that simultaneous selection for these traits would be effective in enhancing seed yield in sesame.

Keywords: *Correlation. genetic advance as per cent mean, GCV, heritability, PCV, sesame*

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Genetic variability and character association studies for yield and yield contributing traits in bold seeded sesame (*Sesamum indicum* L.)

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Sesame (*Sesamum indicum* L.) indigenous crop of India is a crucial oilseed crop called as “Queen of oil seeds” known for its highest quality oil, high protein content and minerals and vitamins, making it an important food (cooking oil, baking sweets), traditional medicine (heart, inflation) animal feed (protein –

rich cake), and industrial uses, export potential with its cultivation offering resilience in arid and semi-arid regions where other crops struggle through challenges like low yields persist despite technological advancements. Despite its nutritional and economic importance, genetic improvement in sesame has lagged behind other oilseed crops, primarily due to its narrow genetic base, indeterminate growth habit, and limited research focus. The sesame productivity remains low and stagnant in many regions, which underscores the need for systematic genetic studies to identify and utilize promising traits for crop improvement. The present study consisted of eleven bold seeded sesame mutants (1000 seed weight > 4.0 g) that were developed earlier at BARC, Mumbai along with two checks DS-5 and TKG-22. The experiment was laid out in a randomized complete block design with two replications at AICRP on Sesame and Niger, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during summer 2024-25. Observations were recorded on eight yield and yield related characters. Data was subjected to statistical analysis. Analysis of variance indicated highly significant differences among the genotypes studied for traits *viz.*, capsule length, 1000 seed weight, days to fifty percent flowering, days to maturity, oil content and seed yield per hectare confirming presence of sufficient variability for selection. All the mutant genotypes recorded 1000 seed weight more than 4 g and it ranged from 4.1 g to 4.8 g. The genotype TS -25 recorded highest 1000 seed weight of 4.8 g while, DS-5 ckeck variety showed 3.4 g. The PCV was found to be higher than GCV which indicates the important role of environment in expression of traits. High to moderate coefficient of variation were observed for number of primary branches, number of capsules per plant, capsule length, 1000 seed weight, days to fifty percent flowering, days to maturity, oil content and seed yield per hectare except number of capsules per plant coupled with high to moderate genetic advance over mean. The combination of high heritability and high genetic advance provide the clear image that direct selection of these traits could be effective in crop improvement programme. Further, correlation studies revealed strong positive associations of seed yield with number of capsules per plant, capsule length and significant correlation with 1000 seed weight at genotypic level. Path analysis showed positive direct effect of capsule length, number of branches per plant on seed yield, whereas other traits exerted negative direct effects indicating their limited contribution in yield improvement. The genotype TS-5, TS -6 TS-25 and TS-17 recorded high seed yield with high test weight. Evaluation of these genotypes in multilocation confirm their performance which aid in identification of elite high yielding sesame cultures.

Keywords: *Correlation, genetic variability, path analysis, sesame*

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Genetic variability studies in sesame (*Sesamum indicum* L.)

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Sesame (*Sesamum indicum* L.) is an important oil seed crop that can be cultivated even under low productive and poor management conditions. It has a good source of edible oil which is often considered as the “queen” of vegetable oils. The seed contains 50 - 60 per cent oil with high variability between varieties. In addition to high value oil, sesame seeds and oil have industrial and pharmaceutical uses. The present study was carried out at Agricultural College and Research Institute, (TNAU) Vazhavachanur, Tamil Nadu, India, during 2023 to assess variability, heritability and genetic advance in sesame for seven quantitative traits in F_2 progenies involving two crosses *viz*., TMV 4 x SVPR 1 and TMV 4 x VRI 3. The results revealed that the coefficient of variation at phenotypic (PVC) and genotypic (GCV) level were high to medium for plant height, number of branches per plant, number of capsules per plant and seed yield per plant and low for other traits. High heritability along with high genetic advance was recorded in plant height, number of branches per plant, number of capsules per plant, capsule length, number of seeds

per capsule and seed yield per plant. Hence, a simple selection is effective for the improvement of these traits. However, high heritability with low genetic advance was observed for days to maturity and 1000-seed weight indicating non-additive gene action, in this situation, selection will be postponed to later generation for getting desirable genotypes.

Keywords: *Heritability, quantitative, sesame*

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Stability analysis of sesame genotypes across multi-environments

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Sesame (*Sesamum indicum* L., 2n = 26) is an ancient oilseed crop, commonly known as "Queen of oilseeds" and famous for the medicinal properties. It is a short duration crop and fits well in a number of multiple cropping systems either as a catch crop or a sequence. In spite of its superior quality oil and health benefits, its cultivation is not widespread and popular in India due to poor yield. In India, sesame is grown under diverse agro-climatic conditions, which resulted in fluctuation for its production. Varietal adaptation to environmental fluctuations is important for stabilization of sesame production. The study of G x E interactions leads to identify a cultivar that gives consistently high yield in a broad range of environments and to increase efficiency of breeding program and selection of best genotypes. Keeping the above points in view, the present investigation was planned to evaluate 829 sesame genotypes including 04 checks and identify stable and high-yielding sesame genotypes through multi-environment trials (METs) using Eberhart and Russell (1966) model. Results revealed significant variability among genotypes for all studied traits, indicating diverse genetic responses to environmental changes. The magnitude of regression coefficients and deviations from regression varied widely for phenological traits, yield components, oil content, and seed yield per plant, confirming that stability is an inherent genetic property and genotype-specific. Based on combined consideration of mean performance and stability parameters, several genotypes were identified as stable for individual traits. For seed yield per plant, genotypes KM-12, KIS-297-2, SI-254, PCU-123, NIC-16143, NIC-8279, NIC-1615-B, and IS-187-A exhibited high mean yield with ideal stability across environments. In addition, NIC-16387-A, KMR-5, KMR-36, NIC-16414, NIC-17380, KMS-5-363-A, IC-42952, SI-3281, and GRT-8602-A showed stable performance for seed yield along with several yield-contributing traits. Thus, the identified stable and high-yielding genotypes possess wide adaptability and can be effectively utilized in sesame breeding programs to improve yield stability and performance across diverse agro-climatic conditions.

Keywords: *Genotype × environment interaction, stability analysis, multi-environment trials, sesame, seed yield, wide adaptability*

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Stability analysis for seed yield and yield contributing traits in sesame (*Sesamum indicum* L.)

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A combined analysis across environments indicated significant differences among genotypes for yield and yield-attributing traits, highlighting substantial genetic diversity. The pooled analysis further demonstrated that environmental variations had a pronounced influence on the performance and stability of sesame genotypes. Stability analysis of variance for grain yield and its components revealed that the genotypes differ significantly for all characters indicating the presence of variability in the material. Both linear and

non-linear components of G x E interactions were significant for all the characters indicating that sesame genotypes responded linearly to environmental changes in respect of these characters. An environment E1 i.e. sowing of sesamum on 16th June was found most favourable for expression of most of the characters including grain yield. Linear and non-linear component of G x E interactions were found significant for all the characters under study. These results indicate the importance of selecting stable and high-yielding genotypes with wide adaptability across environments. The identified favourable environment and responsive genotypes can be effectively utilized in future breeding programmes for enhancing sesame productivity.

Keywords: *G X E interaction, genotypes, stability, sesame*

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Identification of climate-resilient parental lines in sunflower through genetic variability and fertility restoration analysis

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Climate change induced variability in temperature, rainfall, and associated biotic pressures has emerged as a major constraint to sustainable oilseed production, necessitating the development of climate-resilient cultivars with stable performance across environments. Sunflower (*Helianthus annuus* L.), owing to its wide adaptability and short duration, represents a strategic oilseed crop for climate-resilient agriculture; however, effective utilization of genetic variability and stable fertility restoration systems is essential for enhancing yield stability. The present investigation was undertaken to assess genetic variability, character association and fertility restoration behaviour of sunflower inbred lines for their potential use in climate-resilient hybrid breeding programmes. The experimental material consisted of thirty high temperature tolerant inbred lines along with two standard checks, Phule Bhaskar and DRSF-113, evaluated during *Kharif* 2023 at the Oilseeds Research Station, Latur, using a randomized block design with two replications. To exploit heterosis and assess cytoplasmic stability, the inbred lines were crossed with three diverse cytoplasmic male sterile (CMS) lines-CMS-47A, NDCMS-2A, and ARM-249A in a line x tester mating design, generating ninety-six experimental hybrids. These hybrids were evaluated during *Rabi* 2023-24 to identify stable fertility restorers and sterility maintainers under field conditions representative of seasonal climatic variability. Analysis of variance revealed highly significant differences among genotypes for all studied characters, indicating the presence of substantial genetic variability amenable to selection. High heritability coupled with high genetic advance was recorded for volume weight, days to 50 per cent flowering, days to maturity, and seed filling percentage, suggesting predominance of additive gene action and effectiveness of selection for these traits. These characters are of particular relevance under climate stress conditions, as they contribute to stress escape, efficient assimilate partitioning, and yield stability. High magnitudes of genotypic and phenotypic coefficients of variation were observed for seed yield per plant, head diameter, 100-seed weight, volume weight, plant height, hull content, seed filling percentage, and oil content, indicating their potential utility in climate-resilient sunflower improvement programmes. Correlation analysis revealed that seed yield exhibited significant positive associations with head diameter, 100-seed weight, seed filling percentage, days to 50% flowering, days to maturity, plant height, and volume weight, while showing a negative association with hull content. These relationships highlight reliable indirect selection criteria for improving yield stability under variable environments. Fertility restoration studies identified ten inbred lines *viz.*, LSFI-3, LSFI-8, LSFI-13, LSFI-14, LSFI-15, LSFI-26, LSFI-27, LSFI-28, LSFI-29 and LSFI-30 as complete restorers across CMS backgrounds, while two inbreds viz., LSFI-20 and DRSF-113 consistently behaved as stable sterility maintainers. Inbred lines LSFI-20, LSFI-11, and LSFI-27, exhibiting superior mean performance for multiple yield-contributing traits, were identified as promising parental lines for using in future climate-resilient breeding programme to enhance the seed yield in sunflower.

Keywords: *Cytoplasmic male sterility, fertility restoration, genetic variability, sunflower, stability*

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Exploiting genetic variability, self-fertility and yield-related traits for climate resilient breeding in sunflower (*Helianthus annuus* L.)

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Climate change-driven fluctuations in temperature, rainfall patterns and pollinator dynamics have intensified the need for climate-resilient oilseed cultivars capable of maintaining stable yield under variable environments. Sunflower (*Helianthus annuus* L.), an important edible oilseed crop, requires systematic exploitation of genetic variability, self-fertility and yield-contributing traits to enhance resilience against such climatic uncertainties. The present investigation was conducted to assess genetic variability, trait associations and adaptive reproductive traits relevant to climate-resilient sunflower breeding. A total of forty-six sunflower genotypes along with four standard checks were evaluated over two contrasting seasons, *Kharif* 2023 and *rabi* 2024, at the Oilseeds Research Station using a randomized block design. Twelve quantitative traits including phenology, plant architecture, yield components, reproductive traits (autogamy and self-fertility), oil content and seed yield per plant were recorded. Analysis of variance revealed highly significant differences among genotypes for all characters in both seasons, indicating the presence of substantial genetic variability exploitable for selection under variable climatic conditions. High genotypic and phenotypic coefficients of variation were observed for seed yield per plant, 100-seed weight, head diameter, autogamy percentage, and plant height across seasons, reflecting broad adaptive potential. Notably, high heritability coupled with high genetic advance was recorded for seed yield per plant, plant height, autogamy percentage, seed set under open pollination and self-fertility, suggesting predominance of additive gene action and effectiveness of direct selection. These traits are critically important under climate stress scenarios, as enhanced self-fertility and autogamy can buffer yield losses arising from reduced pollinator activity and erratic weather conditions. Correlation and path analysis indicated that seed yield per plant was positively influenced by head diameter, 100-seed weight, seed set percentage, volume weight, plant height, and self-fertility, while husk content exerted a negative effect. Such associations provide reliable indirect selection criteria for improving yield stability under climate-induced stress environments. Several genotypes, including EC-198072, GMU-249, GMU-477, CMS-103B, and EC-934477-1, consistently exhibited superior seed yield and favourable adaptive traits across both seasons, highlighting their suitability as donor or recurrent parents.

Keywords: *Adaptation, autogamy, genetic variability, self-fertility, stability, sunflower*

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Regression-based prediction of heterosis using genetic divergence among parental lines in sunflower

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Sunflower is a cross-pollinated crop making it ideal for heterosis exploitation. For development of high performing hybrids selection of parents is vital. The criteria used by breeders for selection of suitable parents include estimation of combining ability of the parents and their genetic divergence. However, several reporters have reported that there is no correspondence between genetic distance between the parents and heterosis. Thus, the present investigation was conducted to elucidate the pattern that exists between genetic divergence and heterosis. The material for present investigation included 115 hybrids and 29 inbreds (nine female parents and 20 restorers) of sunflower. The experiment was conducted

during spring 2022 in alpha lattice design with two replications. The data was recorded for nine traits such as days to fifty percent flowering (days), days to maturity (days), plant height (cm), head diameter (cm), seed yield per hectare (kg/ha), volume weight (g/100ml), hundred seed weight (g), oil content (%) and oil yield per hectare (kg/ha). The analysis of data included partitioning of variance, principal component analysis, estimation of Mahalanobis distance and regression analysis was conducted based on nonlinear model. Analysis of variation revealed significant differences among hybrids for all of the traits and among inbred for all traits but for hundred seed weight. The principle component analysis revealed that of the nine components first two components had eigen values higher than one and cumulatively these two components explained 68.6 % of the total variability. The individual contributions of PC1 and PC2 were 44.5 % and 24.0% respectively. When the PC scores for individual components were considered for PC1 the eigen vectors in positive direction were exhibited by oil yield per hectare (0.91), plant height (0.88), seed yield per ha (0.79), oil content (0.62) and head diameter (0.55). While days to fifty percent flowering (-0.70) and days to maturity (-0.63) contributed in negative direction. Based on contribution of the traits towards PC1, oil yield per hectare contributed maximum followed by plant height, seed yield per ha and days to 50% flowering. The Quality of scores was good for first three ($cos^2 > 0.5$). In case of PC2 oil content exhibited eigen vectors in positive direction while hundred seed weight (-0.69), head diameter (-0.64), days to maturity (-0.63) and days to fifty percent flowering (-0.52) revealed eigen vectors in opposite direction. The contribution to PC2 was higher for hundred seed weight followed by head diameter, days to maturity and oil content. The biplot based on first two principal components suggested that the distribution of hybrids and inbreds were overlapping. There was clustering of some restorers and hybrids while, the female parents were more spread out. High correlation was observed for seed yield per hectare, oil yield per hectare, volume weight, plant height and head diameter. Average heterosis and heterobeltosis was estimated by comparing performance of F_1s and their respective parents and genetic distance was estimated using Mahalanobis D^2 analysis. Linear and spline regression analysis was conducted between average heterosis and heterobeltosis with genetic distance. However, the regression analysis suggested that high genetic distances based on morphological parameters do not result in high degree of heterosis. For traits such as seed yield per hectare and oil content, heterosis seems to decline with increase in genetic distance and then again leads to slight increase. Although there are differences present among inbreds, the maintainer lines and restorer lines are not that divergent from each other. The genetic distance alone is not sufficient to explain or predict the heterosis.

Keywords: *Heterosis, genetic divergence, parental lines, principle component analysis, sunflower*

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Comparative evaluation of interspecific crosses and hybrids in sunflower (*Helianthus annuus* L.) for yield and associated traits under moisture stress

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Screening of germplasm is vital for identification of genotypes responding well to moisture stress so that climate resilient crop varieties can be developed. Sunflower is grown in Punjab during spring season under irrigated conditions. Under normal conditions, 6-9 irrigations are given to this 100-day duration crop. Identification of genotypes having high water use efficiency will allow us to reduce the number of irrigations. The experimental material comprised 28 sunflower hybrids and 70 interspecific derivatives from *H. annuus* × *H. argophyllus* crosses. These genotypes were evaluated under two environments: irrigated and moisture-stressed conditions. Moisture stress was created by skipping every alternate irrigation from normal irrigations. Data was recorded for days to flowering (DTF), plant height (PH), head diameter (HD), hundred seed weight (HSW), seed yield per plant (SYPP) and oil content (OC). Analysis of variance (ANOVA) was performed to assess genetic variability among genotypes and environments. Principal Component Analysis (PCA) was conducted to study trait associations and performance of

interspecific derivatives under normal and irrigated conditions. Analysis of variance revealed significant differences ($p<0.001$) among genotypes, irrigation regimes and their interactions. The genotype x environment interaction was significant for all traits in case of interspecific derivatives, except DTF and PH, while in hybrids it was found significant for all traits except DTF and HD. Among environments the stress and optimum moisture revealed differences for all traits except for oil content. Further evaluation of genotype x environment interaction revealed that, for DTF and OC cross over interactions were present and for rest of the traits parallel interactions were there. Entries that performed well under both moisture and stress conditions for SYPP were ID-34, ID- 26 and ID-23 while for OC were ID-48, ID-64 and ID-60. Principal component analysis based on DTF, PH, HD, TSW, SYPP, and OC under stressed and moisture conditions revealed that the first two principal components explained a substantial proportion of the total variability. Under stressed conditions, PC1 and PC2 accounted for 40.3% and 19.7% of the variation, respectively, while under moisture conditions they explained 40.1% and 21.1%. Across both environments, oil content (OC) exhibited a strong positive loading on PC1. Seed yield per plant (SYPP) and days to flowering (DTF) contributed predominantly to PC2, indicating their importance in genotype differentiation, particularly under stressed conditions. Plant height (PH) showed an opposite orientation to yield-related traits in both environments, suggesting a weak or negative association. The dispersion of genotypes across quadrants in both biplots reflected considerable genetic variability and distinct trait associations influenced by irrigation regime. The study demonstrates that while sunflower hybrids provide superior and stable yield performance under moisture stress, interspecific crosses possess substantial genetic variability that can be exploited for improving drought tolerance and broadening the genetic base of sunflower breeding programmes.

Keywords: *Interspecific crosses, genetic variability, genotypes, moisture stress, sunflower, yield*

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Identification of candidate powdery mildew susceptibility *MLO* genes in sunflower as targets for CRISPR/Cas-mediated disease resistance

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Sunflower (*Helianthus annuus* L.) cultivation is severely constrained by several biotic stresses, among which powdery mildew is an emerging and economically important disease, particularly under tropical and subtropical agro-climatic conditions. Powdery mildew, caused by the obligate fungal pathogen *Golovinomyces orontii*, leads to substantial yield losses, deterioration of seed quality, and reduction in oil content, thereby threatening the sustainability of sunflower-based oil production systems. In dicotyledonous plant species, members of the Mildew Resistance Locus O (*MLO*) gene family have been widely reported as negative regulators of powdery mildew resistance. Functional studies across several crops, including *Arabidopsis thaliana*, tomato, pea, grapevine, and pepper, barley, etc have demonstrated that loss-of-function mutations in specific *MLO* genes confer durable, broad-spectrum, and race-independent resistance to powdery mildew. Such *mlo*-based resistance is considered highly stable and environmentally resilient, making it an attractive target for sustainable disease management through modern breeding and genome editing approaches. The present study aimed to identify and characterize candidate *MLO* genes in sunflower that may function as susceptibility factors to powdery mildew. A genome-wide search of the *Helianthus annuus* reference genome retrieved a total of 38 putative *HaMLO* genes. To enable comparative analysis, *MLO* protein sequences from 10 well-characterized dicot species-*Arabidopsis thaliana*, *Solanum lycopersicum*, *Capsicum annuum*, *Pisum sativum*, *Vitis vinifera*, *Cucumis melo, Cucumis sativus, Nicotiana tabacum, Malus domestica,* and *Glycine max* were collected based on the availability of experimentally validated powdery mildew-susceptible *MLO* genes. Multiple sequence alignment and phylogenetic analysis were performed to determine evolutionary relationships among sunflower and

reference *MLO* proteins. The analysis showed that seven HaMLO genes grouped within Clade V together with well-characterized powdery mildew susceptibility–related MLO genes from nine of the ten reference dicot species, suggesting a conserved role in disease susceptibility. Domain analysis further confirmed hallmark features of functional MLO proteins, including the conserved MLO family domain and the C-terminal DFSF tetrapeptide motif. Notably, this motif—strongly associated with powdery mildew susceptibility in dicots—was present in five of the seven Clade V HaMLO genes. Experimental evidences in other crops have demonstrated that the implicated MLO proteins contain calmodulin binding domain (CaMBD). When the identified HaMLO proteins were analysed for this aspect, all of them showed the presence of CaMBD. Transcriptomic analysis (Duruvasula *et al*., 2024) has identified nine of the HaMLOs showing up-regulation in the susceptible genotype compared to the resistant genotype. Of the five HaMLOs that showed all the other features, two of them showed elevated expression in the susceptible genotype upon pathogen infection strongly indicating that these two HaMLOs could be the candidate genes for genome editing. The identification of the candidate *HaMLO* genes provides valuable targets for downstream functional validation and resistance breeding. From a national perspective, the development of *mlo*-based powdery mildew-resistant sunflower cultivars could significantly reduce yield losses, lower dependence on fungicides, and improve oilseed productivity. Additionally, the candidate genes identified in this study provide opportunities for integrating molecular breeding with advanced biotechnological tools such as CRISPR/Cas-mediated genome editing and marker-assisted selection. Targeted manipulation of susceptibility genes offers a precise and transgene-free strategy to accelerate the development of improved sunflower cultivars adapted to diverse agro-ecological regions of India. The results obtained will be discussed during the presentation.

Keywords: *CRISPR/Cas-mediated disease resistance, MLO genes, powdery mildew, sunflower*

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Large scale diversity studies and development of core germplasm collection for effective improvement of sunflower in India

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Establishing a core collection that represents genetic diversity of the entire collection with minimum loss of its original diversity and minimum redundancy is an important issue for gene-bank curators and crop breeders. The work on collection, evaluation and maintenance of sunflower germplasm was carried out at Germplasm Management Unit (GMU) located at the Project Coordinating Unit (PC, Unit Sunflower), Bengaluru from 1983 till 2001. Subsequent to the shifting of the Project Coordinating Unit (Sunflower) from UAS, Bengaluru, the germplasm maintained at PC Unit has also been shifted to IIOR (formerly DOR) during July 2001. Between 1983 and 2001 introductions for useful traits were made from the countries *viz*., Rome, Hungary, Yugoslavia, Turkey, USA, USSR, Israel, Netherlands, Serbia, France, and East Germany. In the recent past additional introductions were made from France, Serbia, and USDA. To develop sunflower core the 'R software' based package "ccChooser" was used. For the development of core collection systematic conducted diversity study data during 2011-2013 on 7 agro-morphological traits of 2140 accessions were used and the analysis was carried out in three parts in a stepwise approach and grouping methods. In the first part, the cluster analysis was performed and two classical methods (UPGMA and Ward methods) and the number of groups was designated based on the dendrograms (function - cuttree). Second part of the analysis was involved in allocating the assign genotypes from original collection to core collection based on four allocation methods. The last part of the analysis was used to evaluate the cluster analysis and allocation methods. The Ward cluster analysis and D3 allocation method proved to be the most optimal and efficient in development of the sunflower core collection from the dataset. The representativeness of the core collections was validated by the difference of means (MD%) and difference of mean squared Euclidean distance (dD%) for the studied traits in the core

subsets and the entire collection. From the results of the analysis sunflower core collection was created as a result of lowest value for dD% (5.080867) and relatively low value for MD% (0.78302285). Based on this strategy, a total of 216 accessions were selected for core collection which is approximately 10% of the entire collection of 2140. The core set developed will be further validated at different agro-climatic conditions and will be utilized for development of mini core set to enhance the germplasm utilization by sunflower researchers and development of climate resilient improved varieties and hybrids.

Keywords: *Breeding, core collection, germplasm, sunflower, utilization*

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Development of a GMS-assisted recurrent selection strategy for population improvement in safflower

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Safflower is an important traditional oilseed crop of India. However, the current safflower varieties have low seed yield and oil content. Therefore, improving per se seed yield and oil yield potential is critically important. Among the breeding methods used for varietal development in safflower, pedigree selection has been the most widely adopted. However, pedigree selection has so far resulted in improvement of either seed yield or oil content, while simultaneous improvement of both traits has been very slow. Simultaneous improvement of seed yield and oil content is challenging due to the negative genetic relationship between these traits.To overcome this limitation and break the yield stagnation, a population improvement strategy is being contemplated. The success of such a strategy depends on achieving 100% random mating within the population. Therefore, a Genetic Male Sterility (GMS) system is being exploited to facilitate random mating.As a first step, the popular safflower variety A-1 was converted into a GMS background so that the male sterility trait is incorporated into an agronomically superior genetic background. A GMS source of safflower, MMS-1-3, obtained from the AICRP-Safflower Centre, Akola, was crossed with A-1. The resulting F• plants were confirmed to be fertile. The F, population showed segregation for fertility and sterility, from which three sterile plants were selected and backcrossed with A-1. A total of 731 F, -derived BC• F• seeds were produced. These BC• F• plants were selfed to generate F, -derived BC• F, progenies. Sterile plants identified from the segregating BC• F, progenies were used for a third backcross with A-1 to produce BC*f* F• seeds, which were subsequently selfed to obtain the BC*f* F, population.Currently, the BC*f* F, population is being grown in the field, and random mating has been initiated using a donor genotype panel comprising 100 accessions to generate the first cycle of a random mating population. Multiple cycles of random mating will be carried out to enable recurrent selection for improved seed yield and oil yield in safflower.

Keywords: *Breeding, crop improvement, GMS, safflower*

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Restructuring of plant types for enhanced productivity, oil content and nutritional quality in sesame (*Sesamum indicum* L.)

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Sesame, an important oil-yielding crop evinces good promise in the state of West Bengal being higher productive in this region than national average. India ranks low in terms of productivity mainly due to dearth of high yielding varieties. On the other hand, development of superior varieties may foster higher production of sesame in the country both through horizontal and vertical expansion and obviously is likely to reduce the huge demand supply gap of oilseeds. Conversely, micronutrient malnutrition, especially iron and zinc deficiencies, is one of the emerging challenges to food and nutritional security particularly in developing countries. Hence, there is an urgent and compelling requirement to develop high yielding micronutrient rich genotypes to address this challenge to alleviate the hidden hunger of the poor population. The present investigation is oriented towards development of high yielding genotypes with good oil content and nutritional quality through induced mutation. Twenty three genotypes of sesame representing different parts of India were evaluated for agro-morphological and biochemical traits. Three genotypes chosen on the basis of phenotypic and seed storage protein diversity through SDS-PAGE were treated with ã-rays and ethyl methane sulphonate, (EMS), individually. Three doses of ã-rays namely 200 Gy, 400 Gy and 600 Gy and four concentrations of EMS (0.5%, 1.0%, 1.5% and 2.0%) were used to induce mutation. Simultaneously these three genotypes were hybridized to produce F_1s and the F_1s were further treated with EMS. Mutants from genotypes as well from F_1s were advanced upto M_4 and F_4M_4 generations, respectively. Nineteen superior M_4 lines and seven promising F_4M_4 lines based on seed yield, oil content and fatty acid composition were selected for multilocation trials to assess the stability of desirable mutants. The newly developed 26 elite lines were evaluated in seven locations in West Bengal over four consecutive years. Out of 26, two outstanding promising M_8 lines viz. CUMS-17 (Suprava) and CUMS-09A (Tanjila) were already tested separately in multilocation evaluation trials under AICRP on Sesame and Niger for three consecutive years. Suprava was released by CVRC in August 2018 for its cultivation throughout India during summer; and notification was published in February, 2019. Conversely, Tanjila was also released by CVRC in August 2024 vide notification No. S.O. 4388 (E) dated 08.10.2024. The new variety, CUMS-09A recorded 1.05% oxalic acid, while both the national checks (GT-10 and TKG-22) registered 1.41% oxalic acid. Interestingly, CUMS-17 recorded 24.80% carbohydrate, while it was 9.92% in best national check, TKG-22. Ash content of CUMS-17 was 7.0% albeit the value was 5.3% in the best national check, GT-10. Both the new varieties professed higher iron and zinc content than the national checks. Apart from these two released varieties 14 outstanding promising advanced lines having seed yield range 1169 kg/ha to 1775 kg/ha and oil content 45.4% to 48.3% are in pipeline and ready for testing in multilocation evaluation trial under AICRP on Sesame and Niger. Hopefully, these released varieties as well as promising and stable mutant lines having higher productivity, oil content and improved nutritional quality would not only ameliorate sesame production and productivity, but also would alleviate micronutrient malnutrition of poor population in our country.

Keywords: *Sesame, yield, genotype*

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Strengthening edible oil ecosystem of Jharkhand *vis-à-vis*-Eastern India for boosting oleiferous *brassica* production: Stepping towards "Atmanirvar Bharat"

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Edible oils play a vital role in Indian economy, form an essential component of food and nutritional security and facilitate livelihoods for millions of farmers. They are a chief source of dietary fats, energy, and fat-soluble vitamins, helping to overcome the hidden hunger and improve calorie intake, particularly among underprivileged and malnourished populations. Oilseeds contribute not only to nutritional security but also to farmers' welfare, serving as an important cash crop that sustains rural incomes and employment. Despite these several importance, the country's growing demand for edible oils has outpaced domestic production. India's per capita domestic consumption of edible oils increased substantially, from 5.76 kg/year in rural areas and 7.92 kg/year in urban areas in 2004–05 to 10.58 kg/year and 11.78 kg/year, respectively, in 2022–23. This reflects a growth of 83.68% in rural and 48.74% in urban consumption of edible oils over the period resulting in to increase in the demand of edible oils in the country to the tune of 278 million tonnes (2023-24). On the other hand, India's total edible oil production was recorded at 12.18 million tonnes during 2023-24. which could be able to meet only 44 percent of its domestic demand. For remaining (56%) of the requirement, India remains substantially dependent on imports to bridge the edible oil gap despite being among the world's largest producers of oilseeds. This dependence poses challenges to boost up both the production and productivity of edible oils and oilseeds to achieve economic stability and agricultural self-reliance in edible oil production to make the country "ATMANIRVAR". This goal could be achieved through strengthening the edible oil ecosystem of Jharkhand as well as Eastern states of the country.

In India, among the nine oilseeds, three oilseeds viz., Rapeseed-Mustard, Soybean and Groundnut are considered as the major oilseeds and contributed jointly more than 90% to the national pool of oilseeds production. Out of these three major oilseeds, Rapeseed-mustard ranks first in production (13.26 million tonnes) followed by Soybean (13.06 million tonnes) from the second largest acreage of 9.18 million hectare with an average productivity of 14.47q/ha during 2023-24. It's share to the oilseed basket of the country was highest (33.43%) followed by Soybean (32.93%) and Groundnut (25.67%). Among the different Rapeseed-mustard growing states of the country, the leading producers were the Rajasthan (43.4%), Madhya Pradesh (14.8%), Uttar Pradesh (14.5%) and Haryana (10.1%) contributing altogether more than 80% of total national production of brassica. But these states almost reached to the plateau and further very limited scope for increase in productivity and area expansion under Rapeseed-Mustard would be expected. To meet the challenges of edible oil requirement of the country, both horizontal and vertical expansion of area and production of Rapeseed-Mustard need to be explored. Non-traditional areas like eastern States of the country comprising West Bengal, Jharkhand Assam, Bihar , Odissa, Chhattisgarh and seven sisters of NEH regions would be the emerging States having sizable area (>16 %) under brassica with a production of >17% of the country during 2023-24 which would contribute substantially towards attaining edible oil security of the nation. Among eastern states, Jharkhand has the second largest acreage under Rapeseed-Mustard (>4.8 Lakh ha) next to West Bengal (>6.3 Lakh ha) during 2024-25 and targeted to cover > 5.5 Lakh ha during 2025-26. This State has immense scope for further horizontal expansion of area as well as production by capitalizing 12.5lakh ha Rice-fallow areas under Rapeseed-Mustard production.

But, the productivity of the oilseed brassica in this states is far behind (800 kg/ha) the national average (1414 kg/ha) during 2023-24. This may be due to cultivation under rainfed condition, delayed sowing, non-availability of climate resilient varieties, lack of quality seed availability, limited technological interventions, biotic and abiotic stresses, low SRR/VRR, lack of suitable procurement policy, non-availability of post-harvest processing facilities and resource crunch etc in addition to facing the challenges of low genotypic potential and climate change. Rapeseed-Mustard production could be boost up in these states in terms of

per unit area, time and resources by overcoming these challenges through strengthening oilseed production ecosystem pertaining to technological interventions supported with improved varieties/plant types, backstopping research to generate location specific climate resilient smart technologies, biotic and abiotic stresses management, dissemination of proven technologies, establishment of seed hub , increase in SRR/VRR, capacity building of farmers, scientific and resource personals, creation of awareness, creation of post harvest processing facilities, along with recommended package of practices, procurement and suitable policy framework etc. Little efforts have been made in this direction by developing Birsa Bhabha Mustard-1 variety for timely sown condition in 2022 which is in great demand in the state within last two to three years. Recently in Jan.,2026 seed hub for Mustard has been sanctioned by MoA &FW, GoI for ensuring quality seed requirement of the State under NMEO-OS .

Further, more interventions are required to develop and implement well-planned strategies with multi-scientific inputs, policy interface and table price systems in Eastern State in general and Jharkhand particular in having great potential to meet the objectives of NMEO-OS up to the desired level in order to contribute significantly towards Edible Oil Security for Atmanirbhar Bharat in the years ahead.

Keywords: *Rapeseed-mustard, demand, policy, edible oil security, NMEO-OS, rice-fallow,*

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Air desiccation-mediated cryopreservation of oil palm embryos for long-term germplasm conservation

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Cryobanking represents a frontier technology in the long-term conservation of plant genetic resources, providing an efficient, secure, and cost-effective method to conserve biodiversity at sub-zero temperatures. For crops like oil palm (*Elaeis guineensis* Jacq.), where conventional seed or field genebanks have limitations due to recalcitrant seed behavior, large space requirements, pest and disease outbreaks or climatic extremes, cryopreservation offers a sustainable alternative. Through the cryogenic storage of pollen, embryos, tissues, or somatic cells, cryobanking ensures the maintenance of genetic integrity and viability over extended cryopreservation, the highest embryo viability (99-100%) was observed in fresh embryos (40-42% moisture content) which was significantly superior to longer desiccation durations (1-5 periods, enabling their use in breeding and restoration programs when needed. Preliminary studies were conducted at ICAR-IIOPR, RC, Palode to study the effect of embryo desiccation on the embryo viability after cryopreservation in different genotypes. Results showed that desiccation duration of embryo had a highly significant ($p < 0.01$) effect on embryo viability, indicating that the degree of desiccation influenced the survival of embryos. After cryopreservation, the mean viability was highest (80-90%) when embryos were desiccated to 11-12% moisture content which took 3-4 hours of desiccation across the genotypes. The non-desiccated treatment completely lost viability after liquid nitrogen exposure. Partial desiccation of embryos (1-2 hrs) provided limited viability (50-60%), while moderate desiccation treatments (3-4 hrs) resulted in markedly higher post-thaw viability (80–90%). The study revealed that desiccation plays a pivotal role in determining the survival and post-thaw recovery of oil palm embryos during cryopreservation.

Keywords*: Oil palm, cryopreservation, embryo, viability, desiccation*

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Development of a GMS-assisted recurrent selection strategy for population improvement in safflower

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Safflower is an important traditional oilseed crop of India. However, the current safflower varieties have low seed yield and oil content. Therefore, improving *per se* seed yield and oil yield potential is critically important. Among the breeding methods used for varietal development in safflower, pedigree selection has been the most widely adopted. However, pedigree selection has so far resulted in improvement of either seed yield or oil content, while simultaneous improvement of both traits has been very slow. Simultaneous improvement of seed yield and oil content is challenging due to the negative genetic relationship between these traits. To overcome this limitation and break the yield stagnation, a population improvement strategy is being contemplated. The success of such a strategy depends on achieving 100% random mating within the population. Therefore, a Genetic Male Sterility (GMS) system is being exploited to facilitate random mating. As a first step, the popular safflower variety A-1 was converted into a GMS background so that the male sterility trait is incorporated into an agronomically superior genetic background. A GMS source of safflower, MMS-1-3, obtained from the AICRP-Safflower Centre, Akola, was crossed with A-1. The resulting F_1 plants were confirmed to be fertile. The F_2 population showed segregation for fertility and sterility, from which three sterile plants were selected and backcrossed with A-1. A total of 731 F, -derived BC_1F_1 seeds were produced. These BC_1F_2 plants were selfed to generate F_2-derived BC• F, progenies. Sterile plants identified from the segregating BC_1F_2 progenies were used for a third backcross with A-1 to produce BC_3F_1 seeds, which were subsequently selfed to obtain the BC*f* F, population. Currently, the BC_3F_2 population is being grown in the field, and random mating has been initiated using a donor genotype panel comprising 100 accessions to generate the first cycle of a random mating population. Multiple cycles of random mating will be carried out to enable recurrent selection for improved seed yield and oil yield in safflower.
Keywords: *Safflower, genotype, genetic male sterility*

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Investigation of variance components among yield and other traits in biparental progenies of RH 725 x Urvashi of Indian mustard [*Brassica juncea* (L.) Czern. & Coss.]

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The present investigation was carried out to study the variance components among yield and other traits in the biparental progenies (BIPs) of RH 725 x Urvashi of Indian mustard [Brassica juncea (L.) Czern. & Coss.] during rabi 2023-24. The findings indicated substantial additive effects for the traits viz., plant height, number of primary branches and biological yield per plant. Rest of the characters exhibited dominance variance. The dominance ratios provided further insights into the genetic architecture. The traits such as plant height, number of primary branches, and biological yield per plant were indicative of the prevalence of dominant alleles. The average degree of dominance values proposed a scenario of

partial dominance for the number of primary branches per plant. However, other traits showed over-dominance. Therefore, selection should be practiced at advanced segregating generations of this biparental progenies to achieve the desired changes.

Keywords: *Biparental progenies (BIPs), Indian mustard, Brassica juncea, variance components*

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Non-Destructive Electromagnetic Spectroscopy for Genetic Purity Assessment in Groundnut

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In the context of global food security challenges and the increasing impacts of climate change, ensuring genetic purity of crop varieties is fundamental to sustainable agriculture. Groundnut, a major oilseed and food crop cultivated extensively in semi-arid regions, plays a crucial role in rural livelihoods, nutritional security and agro-based industries. However, maintaining varietal purity in groundnut is inherently challenging, as conventional certification methods based on morphological traits are constrained by phenotypic overlap, environmental variability and subjective assessment. Although molecular marker-based approaches have largely addressed the limitations of conventional purity testing by offering high precision and objectivity, their routine adoption is constrained by high costs, the need for specialized laboratory infrastructure, skilled manpower and longer turnaround times. These limitations restrict their widespread use, particularly in large-scale seed certification and resource-limited settings. Our study demonstrates the effectiveness of electromagnetic spectroscopy as a reliable and scalable approach for varietal identification and genetic purity assessment in groundnut, with performance comparable to molecular marker-based methods. High-resolution spectroscopic data captured distinct and consistent varietal signatures, enabling accurate discrimination among varieties and detection of varietal admixtures. The electromagnetic spectroscopic outputs showed strong concordance with Single Nucleotide Polymorphism (SNP) based DNA fingerprinting, including the detection and quantification of admixtures at contamination levels as low as 1%. These results establish electromagnetic spectroscopic analysis as a robust substitute for molecular assays, particularly in routine seed purity testing where cost, time and laboratory infrastructure are limiting factors. Ensuring genetic purity in groundnut has implications beyond seed certification, as even minor admixtures, especially between high-oleic and low-oleic types, can adversely affect oil quality, shelf life and industrial processing efficiency. By enabling rapid, non-destructive and high-throughput assessment, electromagnetic spectroscopic analysis supports the preservation of both nutritional quality and market value. Continued refinement of spectroscopic models and analytical frameworks will be essential to enhance reliability, broaden applicability across seed classes and crops, and fully realize the potential of electromagnetic spectroscopy for seed quality and varietal characterization.

Keywords: *Electromagnetic spectroscopy, genetic purity groundnut, seed certification, varietal identification*

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Targeted editing of fatty acid pathways and yield in oilseeds using CRISPR/Cas system

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Oilseed crops such as soybean, mustard, rapeseed, sunflower, and groundnut constitute major sources of edible oil worldwide. The global demand for edible oils is steadily increasing due to rapid population growth and rising consumption of agricultural commodities. Although conventional breeding approaches have substantially improved oilseed productivity and quality, their effectiveness is constrained by the complex inheritance of oil-related traits, linkage drag, long breeding cycles, and gene redundancy. In recent years, genome-editing technologies particularly, the CRISPR/Cas system have emerged as powerful tools for precise and efficient modification of oilseed genomes. The CRISPR/Cas system, derived from the bacterial adaptive immune mechanism, comprises the Cas nuclease, single-guide RNA (sgRNA), and a protospacer adjacent motif (PAM) sequence. Its simplicity, cost-effectiveness, high accuracy, multiplexing capability and versatility make it highly attractive for crop improvement. CRISPR/Cas-mediated genome editing has been successfully employed to enhance oil quality and yield by knocking out negative regulators or modifying key enzymes involved in fatty acid biosynthesis. Targeted editing of yield-related genes influencing plant architecture, flowering time and seed development has further contributed to productivity gains in oilseed crops.

For instance, CRISPR/Cas-mediated modification of *CLAVATA* and *FT* homologs in rapeseed and soybean has resulted in increased silique number, seed size, and overall economic yield. Similarly, targeted disruption of *FAD2* genes in canola, soybean, groundnut and sunflower has elevated oleic acid content while reducing polyunsaturated fatty acids (PUFAs), thereby improving oil stability and nutritional quality. Editing of the soybean gene *GmSACPD* (Stearoyl-Acyl Carrier Protein Desaturase) has enhanced oleic acid levels by lowering stearic acid content and improving oxidative stability. Moreover, CRISPR/Cas-mediated disruption of the *WRL1* transcription factor and *KAS* (â-ketoacyl-ACP synthase) homologs has significantly increased total oil accumulation in sunflower. Overall, CRISPR/Cas-based targeted genome editing represents a transformative strategy for developing high-yielding, nutritionally enhanced and climate-resilient oilseed crops, offering substantial promise for sustainable agriculture and global food security.

Keywords : *CRISPR/Cas, oilseed, food security, PUFAs, climate-resilient*

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Niger (*Guizotia abyssinica* L.f.) as a viable *Rabi* oilseed for enhancing land use efficiency in Rice-Based Double Cropping in the North Bank Plain Zone of Assam

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Niger (*Guizotia abyssinica* L. f.) is an underutilized, lesser known oilseed crop with considerable potential for strengthening double-cropping systems in the North Bank Plain Zone (NBPZ) of Assam. The seed is highly nutritious, has anti - oxidant and anti - inflammatory property, and promotes hair and skin health. It contains around 35-45 % oil, 18–20 % protein and is free from any harmful substance. The pale yellow colour of oil is due to presence of 38 % oleic acid and 50 % linoleic acid which also renders short shelf life. In Assam, the crop is sown as *Rabi* crop in the month of November- December after the harvest of Sali paddy, owing to shorter duration, low input requirement and adaptations to residual moisture and fertility.

The study constituted of four niger varieties (NB-1, JNS-9, GA-10), and NG-1 (Check) introduced through multilocation trials which were evaluated for their performance over years to assess their suitability in Rice–Niger double-cropping sequence under rainfed condition. The experiment was laid in 4 replications following Randomized Block Design during *rabi* seasons for three consecutive years at Research and experimental Farm, AAU - Zonal Research Station, North Lakhimpur, Assam. Key agro-morphological traits, including days to maturity (DM), plant height (PH), and seed yield, were recorded and pooled means were estimated.

Across the years, DM ranged from 102.0 to 112.0 days, indicating compatible growth duration suitable for harvesting before the advent of pre-monsoon. Plant height varied between 71.0 and 82.3 cm, reflecting adequate vegetative growth under residual moisture and fertility conditions. Among the tested varieties, NB-1 recorded the highest mean seed yield (5.4 q ha{ ¹), followed by NG-1 (4.4 q ha{ ¹), JNS-9 (3.9 q ha{ ¹), and GA-10 (3.5 q ha{ ¹). Yield stability over years further highlights the resilience of Niger crop to climatic variability typical of the region and facilitated in promoting the variety NB-1 to All India Coordinated Research Project (AICRP) on Niger and Sesamum The findings underscore the importance of the crop as a viable Rabi oilseed crop second to toria for NBPZ of Assam, enhancing land use efficiency, oilseed self-reliance, and farmers' income without competing with the main rice crop. Promotion of suitable varieties such as NB-1 can significantly contribute to sustainable intensification through rice–niger double cropping in flood-prone agro-ecosystems of Assam.

Keywords: *Niger, double cropping, Rabi oilseed, Rice–Niger system, land use efficiency, flood prone agro-ecosystems*

THEME - II

STRATEGIES TO MITIGATE BIOTIC AND ABIOTIC STRESS IN THE FACE OF CLIMATE CHANGE

Abiotic stress management for optimum production of oilseed Brassica

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Crop growth, productivity, and genome stability are greatly affected by environmental conditions, which prevent crops from reaching their full genetic potential and therefore limit productivity worldwide. Stress conditions such as extreme temperatures, water availability, low light, and salinity/ion toxicity represent abiotic stresses which, when they coincide with critical growth phases and prolonged stress duration, cause considerable yield losses. Most Brassica cultivars exhibit indeterminate growth, except for the newly released determinate plant type in African sarson (PC-6), and have inherent constraints such as suboptimal canopy architecture, unproductive lower branches, poor growth and development of late-formed siliquae, inefficient assimilate partitioning, and reduced biomass, resulting in a lower harvest index (HI). Plant growth-regulating substances can alter the source–sink relationship by enhancing mobilization, and the application of microbial inoculants offers an eco-friendly and cost-effective approach for improving productivity by counteracting the negative effects of stresses on metabolic processes. Such an approach is required for rapeseed-mustard, which is grown under conserved moisture and heat stress conditions over a considerable area worldwide. Rainfed variety PBR 97 was sown only with pre sowing irrigation during the normal planting time with recommended package of practices in RBD with three replication from 2015-16 to 2024-2025. Two foliar sprays of PGRs were given at the time of flower initiation and ten days thereafter. Treatments comprised were: Brassinolide (BR) :10 and 20ppm, Salicylic acid (SA) :100 and 200ppm Urea: 1 and 2 %, KNO 3:1 and 2%, Water spray and Control (no water spray). Two independent field experiments were conducted to evaluate the impact of microbes for 3 years (2020-21 to 2022-23) to mitigate drought which consisted of variety PBR357 with six microbal treatments and three irrigation modules .Experiment for temperature stress mitigation consisted of three released varieties from different agro-climatic zones sown at two dates (normal and late planting) were in main plots while seed dressing with Microbial formulation as bio stimulant (MFs) and Stress adaptive consortium (Pusa Sanjeevani PS) in sub plots Photosynthetic pigments , membrane stability, RWC (70 DAS) , CTD (90 DAS) were investigated along with yield and yield components at harvest. Total chlorophyll improved significantly with 20 ppm BR, 100ppm SA and 1% KNO3. Both the concentrations of urea increased carotenoids, number of branches primary (6.3%) with SA and KNO3whereas secondary by 13.1% with 2% urea. Total siliquae/ plant, seed weight and biomass enhanced significantly with PGR's application. Seed filling improved as the fully developed seeds enhanced by 8.9% with BR@20ppm,13.4% with urea @1% and 12.5% with 1% KNO3.SA@100ppm enhanced seed weight (12.5%) and seed yield by 14.8 % whereas brassinolide@20ppm increased seed number (7.3%) and seed yield (18.4%) over water sprayed control in PBR97. HI increased with BR@20ppm and KNO3 @1% indicating efficient partitioning. Water stress impeded the studied physiological traits however, the different microbes improved them to variable extent. Increase in total chlorophyll varied from 2.09-2.55 and carotenoids from 0.411-0.469 mg g-1 FW over control. CRIDA MI-II was effective in improving RWC, proline and seed yield (13.8%) while Biophos & Biophos+ enhanced total sugars and yield (14.8%). Microbial formulation and Pusa Sanjeevani inoculated varieties registered higher chlorophyll, carotenoids and maintained cooler canopies under late sown condition. However, membrane stability was improved by 9.5% with microbial formulation and 19.3% with Pusa Sanjeevani over control in PBR 357only. Microbial seed treatments improved seed yield (7.9 - 10.7%) under heat stress caused by late sowing. Exogenous application of PGRs and microbial treatments improved the RWC, LWR, CSI, altered source sink relationship by enhancing remobilization efficiency thus improving the performance of Brassica under varied climatic conditions. Increase in total chlorophyll and proline with CRIDA MI-II and total sugars with Biophos & Biophos+.Variations existed in *B. juncea* varieties for the physiological and yield traits with microbial formulation and stress adaptive consortium under normal and late sown conditions. Both the microbial inoculations were effective in improving yield under late sown condition.

Keywords: *Abiotic stress management, oilseed Brassica, rapeseed-mustard, crop productivity*

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Assessment of genetic diversity and antimycotic potential of Trichoderma isolates collected from mustard rhizosphere in Bundelkhand region of U.P.

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Indian mustard (*Brassica juncea* (L.) Czernj. & Cosson) a member of the family Brassicaceae, is one of the major oilseed crops grown during rabi season in India. A comprehensive survey was conducted across five districts (viz., Jhansi, Mahoba, Hamirpur, Banda & Lalitpur) of the Bundelkhand region of Uttar Pradesh to identify the diversity of Trichoderma species associated with the mustard rhizosphere. A total of 700 soil samples were collected and serial dilution was performed for isolation of Trichoderma spp. which resulted in a total of 17 distinct Trichoderma isolates. Further, for these 17 isolates morphological and cultural characterization was carried out which revealed considerable variability among the isolates, particularly in phialide dimensions, which ranged from 3.4–13.8 × 2.2–4.4 ìm. Physiological evaluation for high-temperature tolerance indicated that nine isolates (RLBT4, RLBT7, RLBT8, RLBT9, RLBT11, RLBT12, RLBT13, RLBT16, and RLBT17) were capable of sustaining robust growth (>55 mm) even at 45 °C, highlighting their potential adaptability to hot climatic conditions. Antagonistic potential of the isolates was assessed against Sclerotinia sclerotiorum (Accession number: PQ340680), stem rot causing fungi of mustard using both dual culture and volatile assays. In the dual culture assay, isolates RLBT4, RLBT12, and RLBT13 achieved the highest inhibition of mycelial growth, whereas in the volatile assay, isolates RLBT4, RLBT6, and RLBT13 exhibited superior inhibitory activity, by production of effective volatile antifungal compounds. Biochemical characterization further demonstrated that isolates RLBT4 and RLBT11 exhibited the highest chitinase activity when cultured on colloidal chitin-supplemented media. Spectrophotometric quantification confirmed that isolate RLBT4 possessed the highest levels of both glucanase and chitinase 74 activity, indicating its strong enzymatic activity for mycoparasitism.

Keywords: *Brassica juncea, genetic diversity, rhizosphere, Trichoderma*

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Plant-based novel biostimulants enhance drought tolerance, physiological resilience and yield of mustard under rainfed conditions

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Drought stress remains a major yield-limiting factor for mustard cultivation in rainfed agro-ecological regions of eastern India. Although seaweed extract-based biostimulants are well documented, evidence on the performance and economic feasibility of locally available plant-based novel biostimulants is limited. Therefore, a field experiment was conducted during Rabi 2024–25 at the Research Farm of Tirhut College of Agriculture, Dholi, Bihar, to evaluate the effectiveness of Hathisud (*Heliotropium indicum*) and Guma (*Leucas aspera*) leaf extracts in enhancing drought tolerance, productivity and economic returns of Indian mustard (*Brassica juncea* L.) variety Rajendra Sufalam-1 under natural rainfed conditions. The experiment was laid out in a Randomized Block Design with three replications and nine foliar treatments comprising seaweed extract (SWE), Hathisud, Guma and Moringa leaf extracts applied at 3 and 5 mL/L, along with water spray and untreated control. The crop was raised entirely under rainfed conditions without irrigation, exposing it to natural moisture deficit stress. Physiological, biochemical, yield and economic parameters were recorded to assess drought tolerance and treatment profitability.

Drought stress severely reduced photosynthetic pigments, plant water status and antioxidative enzyme activity in untreated control plants. Foliar application of Hathisud and Guma at 5 mL/L significantly improved key drought-responsive physiological parameters and remained statistically at par with SWE (5 mL/L). Hathisud (5 mL/L) recorded chlorophyll a (1.535 mg/g FW), total chlorophyll (2.239 mg/g FW), relative water content (83.09%), water use efficiency (20.63 kg/ha/mm) and membrane stability index (74.97%). Similarly, Guma (5 mL/L) enhanced chlorophyll a (1.514 mg/g FW), total chlorophyll (2.210 mg/g FW), RWC (82.01%) and WUE (19.78 kg/ha/mm), values comparable to SWE. Biochemical analyses revealed substantial enhancement of antioxidative defense under plant-based biostimulants. Hathisud (5 mL/L) significantly increased SOD (66.58 U/g FW), CAT (27.11 micromol/min/g FW) and proline accumulation (H”108 ìg/g FW), while reducing lipid peroxidation. Yield performance reflected these physiological advantages, with seed yield of 1947 kg/ha under Hathisud (5 mL/L), closely comparable to SWE (1960 kg/ha).

Importantly, economic analysis revealed a distinct advantage of plant-based biostimulants. Hathisud (5 mL/L) recorded the highest benefit–cost ratio (7.58), followed by Guma (5 mL/L) (7.29), which were markedly superior to SWE (2.24) and control (1.38). The higher profitability of Hathisud and Guma was attributed to lower input costs combined with comparable yield gains. The study clearly demonstrates that Hathisud and Guma are effective, eco-friendly and cost-effective plant-based novel biostimulants, capable of enhancing drought tolerance and productivity of mustard under rainfed conditions. Their performance, comparable to seaweed extract, highlights their strong potential for climate-resilient and sustainable mustard cultivation in drought-prone regions.

Keywords: *Biostimulant, Heliotropium indicum, Leucas aspera, mustard, Moringa oleifera, seaweed*

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Characterization of prevailing alternaria species and management practices for leaf blight in mustard

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Alternaria blight causes severe foliar damage to Indian mustard and caused by four species of Alternaria viz., *Alternaria brassicae* (Berk.) Sacc., *Alternaria brassicicola* (Schwein.) wiltsh., *Alternaria raphani* Groves and Skolko, and *Alternaria alternata* (Fr.) Keissl. These infections lead to a significant loss in viable seeds and produce. Since no resistant sources are reported for Alternaria blight disease in mustard so far. Hence there is a need to identify effective management practices to combat with these pathogens collectively. In context to this, prevalence of the Alternaria species in and around the Bundelkhand region and effective management practices specifically for this region are required urgently. Keeping this in view an extensive survey was conducted during January- February, 2021-22. Two hundred twenty-five infected leaf samples were collected from farmer’s fields of Jhansi, Datia and Tikamgarh districts of Bundelkhand region. One hundred Alternaria isolates were isolated on PDA. The cultures were purified and identified on the basis of conidial morphology as described by Ellis, 1971; Simmons, 2007 and Meena et al. 2010. Based on microscopic observations, twenty-four isolates with typical Alternaria type conidial morphology abbreviated as Alt. and selected for further studies. The isolates were characterized for cultural, morphological, pathogenic and molecular variations. Based on mycelia growth on PDA at 168h, all 24 isolates were categorised as Fast growing (Alt.1,2,3,4,5,6,7,8,11,12,13,16,17,18,19,20,22,23 and 24), Medium growing (Alt. 15 and 21) and Slow growing (Alt. 9, 10 and 14). Based on microscopic observations all twenty-four isolates were categorized into three groups. Thirteen isolates namely Alt.1,2,3,4,5,6,11,13,16,20,22,23 and 24 with large size conidia (18.0-35.0µm) were categorised in group1. While isolates Alt.7, 8, 9, 10, 12, 17 and 19 with medium size conidia (12.0-28.0 µm) were kept in group 2. Alternaria isolates Alt. 14, 15, 18 and 21 with 8.0-15.0µm conidia size were termed as small size and kept under group 3. All twenty-four Alternaria isolates were evaluated for pathogenic ability based on size of lesions produced on mustard variety Varuna. Alternaria

isolates Alt.1,3,6,9,11,13,14,16,20,22,23 and 24 produced largest lesions with 10.0-15.0 mm dia. after five days of inoculation and categorised as Highly virulent. On other hand eight isolates Alt.2,4,8,10,12,17,18 and 21 caused yellowing symptoms on inoculated leaves and categorised as Moderately virulent while 4 isolates viz; Alt.5,7,15 and 19 did not produced any symptoms on inoculated leaves and termed as Avirulent. All 12 virulent isolates were selected for further studies. ITS primer 1 and 4 were used for species level identificaton. The identified species were *Alternaria brassicae*, *Alternaria brassicicola*, *Alternaria alternata* and *Alternaria burnsii*. Among twelve isolates, six were identified as *Alternaria alternata* collected from Jhansi and Tikamgarh districts of Bundelkhand region. Alternaria isolates Alt. 1 and 9 from Jhansi were identified as *Alternaria brassicicola* while Alt. 3 was characterised as *Alternaria burnsii*. Rest of the isolates were identified as *Alternaria alternata*. Two fungal bioagents viz; *T. harzianum*, and *T. asperellum* were evaluated for their antimycotic potential against all 12 Alternaria isolates using dual culture technique. Among them *T. harzianum* was found most effective caused 21.4 to 50.0 percent inhibition in mycelia growth over untreated control. In-vitro efficacy of five different fungicides viz; Tebuconazole 50% + Trifloxostorbin 25% WG, Metalaxyl 4% + Mancozeb 64%, Azoxystorbin 11%+ Tebuconazole 18.3% SC, Hexaconazole and Propiconazole was assessed @100, 150, 180 and 200 ppm concentration against Alternaria isolates using poisoned food, well diffusion and disc diffusion technique. Hexaconozole 5% SC followed by Metalaxyl 4% + Mancozeb 64% were found most effective using three different techniques. Based on in-vitro studies it was concluded that 100 ppm is Minimum inhibitory concentration (MIC) and 200 ppm is Highest inhibitory concentration (HIC) for all tested fungicides. Seed treatment with *T. harzianum* (Th) @ 10g/kg + Hexaconozole 5% SC @ 0.1% was found best in efficacy evaluation of bioagent and fungicides against Alternaria blight pathogen under in-vitro and field conditions.

Keywords: *Alternaria species, bioagents, leaf blight of mustard, Trichoderma species*

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Improving physiological performance of Indian mustard genotype RH 725 under terminal heat stress using orthosilicic acid

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Terminal heat stress is a vital factor that effect the productivity of Indian mustard under changing climate scenarios, majorly for late sown conditions. Elevated temperature at reproductive and seed filling stage has direct influence on the plant water relations, photosynthetic efficiency that led to accelerated senescence and results in yield reduction. A field experiment was conducted during rabi season 2022-23 to analyse the effect of biostimulant *i.e.* orthosilicic acid application in enhanced physiology and stress tolerance of *Brassica juncea* RH 725 genotype under terminal heat stress conditions. Foliar application of differential concentrations of orthosilicic acid caused improvement in relative water content, SPAD chlorophyll content, photosynthetic rate and stomatal conductance to a significant level, which furthermore led to improved yield attributes. 20 ppm OSA application improved RWC by 15%, chlorophyll content by 31% and photosynthetic rate by 35%. It also caused a decline in canopy temperature by declining canopy temperature depression by 26% compared to control after 30 ppm OSA application. A significant enhancement was also noted in nitrogen balance Index by 32%. Among the treatments, 20 ppm OSA showed best performance, showing yield improvement of 22% over untreated plants across mustard genotypes. Improved plant water status and maintained photosynthetic rate resulted in delayed stress-induced senescence. These findings demonstrated that biostimulant based foliar interventions offer promising climate smart strategy for alleviating terminal heat stress and sustaining productivity of Indian mustard under warming climate scenarios.

Keywords: *Biostimulants, canopy temperature, gaseous exchange, thermal regulation*

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Influence of exogenously applied nanoparticles on Indian mustard (*Brassica juncea* L.) under terminal heat stress

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Brassica juncea, also known as Indian mustard, is an important oilseed crop that is planted widely in Europe, Africa, North America, and Asia. Mustard is much sensitive to changes in weather and hence climate change could have significant effect on its production. High temperature during growth and developmental phases can cause substantial yield losses in Brassica species. Crop yield reductions due to high temperature stress are evident from the large differences in yield between areas with cooler and with warmer temperatures. Better agricultural production can be achieved by using nanoscale nutrients smaller than 100 nm, as it enters plant leaves more efficiently, achieve higher nutrient utilization efficiency (NUE) than their bulk counterparts. The present investigation was conducted to evaluate the Influence of exogenously applied nanoparticles (Zn-NP's, S-NP's, Si-NP's & nanonitrogen) on two genotypes (RH 1706 and RH 1975) under terminal heat stress. Two different concentrations (1ml/L and 2ml/L) of NPs were used as foliar spray. Biochemical observation was recorded at flowering and vegetative stages (Proline, superoxide dismutase, catalase and peroxidase). Yield and yield attributes were recorded at harvest. SOD showed maximum increase in their activity with nanonitrogen at 2ml/L in RH 1706 and with nanozinc at 2ml/L in RH 1975. These results indicate enhanced oxidative stress tolerance and improved physiological efficiency. Yield attributes showed significant improvements, with seed yield increasing with 1 ml/L Nanonitrogen in RH 1706 and RH 1975. Among all nanoparticle treatment, Nanonitrogen (1 ml/L) perform best followed by Si-NP's (1ml/L) and Zn-NP (2ml/l), that resulted into increased activity of antioxidant enzyme. These findings suggest that nanoparticles improve crop resilience to terminal heat stress by enhancing physiological and antioxidant enzyme activity, which ultimately contributed to better yield.

Keywords: *Brassica juncea, heat stress, nanoparticles (NPs), yield*

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Physiological responses of mustard (*Brassica spp.*) germplasm to multiple abiotic stresses.

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Mustard (*Brassica spp.*) is an important oilseed crop increasingly exposed to multiple abiotic stresses as a consequence of climate variability. In agro-ecosystems, stresses such as drought, salinity, heat, and frost frequently occur simultaneously or sequentially, imposing complex and non-additive constraints on plant physiological performance. In the present study, thirty-five mustard germplasm lines were systematically screened for tolerance to multiple abiotic stresses, including frost, salinity, heat and drought were conducted at Agricultural Research Station, Fatehpur - Shekhawati, Sikar (Rajasthan). Stress treatments were imposed individually and in combination at key growth stages to assess differential physiological responses among genotypes. Combined stress exposure resulted in significant reductions in growth, photosynthetic efficiency and water relations across germplasm lines; however, substantial genotypic variation was observed. Frost stress, particularly when interacting with drought or salinity, caused severe membrane injury and impaired physiological stability, while heat and drought combinations

markedly reduced photosynthetic performance. Tolerant germplasm lines maintained higher chlorophyll content, relative water content, membrane stability and water-use efficiency under multi-stress conditions compared with sensitive lines. Multivariate analysis enabled the identification of superior genotypes exhibiting broad-spectrum tolerance to multiple abiotic stresses. The identified germplasm represents valuable genetic resources for breeding programs aimed at developing climate-resilient mustard cultivars.

Keywords: *Brassica juncea, multiple stress, physiology, yield*

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Latent attributes of toria variety TS-67 under delayed sowing: Implications for yield and profitability during cold and dry winter in Assam

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Toria (*Brassica rapa* var. toria) is traditionally grown in Assam as a post-rainy oilseed using residual moisture after Sali rice, favoured for its short duration and low inputs but highly sensitive to sowing time. Erratic weather-early pre-monsoon rains, recurrent flooding, thunderstorms, hailstorms and prolonged water logging-delays field drainage, pushing sowing to early January, when most varieties perform poorly. To address this, AAU-ZRS, Shillongani developed TS-67 for delayed sowing and documents performance. The study was carried out through a combination of on-station trials at AAU-Zonal Research Station (AAU-ZRS), Shillongani, Nagaon, and on-farm demonstrations in selected flood-prone districts of Assam to evaluate the performance of toria variety TS-67 under delayed sowing conditions. Sowing was undertaken between the end of December and the first week of January, coinciding with farmers' actual late planting situations. The crop was raised following recommended agronomic practices, including appropriate seed rate and spacing, minimum tillage in flood-affected fields, need-based weed management, and minimal fertilizer application suited to late sowing conditions. Systematic observations were recorded on germination percentage and seedling vigor, plant height, number of branches per plant, days to flowering and maturity, and seed yield (q ha{ ¹). In addition, farmers' feedback regarding crop performance, adaptability, and acceptability was documented to assess field-level suitability of the variety. TS-67 demonstrated strong adaptability to delayed sowing by showing better emergence under low temperatures, synchronized flowering, reduced frost and cold stress damage, and stable pod formation under dry winter conditions. Across multiple locations and years, the variety consistently produced 9.0–10.0 q ha{ ¹ seed yield with a crop duration of about 90 days, ensuring timely maturity before the onset of pre-monsoon rainfall. This performance is considered satisfactory for late-sown toria in flood-affected ecosystems of Assam, where conventional varieties often fail. Farmers widely preferred TS-67 because of its short duration, reliable yield under delayed sowing, lower risk of crop failure, and suitability for contingency planning. Overall, TS-67 offers a practical climate-resilient option to enhance cropping intensity and farm income in vulnerable agro-ecosystems. The toria variety TS-67 demonstrates strong potential for cultivation under delayed sowing in Assam's flood-prone regions. It offers stable yield, short duration, and safe harvest before pre-monsoon rainfall, making it an excellent alternative for risk-prone farmers.

Keywords: *Assam, contingency crop, delayed sowing, pre-monsoon rainfall, toria, TS-67*

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Deciphering host-pathogen interactions in *Brassica juncea-Albugo candida* host-pathosystem

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Albugo candida belonging to oomycetes causes white rust disease in Indian mustard (*Brassica juncea*) and in several other hosts of Brassicaceae family. *Albugo candida* is an obligate biotrophic pathogen and causes significant yield losses in Indian mustard in the country. The major reason for the yield losses is the highly variable nature of *Albugo candida* which leads to continuous evolution of new races of the pathogen leading to the breakdown of host resistance. Due to the above said reasons, it is essential to understand the host-pathogen interactions occurring in *Brassica juncea-Albugo candida* host-pathosystem. In this study, a total of 26 *Albugo candida* isolates were collected from various mustard growing areas of the country. The isolates were purified followed by their morphological characterization. The incubation period of all the isolates on the susceptible genotype of Indian mustard was characterized. Further, in order to check the race structure of *Albugo candida* population infecting Indian mustard, pathogenic reaction of all the isolates was checked invitro on 15 genotypes of Indian mustard which includes some known resistance donors as well as cultivated varieties. The pathogenic reaction on different Indian mustard genotypes revealed considerable pathogenic variability in *Albugo candida* population and existence of at least 13 races of the pathogen. The results indicate that there is considerable variability in *Albugo candida* population in the country and continuous efforts must be made towards breeding white rusts resistance Indian mustard varieties for preventing severe white rust epidemic and ensuring edible oil security in the country.

Keywords: *Albugo candida, Brassica juncea, edible oil, host-pathogen interactions*

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Evaluation of biocontrol agents for the management of fungal diseases in rapeseed–mustard (*Brassica spp.*)

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Rapeseed–mustard (*Brassica spp.*) is an important group of oilseed crops widely cultivated for edible oil production; however, its productivity is severely constrained by several soil-borne and foliar fungal diseases. The excessive use of chemical fungicides for disease management has raised concerns related to environmental pollution, disturbance of beneficial soil microflora and the development of fungicide-resistant pathogens. Under these circumstances, biological control has emerged as a sustainable and eco-friendly alternative, as reported in earlier studies. The present investigation was undertaken to evaluate the efficacy of selected biocontrol agents against major fungal pathogens of rapeseed–mustard under laboratory and field conditions. Biocontrol agents including *Trichoderma harzianum*, Trichoderma viride, Pseudomonas fluorescens, and Bacillus subtilis were screened for their antagonistic activity using standard dual culture techniques to assess inhibition of pathogen mycelial growth. Promising agents were further evaluated through seed and soil application to study their effect on disease incidence, plant growth, and yield parameters. The results revealed that Trichoderma spp. and Pseudomonas fluorescens exhibited significant antagonistic activity through mechanisms such as mycoparasitism, antibiosis, and competition for nutrients and space. Field application of biocontrol agents reduced disease severity and improved plant vigor compared to untreated control. The findings support earlier research highlighting the role of biocontrol

agents in integrated disease management strategies for rapeseed–mustard crops.

Keywords: *Biocontrol agents, fungal diseases, Pseudomonas fluorescens, sustainable agriculture, Trichoderma*

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Mitigation of drought stress Indian mustard (*Brassica juncea L.*) through foliar application of plant growth regulating substances across agro-climatic zones

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Drought stress severely affects the growth, physiology, and productivity of Indian mustard (*Brassica juncea* L.) by reducing photosynthetic efficiency, impairing nutrient uptake, and disrupting metabolic processes, ultimately leading to growth retardation and yield losses. The application of plant growth regulating substances (PGRs) has emerged as an effective agronomic strategy to enhance drought tolerance by modulating physiological, biochemical, and molecular responses under water-limited conditions, thereby stabilizing yield performance. Field experiments were conducted during the cropping season (2020-24) at three AICRP–Rapeseed-Mustard centers representing major agro-climatic zones of India: ICAR–Indian Institute of Rapeseed-Mustard Research (IIRMR), Bharatpur (Agro-climatic Zone III), CCS Haryana Agricultural University, Hisar (Agro-climatic Zone II), and Punjab Agricultural University, Ludhiana (Agro-climatic Zone II). The latest locally recommended rainfed varieties-DRMR 1165-40 at Bharatpur, RH 725 at Hisar, and PBR 97 at Ludhiana—were evaluated for the efficacy of selected growth regulating substances under field conditions. The experiments were laid out in a randomized block design with three replications, where each treatment plot consisted of five rows of 5 m length. Foliar applications of trehalose (10 and 20 mM), urea (1 and 2%), potassium nitrate (KNO_3 2%), water spray, and an untreated control were imposed at critical growth stages. The application of PGRs significantly enhanced key physiological and yield-related attributes, including relative water content (RWC), leaf water retention (LWR), chlorophyll stability index (CSI), photosynthetic pigment concentration, stomatal membrane stability (SMS), total number of siliquae per plant, seeds per siliqua, and thousand-seed weight. Among the treatments, foliar application of potassium nitrate (2%) consistently produced the highest yield improvement under rainfed conditions, resulting in a minimum yield increase of e”15% over the control across all locations. Yield enhancement due to potassium nitrate application at flowering initiation and 50% flowering stages was 26% at ICAR-IIRMR, Bharatpur (Zone III), 15% at CCSHAU, Hisar (Zone II), and 23% at PAU, Ludhiana (Zone II). These findings demonstrate the potential of potassium nitrate as an effective foliar intervention for mitigating drought stress and improving productivity of rainfed Indian mustard across diverse agro-climatic regions.

Keywords: *Foliar application, plant growth regulators substance, potassium nitrate, physiological responses, rainfed conditions*

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Effect of Broomrape (*Orobanche sp.*) on yield and contributing traits in taramira (*Eruca sativa*)

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Phelipanche aegyptiaca (Formally is known as *Orobanche aegyptiaca*) is a serious parasitic weed and a major constraint on Brassicaceae crops, particularly for Rapeseed and Mustard, which causes about 75-80 % of yield losses in India. Effect of Broomrape (*Phelipanche aegyptiaca* formally is known as *Orobanche aegyptiaca*) on yield Taramira (*Eruca sativa*) is a major constraint in its production in Rajasthan. Five taramira varieties viz.- RTM 2002, RTM 314, RTM 1351, T 27 and RTM 1355 were evaluated in Orobanche infested fields in Jobner, Jaipur Rajasthan. The aim of the study was to determine the critical stage of host plants affected by parasite and to evaluate resistance level of taramira genotypes. The degree of infection and host resistance level was evaluated at three host growing stages (flowering, siliqua formation, and maturity stages) using different traits like number of Orobanche emerged per plant, per plot, incidence, and severity. The agronomic data such as stand count at emergence, flowering, siliqua, maturity, plant height, number siliqua, seed per siliqua, test weight, and grain yield were recorded from ten randomly selected plants in the field. The analysis of variance showed that there were high significant variations ($p < 0.01$) in measured traits between the three host growing stages and between genotypes in agronomic traits. The effect of *O. aegyptiaca* on host plant was started from the flowering stage, but the siliqua initiation to seed formation stage is economically important stage at which actual effect of the parasite was observed in field experiments. The analysis of variance was carried out for various characters observed under normal and Orobanche stress condition. All the genotypes exhibited significant differences for all the characters under both the conditions. The pooled analysis of variance also indicated presence of significant difference among the genotypes for all the characters studied.

Keywords: *Broomrape, Orobanche, Phelipanche aegyptiaca, rocket salad, taramira*

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Transcriptomic dissection of cross kingdom crosstalk in *Brassica juncea-Sclerotinia sclerotiorum* pathosystem

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Sclerotinia stem rot caused by the highly destructive phytopathogen *Sclerotinia sclerotiorum*, poses a major constraint to oilseed Brassica production worldwide. A comprehensive understanding of host-pathogen interactions and identification of key genes and pathways are essential for devising effective disease management strategies. In order to understand these approaches, we performed time-dependent (0-72 hours post-inoculation) bulk transcriptome profiling of stem tissues inoculated with S. sclerotiorum from resistant introgression lines and susceptible genotypes of *Brassica juncea* following challenge with S. sclerotiorum isolate 'PAU'. Our transcriptomics analysis revealed expression of 19,666 genes in resistant lines and 34,108 genes in susceptible genotypes upon infection. Among these, ten differentially expressed candidate genes were identified as potentially associated with pathogenicity and host defense responses. Gene enrichment analysis highlighted the involvement of antioxidant activity, cellular and metabolic

processes, plant-pathogen interaction, ribosome biogenesis, signaling pathways and MAPK signaling. Furthermore, weighted gene co-expression network analysis (WGCNA) identified ten gene modules that showed strong correlations with cell signaling and key biochemical pathways. Collectively, these findings enhance our understanding of the Brassica-Sclerotinia pathosystem and provide novel insights into candidate genes and regulatory networks underlying pathogenicity and resistance. The identified potential targets offer promising opportunities for resistance enhancement using RNA interference (RNAi), gene knockout strategies and host-induced gene silencing (HIGS) techniques.

Keywords: *Brassica juncea, differentially expressed genes, effectors, pathogenicity, RNA Sequencing, Sclerotinia sclerotiorum*

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Epidemiology of white rust-downy mildew disease complex of rapeseed-mustard in relation to sowing time and weather conditions

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Rapeseed-mustard is a major oilseed crop of India; however, the concurrent occurrence of white rust (*Albugo candida*) and downy mildew (*Hyaloperonospora parasitica*), collectively known as the white rust-downy mildew disease complex, has emerged as a serious threat to crop productivity. The disease complex causes severe infection of leaves and inflorescences, leading to staghead formation. The present study evaluated the effect of different dates of sowing on disease severity over two consecutive seasons (2022-23 and 2023-24). Late October sowing (29th October) resulted in the earliest disease appearance and the highest disease severity at 90 DAS (37.80% and 36.50%) in varieties Varuna and Kranti, respectively, whereas early October sowing (1st October) delayed disease onset and recorded the lowest severity (15.00% and 15.40%). Peak disease severity was observed during February 1-7, followed by January 25-31. Mean weekly disease severity across all sowing dates peaked during January 25-31 (25.68% and 24.97%) and February 1-7 (26.95% and 26.20%) in Varuna and Kranti, respectively, coinciding with favourable weather conditions characterized by moderate maximum temperatures (17.19-20.91 °C), low minimum temperatures (8.09-8.86 °C), high relative humidity (61.36-94.53%), low sunshine hours (1.85-4.34 hrs.), moderate rainfall (3.80-5.80 mm), and higher wind velocity (3.31-3.99 m s{ ¹). Weather-based correlation and regression analysis revealed strong positive associations of disease severity with wind velocity, rainfall, minimum temperature, and maximum relative humidity, while maximum temperature and sunshine hours showed negative associations. These findings indicate that cool, humid, and rainy conditions coupled with higher wind velocity are highly favourable for the development of the white rust-downy mildew disease complex, with wind velocity emerging as the most decisive contributing factor. The study emphasizes that early sowing combined with an understanding of favourable weather conditions can serve as an effective strategy for reducing disease severity and may aid in developing weather-based disease management and forecasting approaches for rapeseed-mustard.

Keywords: *Disease severity, rapeseed-mustard, white rust-downy mildew disease complex*

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Characterization of trichoderma isolates against *Sclerotinia sclerotiorum* causing stem rot of mustard

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India ranks fourth in global oilseed production, contributing approximately 10% of oilseed production globally. Among various oilseed crops, rapeseed-mustard has emerged as the leading oilseed crop in India. Among various diseases, Sclerotinia stem rot caused by *Sclerotinia sclerotiorum* now has become one of the most destructive diseases of rapeseed-mustard with incidence level of 80-90% and yield losses of 6-45%. In the present study 06 Trichoderma isolates viz. PBTMSR13,16&17 (*T. harzianum*) PBTMSR14&18 (*Trichoderma sp.*) and PBTMSR 15 (*T. azevedoi*), were taken to access their antagonistic potential i.e. mycoparasitization (mycelial and sclerotial parasitization), antibiosis (volatile and non-volatile assay) against *S. sclerotiorum*, compatibility with the fungicides recommended against Sclerotinia rot and low temp. tolerant. In mycelial parasitization, modified dual culture method was used. The results showed that four isolates viz. PBTMSR13 (*T. harzianum*), PBTMSR14 (*Trichoderma sp.*), PBTMSR17 (*T. harzianum*) and PBTMSR18 (*Trichoderma sp.*) achieved 100 % mycelial parasitization of the test pathogen at 12th days after contact, while all the 06 isolates at 15th days after contact. The sclerotial parasitization of S. sclerotiorum were evaluated using two methods (sprayed and dipped with spore suspension of Trichoderma). In both the methods complete sclerotial parasitization (100%) was observed with PBTMSR18 (*Trichoderma sp.*) and 80% parasitization with PBTMSR13 (T. *harzianum*) at 30th days after treatment. However, 100% inhibition of myceliogenic germination of treated sclerotia were observed against all the isolates when plated on PDA medium after 30 days after incubation. In volatile assay (paired plate technique) PBTMSR14 (Trichoderma sp.) showed significantly highest mycelial growth inhibition (86.66%) of test pathogen, followed by PBTMSR18 (Trichoderma sp.) (83.33%), PBTMSR17 (*T. harzianum*) (80%) and PBTMSR16 (*T. harzianum*) (72.22%). In non-volatile assays (cell-free culture filtrates) complete mycelial growth inhibition (100%) of the test pathogen was observed with PBTMSR18 (Trichoderma sp.) at 50% culture filtrate which was significantly higher than PBTMSR16 (*T. harzianum*) (87.22%) and PBTMSR13 (*T. harzianum*) (86.42%). Among various incubation temperature (15-25^{0}C), PBTMSR18 (*Trichoderma sp.*), PBTMSR13 (*T. harzianum*) and PBTMSR17 (*T. harzianum*) showed optimum growth and sporulation even at 15^{0}C and among all the isolates only PBTMSR18 (*Trichoderma sp.*) was found compatible with Carbendazim + Mancozeb, Thiophanate Methyl and Tebuconazole up to 100 ppm and with propiconazole upto 50 ppm. The above studies revealed that among 06 Trichoderma isolates, PBTMSR18 (*Trichoderma sp.*) was found better than other isolates in terms of mycelia and sclerotial parasitization (Mycoparasitic action) and mycelial growth inhibition of test pathogen (Antibiosis action), compatibility with recommended fungicides and survivability even at low temp.(15^{0}C) Since this isolate was isolated from mustard field from the sclerotia, therefore could be exploited for the management of Sclerotinia rot of mustard in integration with compatible fungicides after making suitable formulation and testing at different locations.

Keywords: *Bio-control, disease severity, rapeseed-mustard, stem rot*

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Impact of low temperature stress on yield of taramira (*Eruca sativa*)

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Taramira, also known as rocket salad, is a drought-tolerant, *Rabi* season oilseed crop, primarily grown in the drier regions of north-western India. It belongs to the Brassicaceae family and is characterized by its pungent oil, which is not typically consumed directly but is often used to increase the pungency of mustard oil. In India, the main states cultivating taramira are Rajasthan, Haryana, Punjab, Madhya Pradesh and Uttar Pradesh. Of these, Rajasthan leads the country in both the area under cultivation and taramira production. This crop is well-suited for regions with little to no irrigation, as its deep and efficient root system allows it to access moisture from deeper layers of the soil. In times of severe drought, especially when late Rabi rains occur, taramira often remains the only viable crop option for areas with limited soil moisture. The present investigation was undertaken to assess genetic variability, character association, path coefficient analysis and to identify elite genotypes for low temperature tolerance in taramira [*Eruca sativa* (L.)]. Thirty genotypes, including five released varieties, received from AICRP–Rapeseed-Mustard (Taramira Unit) were evaluated during Rabi 2024–25 at the Instructional Farm, Sri Karan Narendra College of Agriculture, Jobner, in a Randomized Block Design with three replications under two environments (normal and cold stress). Thirteen quantitative and physiological traits were recorded. Analysis of variance revealed highly significant differences among genotypes for all traits, indicating substantial genetic variability. High heritability coupled with high genetic advance and genotypic coefficient of variation (GCV) for seed yield per plant, siliquae per plant and membrane stability index suggested predominance of additive gene action and effectiveness of selection for these traits. In environment E1, high GCV and PCV were observed for primary branches and siliquae per plant, while in E2, siliquae per plant and secondary branches per plant exhibited high variability. Correlation analysis across both environments showed that seed yield per plant had significant positive associations with siliquae per plant, seeds per siliqua, secondary branches per plant, plant height and siliqua length. Path coefficient analysis indicated that plant height, siliquae per plant, siliqua length and secondary branches per plant exerted strong direct effects on seed yield. Based on pooled mean performance, genotypes RTM-314, RTM-2266 and RTM-2201 were identified as superior for seed yield. Additionally, RTM-2249, RTM-1355, RTM-2201, RTM-2226 and RTM-1622 exhibited high membrane stability and minimal yield reduction under cold stress, indicating their potential for low temperature tolerance. These genotypes can serve as valuable donors in breeding programmes aimed at developing cold-tolerant, high-yielding taramira varieties. Traits such as plant height, siliquae density, seeds per siliqua and membrane stability index should be prioritized for effective selection under stress-prone environments.

Keyword: *Cold stress, genetic variability, heritability, low temperature stress, taramira*

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Next-generation Brassica breeding: Integrating physiological acceleration with predictive analytics to combat biotic stress and enhance nutrition

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Rapeseed-mustard plays a pivotal role in India's food and nutritional security as the country's most important edible oilseed crop, contributing substantially to domestic oil availability and rural livelihoods. However, its productivity is increasingly threatened by climate variability, including rising temperatures

and erratic rainfall, along with persistent biotic stresses such as Orobanche infestation and Sclerotinia stem rot. These challenges continue to undermine yield stability and oil quality across major growing states. Conventional breeding has delivered significant genetic gains in rapeseed-mustard, yet its effectiveness is constrained by long generation cycles, environmental noise, and the slow incorporation of complex stress-resilience traits. To address these limitations, speed breeding has emerged as a powerful approach that exploits controlled environments, extended photoperiods, and optimized temperature regimes to accelerate plant growth and reproduction. By enabling 4–6 generations per year, speed breeding facilitates rapid allele fixation, faster trait stabilization, and precise evaluation of climate-adaptive traits. The integration of molecular breeding tools further enhances this process. Marker-assisted selection, genomic selection, QTL mapping, and gene pyramiding enable the efficient introgression of resistance genes for key stresses while maintaining desirable agronomic and quality traits. Artificial intelligence (AI) and high-throughput phenomics strengthen selection efficiency by analyzing multi-omics datasets, environmental variables, and image-based phenotypes. Machine learning–driven models improve the prediction of yield performance and nutritional attributes such as fatty acid composition. By synchronizing physiological acceleration with genomic precision and data-driven decision-making, this integrated framework shifts rapeseed-mustard improvement from a slow, reactive process to a rapid, predictive breeding paradigm. The combined application of speed breeding, molecular tools, AI, and phenomics offers a promising pathway for developing high-yielding, climate-resilient, and nutritionally superior cultivars.

Keywords: *Artificial intelligence (AI), climate resilience, genomic selection, multi-omics integration, nutritional security, speed breeding*

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Novel Cas protein variants and their functional significance in precision genome editing for sustainable crop improvement

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Originally evolved as an adaptive immune defence in bacteria and archaea, the CRISPR/Cas system has now become a transformative genome-editing tool for precise modification of DNA and RNA in diverse organisms. CRISPR/Cas systems are broadly classified into two major classes. Class 1 systems require multi-subunit protein complexes to mediate nuclease activity, while Class 2 systems employ a single, large effector protein guided by RNA for target cleavage. Class 1 includes Types I, III, and IV, which utilize Cas3 (helicase-nuclease), Cas10, and DinG-associated complexes, respectively, and primarily target DNA or RNA using CRISPR RNA (crRNA). Class 2 systems comprise Types II, V, and VI, represented by Cas9, Cas12, and Cas13 nucleases, respectively. While Cas9 targets DNA typically using an engineered single-guide RNA (sgRNA), Cas12 (targeting DNA) and Cas13 (targeting RNA) function with a single CRISPR RNA (crRNA) guide. Among these, Cas9 remains the most widely used genome-editing enzyme due to its simplicity, efficiency, and well-established protocols. Recently discovered smaller nucleases such as Cas14, which target single-stranded DNA without strict PAM requirements, further expand genome-editing possibilities, particularly for compact or difficult-to-access genomic regions. In addition to nuclease-active Cas proteins, catalytically inactive variants such as dCas9 enable gene regulation, epigenome editing, base editing, and genomic imaging without inducing DNA breaks. In plant biotechnology, Cas9, Cas12, and Cas13 have been extensively applied in crops such as rice, wheat, tobacco, tomato, and mustard. In rapeseed-mustard, CRISPR/Cas9 has been successfully employed to improve stress tolerance, nutritional quality, and disease resistance. The expanding repertoire of CRISPR/Cas variants marks a paradigm shift in Brassica biotechnology, offering the precision required to navigate the complex allotetraploid genome.

Keywords: *CRISPR/Cas systems, climate resilience, gene editing, nutritional security*

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Plant growth-promoting bacteria (PGPB) mediated induced resistance against Alternaria blight in *Brassica juncea*: Unravelling biochemical defence signatures across genotypes

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Alternaria blight, caused by *Alternaria brassicae* and *A. brassicicola*, is a highly destructive disease that leads to severe yield losses in *Brassica juncea* (Indian mustard), a pillar of edible oil security in India. Current management practices rely heavily on synthetic fungicides, which impose economic and environmental costs while increasing the risk of pathogen resistance. Biological control using beneficial microorganisms has recently emerged as a sustainable alternative; however, the mechanisms underlying disease suppression remain poorly understood. This communication reports our attempt to evaluate the role of a PGPB consortium (*Pseudomonas putida, P. fluorescens,* and *Bacillus stercoris*) in activating defence-related responses and suppressing Alternaria blight in *B. juncea*. The study was conducted as a pot experiment involving the susceptible check Varuna, three introgression lines (IM152, IM87, and JA8), and a resistant accession of *Sinapis alba*. The objective was to assess the potential of seed treatment combined with foliar application of the PGPB consortium to suppress Alternaria blight by inducing host resistance, as reflected through time-course changes (0-, 3-, 5-, and 7-days post-inoculation; dpi) in defence enzymes (POD, PPO, PAL, and CAT) and metabolites (total phenols,total flavonoids and lignin). Seeds were pretreated with a charcoal-based bacterial formulation prior to sowing and subsequently supplemented with a foliar application of the same formulation 48 h before *A. brassicae* inoculation at 75 days after sowing. Disease severity was recorded at weekly intervals for four weeks following pathogen inoculation. The findings revealed that combined seed and foliar application of the PGPB consortium significantly enhanced the accumulation of defence metabolites compared with control plants inoculated only with the fungus. Disease indexing based on the Conn et al. (1990) scale showed clear genotype-dependent differences in disease response. The introgression line JA8 consistently recorded a low percent disease index (PDI) of 38.8%, which was lower than IM152 (43.0%) and IM87 (48.1%) and substantially lower than the susceptible check Varuna (53.3%). No symptoms of disease appeared in resistant check S. alba. Resistance in JA8 was associated with a pronounced induction of defence enzymes at 5 dpi, showing a 1.6–2.0-fold increase in activity compared with the pathogen-inoculated control. In contrast, IM152 and IM87 showed a moderate response, while the susceptible check Varuna exhibited minimal defence induction. The resistant check S. alba displayed strong activation of defence metabolites, with a 1.3–1.6-fold increase in the accumulation of total phenols, lignin, and flavonoid content relative to the diseased control. The enhanced disease suppression in JA8 highlights its strong response to PGPB-mediated biocontrol and its potential as a valuable genetic resource. Overall, these findings emphasize the need to develop and deploy non-pathogenic biocontrol strains as viable, sustainable alternatives to synthetic fungicides for effective management of Alternaria blight in Brassica.

Keywords: *Induced resistance, non-enzymatic metabolites, plant growth–promoting bacteria (PGPB) consortium, percent disease index (PDI), defence-related enzymes*

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Designing climate smart oilseed crops integrating genome editing and bioinformatics with special reference to *Brassica*

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The ever-increasing demand for edible oils at a rapid pace due to population explosion, growing global affluence, changing dietary choices, and the need for renewable plant-derived resources has necessitated increasing the production of oilseeds crops. However, oilseed production is negatively impacted by unpredictable environmental conditions caused by climate change, and Productivity is compromised in these crops due to biotic and abiotic stresses Although conventional breeding techniques have been used to provide gains in terms of oilseed yields, in past, are increasingly inadequate to address the speed and complexity of climate-induced stresses. Precision breeding has emerged as a powerful strategy for developing climate-smart crops including oilseeds by enabling targeted genetic improvements with high accuracy and efficiency. This approach integrates advanced genome editing technologies, such as CRISPR/Cas systems, ZFN and TALENs, with genomics, phenomics, and bioinformatics to accelerate the identification and manipulation of genes associated with stress tolerance, yield stability, and resource-use efficiency. The integration of bioinformatics-driven data analysis with genome editing allows rapid discovery of climate-adaptive alleles, precise gene targeting, and validation of desirable traits under variable environmental conditions. This review discusses the impacts of climate change on agriculture, the principles and tools of precision breeding, and the synergistic role of genome editing and bioinformatics in developing resilient, high-yielding, and nutritionally enhanced oilseed crops. The potential, challenges, and future prospects of precision breeding for climate-smart breeding are also highlighted.

Keywords: *Bioinformatics, climate-smart crops, CRISPR/Cas, genome editing, precision breeding, sustainable agriculture*

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Screening of brassica genotypes against *Erysiphe cruciferarum* causing powdery mildew in rapeseed-mustard growing areas of Northern Madhya Pradesh under natural conditions

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Rapeseed-mustard group of oil seed crops are the major rabi crops of India. The group is principally coparented by *Brassica rapa* (Syn. *B. campestris* L.), *B. napus* L., *B. juncea* (L.) Czern and Coss and *B. carinata* Braun. In India, rapeseed-mustard are the significant oilseed crops that concealments almost 70% of the country's rapeseed-mustard crop. In world, area, production and productivity of rapeseed-mustard is 43.35 million hectares, 89.77 M tones and 2070 kgha^{-1} respectively (2025, Anonymous). While the area, production and productivity in the India is 8.63 million hectares, 12.61 MT and yield 1461 kgha^{-1}, individually (Anonymous, 2025). The main rapeseed-mustard producing states in India Rajasthan who contribute rank first for both area and production tracked by MP, MH, Karnataka, UP, Bihar, Tamil Nadu, Haryana, West Bengal, and Assam. Madhya Pradesh is second largest rapeseed-mustard producing states in India and donates more than 13% in total production of rapeseed mustard, which is produced on an area of around 10.89 million hectares, production of 16.66 million hectares with productivity 1530 kgha^{-1} correspondingly (Anonymous, 2025). There are four species of Brassica juncea commonly known

as Indian mustard is being grown primarily as source of vegetable oil. The oilseed brassicas generally comprise 38 to 57 % of erucic acid, 4.7 to 13 % linolenic acid and 27 % of oleic acid and linolenic acid, which are of high nutritive value essential for human health. The quantity and quality of rapeseed - mustard is exaggerated by an array of diseases including powdery mildew, sclerotinia stem rot, Alternaria blight, downy mildew and white rust. Powdery mildew incited by *Erysiphe cruciferarum* (Opiz. ex Junell) is considered to be the most destructive fungal disease occurring all over the world. The pathogen is an economically important biotrophic parasite of Brassica spp. Yield losses of crop are ranging between 10-90% because of powdery mildew disease in India. Cultivars, potentially reducing yield by up to 50% across affected regions of India. In present investigation, screening of sixty-one genotypes of rapeseed and mustard group (Brassica species) were carried out during Rabi, 2024-25 under field conditions at RVSKVV-Zonal Agricultural Research Station Morena. Out of them some entries viz; GSL1 (GSC), DLSC1(Bc-C) and RTM 314 (Es-C) were found almost free from this disease. The minimum disease severity (1.80%) was recorded in genotype PT303 (Br-TC), while maximum disease severity (40.50%) was evident in genotype PBR813-2. Putative resistant/tolerant line (s) may be used in crossing programme to breed resistant/ tolerant varieties against afro said disease in upcoming days.

Keywords: *Erysiphe cruciferarum, powdery mildew, rapeseed-mustard*

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Response of macro nutrient and bio-fertilizers in enhancing rapeseed-mustard (*Brassica juncea* L.) productivity and soil health

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Indian mustard annual nature, self-pollinated major oilseed crop in different nations across the world. Family Cruciferae and referred to as locally Laha, Rai and sarson. The oil content ranges from 37 and 42%. India is largest rapeseed-mustard producers, ranking first in terms of area and second in terms of production after China across world. Indian mustard covers approximately 70% of the country's rapeseed-mustard crop. The rapeseed-mustard area, production and productivity in the world have been 43.35 million hectares, 89.77 M tonnes and 2070 kg/ha (2025, Anonymous) and in India area have been 8.63 million hectares with a production of 12.61 MT and yield 1461 kg/ha (Anonymous, 2025). The major mustard producing states in India Rajasthan is contribute rank first for both area and production followed by MP, MH, Karnataka, UP, Bihar, Tamil Nadu, Haryana, West Bengal, and Assam. Madhya Pradesh is second largest repeseed-mustard producing states in india and contributes more than 13% in total production of rapeseed mustard, which is produced on an area of around 10.89 million hectares, production of 16.66 million hectares and productivity 1530 kg/ha (2025, Anonymous). Production constraints of nutrient, water and weed management practices affect directly to mustard productivity. Among the all-other practices nutrient management is contributing more yield losses through inadequate use fertilizers. The total dependency on inorganic fertilizers not only identified as critical limitations for withholding mustard production, they also severely affected the sustainability and pollution of agricultural crops. Continuous use of inorganic fertilizers alone had negative impact physical and chemical characteristics of soil, environmental condition (Bisht, 2018). Bio-fertilizers are known to play an important role are ecologically harmless and in agricultural soil fertility, crop yield and production and cost-effective sources of non-bulky nature that are essential for getting the higher grain yield. Improved absorption of minerals and water, root growth and vegetative growth, solubilizing insoluble form to soluble form and nitrogen fixation are all benefits of using bio-fertilizers. The field experiments were conducted during three consecutive rabi seasons of 2022-23, 2023-24 and 2024-25 at Rajamata Vijayaraj Scindia Krishi Visva Vidhyalay, Zonal Agricultural Research station Morena (MP) in Gird Agro-climatic zone. The maximum temperature ranged between 17.6–33.5^{0}C, 17.7-34.2^{o}C and 19.8-34.9^0 during 2022-23, 2023-24 and 2024-25

respectively. Rainfall data were recorded using a rain gauge installed at the experimental site. During 2022-23, 2023-24 and 2024-25, 21.5, 91.0 and 23.5 mm respectively rainfall were received in during crop season. The experiment was laid out in split plot design with comprising three levels of fertility viz. 100% RDF, 75% RDF, Control main plots and Six treatment of Biofertilizers (M1- Azotobacter, M2-Phosphate solubilizing Microorganism (PSMO), M3-Potassium mobilizing Bio- fertilizer (KMB), M4-Zinc solubilizing Bio-fertilizer (ZSB), M5- NPK consortia + ZSB and M_6-Control (No biofertilizer) in sub plots with replicated thrice. The mustard variety 'RH-725' was sown on 2nd to 3rd week of October in experimental years at a distance of 30 cm x 15 cm by using 4.0 kg ha^{-1} seed rate. The different fertility levels, F1-100% RDF was significant superior over other fertility levels in term of growth attributes (height of plant, number of branches and relative growth rate), yield attributes, yield (2329 kg ha^{-1}), quality and net return (Rs. 111298 ha^{-1}). Among the bio- fertilizers M_5- NPK consortia + ZSB was significantly superior impact over other microbial consortia in respect of growth factors (plant height, number of branches, and relative growth rate), yield attributes, yield (2115 kg ha^{-1}), quality and net return (Rs. 100885 ha^{-1}) as compared other treatments.

Keywords: *Bio-fertilizers, macro nutrient, rapeseed-mustard, yield*

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Management of mustard aphid through crop diversification

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Mustard aphid (*Lipaphis erysimi* Kalt.) is a major biotic constraint limiting productivity of rapeseed–mustard in Assam. A multi-location study was conducted to evaluate the effect of crop diversification through intercropping on aphid population, abundance of natural enemies (*Coccinella* spp.), and productivity of rapeseed–mustard. Field trials were laid out during 2024-25 at four locations *viz*., Shribhumi, North Lakhimpur, Diphu, and Buralikson, comparing three treatments: T• (sole rapeseed–mustard), T, (rapeseed–mustard + fennel), and Tƒ (rapeseed–mustard + coriander). Aphid population and coccinellid density were recorded at flowering and siliqua formation stages, along with yield and economic parameters. Across locations, intercropping significantly reduced aphid population compared to sole cropping. The lowest aphid population was consistently observed in Tƒ , followed by T, , at both crop growth stages. Pooled data indicated a reduction in aphid population from 60.84 and 67.29 aphids/plant in sole mustard to 45.80–57.54 in T, and 49.45–59.31 in Tƒ at flowering and siliqua formation stages, respectively. Intercropping also enhanced the population of *Coccinella* spp., with higher grub and adult densities recorded under T, and Tƒ than in sole cropping, indicating improved conservation of natural enemies. Yield analysis revealed a marked advantage of intercropping systems. The highest mustard equivalent yield (MEY) was recorded under Tƒ (754.17 kg/ha) followed by T, (682.85 kg/ha), compared to sole mustard (473.75 kg/ha) under multi-location trials. Station trials over three consecutive years further confirmed the superiority of intercropping, with pooled MEY of 955.76 kg/ha and the highest benefit–cost ratio (2.55) in Tƒ . The study demonstrates that diversification of rapeseed–mustard with coriander or fennel effectively suppresses aphid infestation, enhances natural enemy activity, and improves yield and economic returns. Intercropping with coriander proved most efficient and can be recommended as a sustainable ecological approach for aphid management and productivity enhancement of rapeseed–mustard in Assam.

Keywords: *Biological control, coccinella spp., crop diversification, intercropping, mustard aphid (Lipaphis erysimi), mustard equivalent yield, rapeseed-mustard*

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Effect of abiotic stress on Alternaria blight disease of rapeseed (*Brassica rapa* var. *toria*)

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The average productivity of rapeseed-mustard which is an important oilseed crop of Assam, is quite low due to different biotic and abiotic stress, and among them *Alternaria* blight is one of the major cause of loss, which is greatly influenced by environmental factors. Regression line showed a strong positive linear relationship between disease severities and, maximum and minimum temperature (T) and, morning relative humidity (RH). The favorable environmental factor for progression of disease was found to be maximum T of 23–24!, minimum T of 10–11!, morning RH of 90–91 %, evening RH of 61-67 % and rainfall of 0–26 mm from 2nd week of January to 1st week of February, during 2016-17 to 2024-25.

Keywords: *Abiotic factor, Alternaria blight, disease severity, rapeseed, regression line*

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Biointensive integrated pest management to manage biotic stresses in Indian mustard (*Brassica juncea* L.)

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Oilseed brassicas [Indian mustard (>80%), *gobhi* sarson, toria and taramira] are one of the important oilseeds crops in India. Among different production constraints, biotic stresses are considered as major constraints and under congenial conditions, these can cause 25-70% yield losses affecting both production as well as farmers' profitability. Major biotic stresses of Indian mustard include *Sclerotinia* stem rot, white rust and aphids. Keeping this in view, biointensive IPM module was developed and evaluated at zonal agricultural research station, Morena of RVSKVV, M.P., during *Rabi* crop season of 2019-20 to 2021-22. The IPM module includes soil incorporation of FYM enriched with *Trichoderma asperellum* @ 2.5 kg/ha + seed treatment with *T. asperellum* @10 g/kg + two foliar spray of freshly prepared aqueous garlic bulb extract (2% w/v) + one foliar spray of Azadirachtin 300 PPM @ 0.5%. Besides other cultural practices such as destruction of previous crop residues to reduce initial inoculum; preparation of leveled and well drained field; rogueing out of *Sclerotinia* rot infected plants based on symptoms of early ripening of infected plants were also followed as a part of IPM module. The data on incidences/ severities of biotic stresses such as white rust and powdery mildew, downy mildew, *Sclerotinia* stem rot and also on seed yield were collected. Three years pooled mean data revealed that biointensive IPM was effective in reducing the diseases *viz*, powdery mildew (from 44.5 to 26.8%), *Sclerotinia* stem rot (from 40.6 to 10.5%) and increasing the seed yield (from 21.9 to 28.1 q/ha). Furthermore, the economic analysis of IPM and farmers' practices revealed that adoption of IPM was superior over farmer's practices in the management of diseases and increasing the seed yield (from 23.0 to 26.2 q/ha) and benefit cost ratio (from 3.99 to 4.45). Besides, the adoption of IPM significantly increased the population of natural enemies and pollinators, and the seed yield (14%). In conclusion, the results of the trials indicated that biointensive IPM module was effective in reducing the pest pressure, pesticide use and increasing the yield and profit from the crop.

Keywords: *Biointensive, lipaphis erysimi, mustard, IPM, sclerotinia, white rust*

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Phytochemical-mediated aphid resistance in different *Brassica* crops at Hisar, Haryana

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Mustard crop comes under the genus *Brassica* that belongs to the family *Brassicaceae*. Rapeseed and mustard are grown in 53 countries across the globe and are cultivated in India during the *Rabi* season in a variety of agro-climatic conditions ranging from the North-Eastern/North-Western highlands to the low lands, under irrigated/rainfed, timely/late sown and mixed cropping and is widely used as edible oil and cattle feed. Production of rapeseed-mustard (*Brassica* sp.) is severely hampered by aphid infestation in India, specifically *Lipaphis erysimi* (Kalt.). Mustard genotypes DRMRIJ 31, GSL 1, PM 30 and GSC 6 were sown on November 15, 2022 at Research Farm, Oilseeds Section, CCS HAU, Hisar in three replications in Randomized Block Design. At the time of initiation of flowering, aphid infestation on one set (T_1) of each genotype *i.e.,* DRMRIJ 31, GSL 1, PM 30 and GSC 6 were made free from aphid attack by application of Dimethoate 30EC @ 1.0 ml/L of water. Second set (T_2) were artificially infested by releasing aphid in the plots and simultaneously allowed to get attacked naturally in field. After 48 hours, plant sample were collected (top 10 cm twig of plant) from both infested and uninfested plots and biochemical constituents analysis were carried out in laboratory. Biochemical constituents were recorded more in plants of different varieties under experimentation that are infested by aphid (T_1) as compared to plants that were uninfested (T_2) or kept protected (T_2) by application of insecticide. In aphid uninfested plants (T_2), mean peroxidase (0.38 µmole/min/mg protein), myrosinase (2.34 µmole/g), total glucosinolates (45.4 µmole/g), total phenols (5.0%), ortho dihydroxy phenols (0.65 mg/g) and flavonols (0.92 mg/g) recorded on lower side contrary to plants infested by aphid (T_1) in different mustard varieties as mean peroxidase (0.53 µmole/min/mg protein), myrosinase (3.15 µmole/g), total glucosinolates (60.3 µmole/g), total phenols (6.7%), ortho dihydroxy phenols (0.95 mg/g) and flavonols (1.53 mg/g) have been registered. Mean yield obtained in aphid uninfested (3.6 aphid/10 cm top twig) in all varieties under surveillance was higher (2544.9 kg/ha) as compared to yield (2034.3 kg/ha) obtained in infested (125.5 aphid/10 cm top twig). Thus, feeding by mustard aphid not only triggered the higher production of different biochemical constituents in plants that also reflected in reduction of yield as compared to aphid uninfested one in the experimental field.

Keywords: *Brassica, yield, aphid, climatic*

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Smart delivery of herbicide for safe and effective control of Egyptian broomrape parasitizing Indian mustard

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Oilseed Brassica, an important edible oilseed crop of the world, is facing severe threat from the parasitic weed 'Egyptian broomrape' [*Phelipanche aegyptiaca* (Pers.) Pomel] with yield penalty of 0-100%. Smart delivery of herbicides to the targeted underground parasite was explored for more effective and environmentally friendly control in Indian mustard. Simple (single) and complex (combinational) smart

herbicide formulations (NE, ME, SE, SC & ZC) were developed and evaluated under hot-spot conditions. The smart formulations were compared for weed control efficiency (WCE), weed index (WI), and seed production of Indian mustard. Initial screening revealed that metsulfuron methyl 20% SC @ 4 ml *a.i.*/ha achieved 100% Egyptian broomrape control compared to oxyfluorfen (5% ME) and pendimethalin (5% ME & NE), however, showed significant phytotoxicity on the host crop. Phytotoxicity decreased by re-designing the formulations and standardizing the rate of application of metsulfuron methyl-based formulations. Among all the smart formulations, metsulfuron methyl 5% SC @ 4 ml *a.i.*/ha applied at pre-emergence stage was found most effective in controlling Egyptian broomrape with no phytotoxicity, and recorded higher seed yield of Indian mustard. Residue analysis using LC-MS/MS revealed that metsulfuron methyl was not detected in soil as well as plant samples thus, it was environmentally safe also. This research successfully demonstrated that metsulfuron methyl-based smart formulations (5% SC) can safely and effectively control Egyptian broomrape in Indian mustard. It may further be explored for the control of parasitic weeds in other economically important crops.

Keywords: *Egyptian broomrape, Indian mustard, metsulfuron methyl, smart formulations, weed indices*

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Traits association among morpho-physiological attributes of Indian mustard *[Brassica juncea* (L.)] advanced breeding lines under rainfed and irrigated conditions

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Indian mustard [*Brassica juncea* (L.)], a major oilseed crop, faced significant yield challenges in India due to climate change and water scarcity, which intensified biotic and abiotic stresses. Considering the challenges, this study was conducted during *Rabi* 2023-24 at Agricultural Research Farm, Institute of Agricultural Sciences, BHU, Varanasi, Uttar Pradesh, to assess the influence of key traits on seed yield in fourteen mustard lines grown under rainfed and irrigated conditions. Nineteen phenological, morphological, and physiological traits were analyzed for correlation and path coefficients to identify those contributing most to seed yield plant^{-1}. Under rainfed conditions, the highest positive correlations with seed yield plant^{-1} were observed for chlorophyll content (0.533P, 0.992G), the number of primary branches (0.600P, 0.983G), main raceme length (0.540P, 0.943G), number of siliquae plant^{-1} (0.669P. 0.902G), plant height (0.615P, 0.883G), number of siliquae on main raceme (0.523P, 0.720G), and test weight (0.554P, 0.920G). In irrigated conditions, traits like number of secondary branches (0.609P, 0.699G), main raceme length (0.422P, 0.936G), chlorophyll content (0.583P, 0.760G), yield ha-1 (0.617P, 0.717G), siliquae plant^{-1} (0.580P, 0.655G), and plant height (0.470P, 0.543G) showed strong correlations with seed yield. Path analysis revealed biological yield and harvest index exhibited the highest positive direct effects on seed yield in both conditions highlighting their importance for direct selection. Therefore, these characters should be considered to improve the seed yield plant^{-1} in rainfed and irrigated conditions.

Keywords: *Correlation, Indian mustard, irrigated, path coefficient, rainfed*

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From plant resistance to climate-resilinent pest management: Leveraging defense mechanisms in Brassica against mustard aphid, *Lipaphis erysimi* (Kaltenbach)

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Aphids constitute one of the most destructive biotic constraints that limit the productivity of rapeseed-mustard in India, a challenge that is expected to intensify under climate change due to altered pest dynamics and increased stress on agro-ecosystems. Heavy dependence on chemical insecticides for aphid management has led to serious concerns regarding environmental pollution, insecticide resistance and residue accumulation in oil and cake. Thus there is an urgent need for climate-resilient and sustainable pest management strategies. In this context, harnessing plant innate immunity through induced defense mechanisms offers a promising alternative. The present study investigated the potential of plant defense elicitors, salicylic acid (SA) and jasmonic acid (JA), to activate host resistance in Indian mustard against the mustard aphid, *Lipaphis erysimi* (Kalt) and to translate these responses into aphid suppression and yield improvement. Field experiments were conducted during two consecutive *Rabi* seasons (2023-24 and 2024-25) using foliar applications of SA and JA at three concentrations (0.5, 1.0 and 1.5 mM) along with methanol solvent, water spray and untreated controls. Data on aphid population were recorded at 3, 7 and 10 days after application under field conditions, whereas the effects of elicitors on aphid biological parameters were assessed under laboratory conditions. During both the seasons, elicitor treatments significantly suppressed aphid populations compared to the untreated control. Salicylic acid was consistently superior to jasmonic acid at all concentrations. The lowest aphid infestation and highest seed yield were recorded with SA @ 1.5 mM (1871.75 kg/ha during 2023-24 and 1717.25 kg/ha during 2024-25) followed by SA @ 1.0 and 0.5 mM. Jasmonic acid treatments resulted in comparatively lower aphid suppression and lower yields. Solvent, water spray and untreated control plots harbored significantly higher aphid populations and recorded the lowest yields. Elicitor application significantly influenced aphid biology. SA treatments significantly reduced the nymphal survival and aphid fecundity, prolonged nymphal development and shortened the adult longevity particularly at the 1.5 mM concentration. JA also induced similar but the effects were comparatively weaker. Biochemical analyses revealed that elicitor-treated plants exhibited enhanced defense responses, characterized by increased levels of glucosinolates, total phenols, and elevated activities of peroxidase, polyphenol oxidase, phenylalanine ammonia lyase and superoxide dismutase. On the other hand, a decline in free amino acids, flavonols and total sugars was observed in SA- and JA-treated plants which indicate reduced nutritional suitability for the aphids. The study demonstrates that elicitor-induced activation of plant defense, particularly through exogenous application of salicylic acid @ 1.5 mM, provides an effective, eco-friendly and climate-resilient strategy for sustainable management of mustard aphid. This approach integrates well with integrated pest management frameworks and national initiatives towards sustainable and climate-resilient oilseed production.

Keywords: *Aphid, insecticides, biotic, rabi, yield*

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Nanoparticle-based mitigation strategies for terminal heat stress in Indian mustard

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Terminal heat stress is a major constraint in Indian mustard (*Brassica juncea*), particularly during the reproductive and grain-filling stages, leading to poor yield and quality. Recent studies suggest that exogenous application of nanoparticles (NPs), such as zinc, silicon, and titanium dioxide, can play a significant role in mitigating heat stress. It has been reported that nanoparticles enhance photosynthetic efficiency, improve membrane stability, and reduce oxidative damage by boosting antioxidant enzyme activities. In addition, NPs regulate osmolyte accumulation, maintain chlorophyll content, and support better pollen viability under high temperatures. The present investigation was conducted to evaluate the impact of nanoparticles on the morphological, physiological, and yield attributes of *Brassica* crops under late sown terminal heat stress conditions. The crop was sown under late sown conditions on 15th November 2023. Nanoparticles (Zn-NP's, S-NP's, Si-NP's & Nanonitrogen) were applied exogenously at vegetative state (30 DAS) and flowering stage (60 DAS), on two genotypes (RH 1706 and RH 1975). The application of Zn-NP, Si-NP's, and Nanonitrogen (2 ml/L) has improved photosynthetic rates by 30.57% with 1 ml/L Zn-NP in RH 1706 and 33.14% with Nanonitrogen in RH 1975. Antioxidant enzyme activities increased with the highest SOD activity observed with (48.83%) 2 ml/L Nanonitrogen in RH 1706 and the highest CAT activity (30.16%) with 1 ml/L Nanonitrogen in RH 1975, which indicates enhanced oxidative stress tolerance and improved physiological efficiency. Yield attributes showed significant improvements with nanoparticle application, enhancing seed yield by 17.57% (1 ml/L Nanonitrogen) in RH 1706 and 16.92% in RH 1975. Among all nanoparticle treatments, Nanonitrogen (1 ml/L) performed best followed by Si-NP's (1ml/L) and Zn-NP (2ml/L) that resulted into enhanced photosynthetic rates and better source to sink strength. These findings suggest that nanoparticles improve crop resilience to terminal heat stress by enhancing physiological and antioxidant enzymes activity, which ultimately contributed to better yield.

Keywords**:** *Brassica juncea, heat stress, nanoparticles, yield*

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Quantitative and qualitative assessment of insect pest complex of mustard and their natural enemies

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The present investigation was conducted at SKN College of Agriculture, Jobner (Rajasthan) during *Rabi* seasons of 2019-20 and 2020-21. The study was undertaken to document the insect pest complex of mustard, their seasonal incidence, population fluctuations, influence of weather parameters and the role of natural enemies in regulating pest populations. During the course of investigation, four insect pests were observed infesting the mustard crop, namely mustard aphid (*Lipaphis erysimi* Kalt.), mustard sawfly (*Athalia lugens proxima* Klug.), painted bug (*Bagrada cruciferarum* Kirk.) and flea beetle (*Phyllotreta cruciferae* Goeze). Among these, mustard aphid was recorded as the major and most destructive pest of mustard throughout the crop growth period. The populations of mustard sawfly, painted bug and flea beetle remained negligible during both years of study and did not cause significant damage to the crop. The population of mustard aphid appeared during the last week of December and gradually increased to attain its peak during the second week of February in both the cropping seasons. The

correlation studies indicated that maximum temperature exerted a significant negative influence on aphid population, whereas minimum temperature and average relative humidity showed non-significant effects during both years. These findings suggest that temperature plays a crucial role in the seasonal abundance of mustard aphid. A total of four natural enemies associated with mustard aphid were recorded during the study, viz., ladybird beetle (*Coccinella septempunctata* Linn.), ladybird beetle (*Coccinella transversalis*), syrphid fly (*Xanthogramma scutellarae* Fab.) and green lacewing (*Chrysoperla carnea*). Among these, *C. septempunctata* and *X. scutellarae* were identified as the predominant and effective predators, actively feeding on mustard aphid. The populations of *C. transversalis* and *C. carnea* were found to be very low and remained negligible during both seasons. The peak activity of major predators coincided with the peak infestation of mustard aphid and exhibited a significant positive correlation with aphid population, indicating their dependence on prey density. The population of *C. septempunctata* showed non-significant correlation with weather parameters, whereas *X. scutellarae* exhibited a significant negative correlation with minimum temperature and non-significant correlation with maximum temperature and average relative humidity. Overall, the study highlights the dominance of mustard aphid as a key pest and underscores the importance of natural enemies in its biological regulation, providing valuable insights for the development of eco-friendly and integrated pest management strategies in mustard cultivation.

Keywords**:** *Brassica juncea, lipaphis erysimi, natural enemies, population dynamics, weather parameters*

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Physiological regulation by mepiquat chloride improves productivity of taramira under water-limited conditions

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Water availability for irrigation as a key input in agricultural production is threatened by climate change and water scarcity as a major limitation to crop production in arid and semi-arid areas. Taramira (*Eruca sativa*) an oilseed crop appears to be promising under these conditions due to its high tolerance. However, little attempt has been made to assess its flexibility and efficiency across the various agro-climatic regions. For taramira responses to moisture, an investigation was conducted during the Rabi season 2022–23 at the Agronomy Research Farm, S.K.N. College of Agriculture, Jobner, to study the morpho-physiological responses of mepiquat chloride on taramira (*Eruca sativa* Mill.) under rainfed conditions. Two varieties (RTM-314 and RTM-1624) were sprayed with mepiquat chloride at 100, 150 and 200 ppm at 40 and 65 DAS. Mepiquat chloride significantly influenced morpho-physiological, biochemical and yield attributes. Higher RWC, membrane stability index, leaf area, chlorophyll, carotenoids, nitrogen and oil content, along with improved yield components and seed yield, were recorded with increasing concentration of mepiquat chloride. The 200 ppm treatment proved superior, enhancing yield and related traits while reducing plant height and days to 50% flowering. Overall, foliar application of mepiquat chloride at 200 ppm at 40–45 and 60–65 DAS improved productivity and oil content of taramira under rainfed conditions by mitigating the adverse effects of moisture stre

Keywords**:** *Mepiquat chloride, moisture stress, morpho-physiological and productivity*

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Population dynamics and varietal preference of major insect pests of mustard [(*Brassica juncea*) (L.) Czern and Coss]

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The investigation was conducted during *rabi*, 2019-20 and *Rabi*, 2020-21. The aphid, *Lipaphis erysimi* Kalt., mustard sawfly, *Athalia lugens proxima* Klug., painted bug, *Bagrada cruciferarum* Kirk. and flea beetle, *Phyllotreta cruciferae* Goeze were found to infest the mustard crop. Among these, mustard aphid, *L. erysimi* was found as a major insect pest of mustard. The population of sawfly, painted bug and flea beetle were found negligible in both the years. In *Rabi* 2019-20 and 2020-21, the aphid, *L. erysimi* population appeared in the last week of December. The peak population of aphid was recorded in the second week of February in both the years. The maximum temperature had significant negative effect on aphid population, whereas, minimum temperature and average relative humidity had non-significant effect in both the years. Total four predators of aphid namely, ladybird beetle, *Coccinella septempunctata* Linn., ladybird beetle, *Coccinella transversalis*, syrphid fly, *Xanthogramma scutellarae* Fab and Green lacewing, *Chrysoperla carnea* were found associated with mustard crop pests, among these ladybird beetle, *C. septempunctata* and syrphid fly, *X. scutellarae* were recorded as important predators, preying on mustard aphid, *L. erysimi*. The population of Ladybird beetle, *C. transversalis* and green lacewing, *C. carnea* were negligible in both the years. The peak activity of ladybird beetle, *C. septempunctata* and syrphid fly, *X. scutellarae* associated with the peak infestation of aphid and these predators showed significant positive correlation with the population of aphid. Ladybird beetle, *C. septempunctata* had non-significant correlation with weather parameters, whereas, syrphid fly, *X. scutellarae* had significant negative correlation with minimum temperature and non-significant correlation with maximum temperature and average relative humidity in both the years. Out of fifteen mustard varieties were screened for their susceptibility against aphid, *L. erysimi*, the two varieties Varuna and Bio-902 were found less susceptible. Nine varieties *viz*., NRCDR-2, Laxmi, Pusa Bold, NRCHB-101, Rohini, Vardan, RH-9304, Durgamani and GM-1 were categorized as moderately susceptible, whereas, four varieties *viz*. Maya, RH-30, GM-2 and Kranti categorized as highly susceptible in both the years. Biophysical parameters of mustard varieties *viz*., plant height, trichome density, number of primary branches, siliquae per plant, seeds per sliqua, seed yield, and test weight showed the significant negative correlation, whereas, initiation of flowering had significant positive correlation and days to maturity non-significant correlation with aphid population during both the years. Biochemical parameters of mustard varieties *viz*., total phenols, ortho-dihydroxy phenols, glucosinolates and oil content showed the significant negative correlation, whereas, flavonols, total sugars and free amino acids significant positive correlation with aphid population during both the years of investigation.

Keywords: *, Phyllotreta cruciferae, coccinella septempunctata, lipaphis erysimi*

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Aphid resistance in Indian mustard: Bridging molecular insights and field validation-A review

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Mustard aphid (*Lipaphis erysimi* Kaltenbach) is a major biotic constraint affecting the productivity of Indian mustard (*Brassica juncea* L.) under tropical and subtropical agro-climatic conditions. Developing

a multi-pronged strategy to identify resistance sources and elucidate underlying mechanisms is imperative, as the pest's explosive reproductive rate renders control measures ineffective once infestation is established. The studies under consideration span a broad spectrum of research, extending from large-scale field evaluations to precise molecular mapping. Plant responses to aphid attack are multifaceted, encompassing biochemical, morphological, and molecular defense mechanisms. Some of the plants innate defence components like Glucosinolates (GLSs) and related morphological traits such as leaf trichomes are recognized as key components for defense against insect herbivores. Collectively, the studies screened a vast diversity of germplasm, including 95 accessions in North-Eastern India, 18 commercial cultivars in New Delhi, 10 varieties in Rajasthan, and large mapping populations (505 GWAS accessions). Methodologies employed robust experimental designs, utilizing Augmented RBD and Randomized Block Designs with 3 to 15 replications, conducted across diverse environments ranging from the acidic soils of Meghalaya to controlled laboratory conditions, under both natural infestation (spanning 1–3 seasons) and artificial release pressures. Phenotypic evaluations identified specific genotypes, including RLC 3, RH 725, NRCHB 101, and CS-2009-332, as stable sources of tolerance, exhibiting lower aphid proliferation and higher yields under stress. Investigating resistance mechanisms revealed a duality of physical and biochemical barriers. Previous studies in *Brassica* spp. have identified several GLS biosynthetic, regulatory, and transport genes, including *GL1*, *GTR2*, *MYB*, and cytochrome P450 family members, and have developed gene-linked and allele-specific molecular markers, many of which are specific to *B. juncea*. Physically, a novel study confirmed that leaf trichomes, regulated by the BjA06.GL1 and BjB02.GL1 genes, significantly reduce aphid density. Biochemically, the role of glucosinolates (GLS) appears complex; while total GLS content showed a negative correlation with aphid infestation in one study (suggesting a deterrent effect), other genomic studies focused on GLS primarily for seed quality or fungal (*Sclerotinia*) resistance. The "mustard oil bomb" defense hypothesis remains relevant, though transcriptional analyses in wild resistant species (*Rorippa indica*) highlight the importance of redox signaling and photosynthetic maintenance over secondary metabolites alone. Despite these strides, a significant research gap persists regarding the scarcity of strong resistance in the primary gene pool and the lack of commercial varieties combining high yield with aphid resistance. Also, robust screening technique needs to be strongly re-validated. Future directions advocate for a holistic breeding strategy: pyramiding physical traits (trichomes) with optimized biochemical profiles (GLS/surface wax) using the identified molecular markers to introgress durable resistance from wild and diverse germplasm into high-yielding backgrounds.

Keywords**:** *Aphid, Brassica juncea, glucosinolate, GTR2, GWAS, MYB, molecular markers,*

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Biostimulant-driven physiological optimization of Indian mustard under late sown conditions

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Global climate change has profound effect on agriculture system and global food security. Delayed sowing of Indian mustard exposes the crop susceptible to elevated temperature stress and high moisture loss during critical growth and developmental stages, disrupting plant water status to reduced photosynthetic efficiency; resulting in forced maturity and reduced productivity. Biostimulants induces physiological and biochemical changes, enhancing growth, development and stress tolerance. The experiment examined effects of amino acids and triacontanol biostimulants on morpho-physiological traits of late sown Indian mustard variety RH 1424 during *rabi* season of 2023-24. Biostimulants treatment significantly enhanced relative water content by 12.2% with treatment amino acid 2ml/L, performed better followed by same biostimulant with higher concentration of 4ml/L. Enhanced plant water status correlated positively with the transpiration rate and a negative correlation with canopy temperature, demonstrating improved plant

physiological functions and thermal regulation under high temperature stress. Enhanced transpiration contributed to canopy cooling, thereby sustaining photosynthetic efficiency and metabolic activity under high temperature stress. The results of this study revealed that the foliar application of amino acid biostimulants, especially at lower concentrations, performed better over control plants morpho-physiological, and yield components under late sown conditions.

Keywords: *Biostimulants, canopy temperature, gaseous exchange, thermal regulation*

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Analysis of physiological, biochemical, and genetic responses of Indian mustard (*Brassica juncea* (L.) Czern. & Coss.) genotypes under moisture deficit stress

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Indian mustard (*Brassica* spp.) is a major global oilseed crop, widely cultivated for its valuable oil and nutritional quality. With changing climatic conditions, identifying drought-tolerant genotypes with strong physiological and biochemical resilience is essential for stable production under moisture deficit. This study evaluated 11 Indian mustard genotypes under rainfed (moisture deficit stress) and irrigated conditions during the 2024–25 season using a Randomized Block Design with three replications. A comprehensive set of yield traits, physiological parameters, and biochemical responses were recorded to capture genotypic variation under stress. Combined analysis of variance showed highly significant ($P < 0.01$) effects of genotype, environment, and their interactions for most traits, indicating considerable differences in drought response among genotypes. The objectives were to estimate susceptibility and tolerance indices for moisture stress; evaluate associations among physiological, morphological, yield and yield-attributed traits; estimate trait contributions using principal component analysis; and identify genetic variability in drought-related traits. Several genotypes displayed effective physiological adjustments and enhanced biochemical defence under moisture deficit, contributing to better yield maintenance and adaptation. These drought-adaptive genotypes are promising candidates for breeding programs to improve drought tolerance in Indian mustard, potentially enhancing productivity in water-limited rainfed environments

Keywords: *Brassica juncea, biochemical responses, drought tolerance, genotypic variation, moisture deficit stress, physiological traits*

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Drought-resilient mustard production: The interplay of conservation agriculture, sap, and plant bioregulators

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Rainfed agriculture faces an existential threat from the dual pressures of deteriorating soil health and erratic water availability, both of which are being exacerbated by the rising intensity of climate-induced droughts. In these ecosystems, crop productivity, particularly for Indian mustard, maize, and pearl millet is frequently compromised by acute moisture stress during critical reproductive stages. This study evaluates a multi-pronged mitigation strategy integrating Conservation Agriculture (CA), Superabsorbent Polymers (SAP), and Plant Bioregulators (PBRs) to stabilize yields and enhance resource-use efficiency under moisture-deficit conditions. The experimental framework utilized CA (flat/ permanent bed planting with crop residue), basal application of SAP (2.5 kg/ha), and foliar sprays of PBRs, specifically Salicylic Acid (SA, 100 ppm), Thiourea (TU, 0.1%),

and Potassium Nitrate (PN, 1.5%). Results indicate that the CA-based maize-mustard system emerged as the most resilient and profitable production system. During the *kharif* season, CA-based maize achieved a superior mustard equivalent yield of 1.79 t/ha, outperforming CA-based pearl millet by 11.6% and conventional tillage (CT)-based pearl millet by a substantial 19.6%. This productivity surge translated into significant economic gains, with net returns (83,039 Rs./ha) exceeding CT-based systems by 30.3%. Among the SAP and PBR combinations, the integrated application of SAP + SA yielded the highest agronomic and economic returns, followed closely by SAP + TU. While post-flowering moisture stress typically reduced mustard seed yields by an average of 3-27.2%, the synergy of CA and SAP+PBRs acted as a robust buffer. Remarkably, mustard grown under CA and SAP+PBRs practices even when subjected to moisture stress, produced yields 8-15% higher than conventionally tilled mustard under normal irrigation without such inputs. Furthermore, the system-wide analysis revealed that the moisture-stressed CA-based maize-mustard system, augmented with SAP+SA, surpassed the performance of the traditional irrigated CT-based fallow-mustard system. System productivity, net returns, and economic efficiency were increased by factors of 1.89, 2.31, and 2.39, respectively, while system production efficiency saw a remarkable 3.31-fold improvement. Thus, this research demonstrates that the transition from conventional fallow-mustard cycles to CA-based maize-mustard systems, fortified with superabsorbent polymers and salicylic acid, offers a transformative pathway for rainfed ecosystems. This integrated approach not only mitigates the risks of drought and enhances edible oil security but also ensures the long-term sustainability of natural resources and farmer livelihoods in a changing climate.

Keywords: *Conservation agriculture, moisture stress mitigation, mustard-based cropping systems, plant bio-regulators, superabsorbent polymer*

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Assessment of new molecule fungicides for the management of *Alternaria* spp. isolate under *in-vitro* conditions

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Alternaria leaf blight is one of the most destructive fungal diseases of mustard (*Brassica* spp.), causing severe yield, and quality losses in major mustard-growing regions. The present investigation was carried out to evaluate the efficacy of new molecule fungicides against *Alternaria* isolate (ALKPCB-4) under *in-vitro* conditions. Nine fungicides were tested at three concentrations (250, 500 and 1000 mgL^{-1}) for their effect on mycelial growth using the poisoned food technique, and on conidial germination using cavity slide and plain slide methods. Results revealed that all the evaluated fungicides significantly inhibited mycelial growth and conidial germination of *Alternaria* isolate at all tested concentrations, with inhibition increasing as fungicide concentration increased. In the poisoned food technique, Azoxystrobin 4.7% + Mancozeb 59% + Tebuconazole 5.6% WG, Tebuconazole 50% + Trifloxystrobin 25% WG, and Metiram 55% + Pyraclostrobin 5% WG recorded 100% inhibition of mycelial growth at all concentrations. Other fungicides showed varying degrees of inhibition, ranging from moderate to high, with the lowest inhibition observed with Metiram 70% WG at 1000 mgL^{-1}. In conidial germination studies, all fungicides caused complete inhibition at 500 and 1000 mgL^{-1}in both cavity slide and plain slide techniques. At 250 mgL^{-1}, most fungicides significantly inhibited conidial germination, though limited germination was observed in Metiram 70% WG, Kasugamycin 5% + Copper oxychloride 45% WP, Fluxapyroxad + Pyraclostrobin SC, and Metiram 55% + Pyraclostrobin 5% WG, while untreated control recorded the highest germination. Overall, the study demonstrated that combination fungicides containing triazoles and strobilurins were highly effective against *Alternaria* isolate corroborating earlier reports. These fungicides can be considered promising candidates for effective management of *Alternaria* diseases under laboratory conditions.

Keywords: *Alternaria leaf blight, mustard, new molecule fungicides, mycelial growth inhibition*

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Identification of heat tolerant genotypes of Indian mustard (*Brassica juncea*) for abiotic stress resilience

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In Eastern Vidarbha region of Maharashtra, usually delayed planting of Indian mustard is favored which resulted into reduced yield due to heat stress during flower initiation stage and seed development. The present study was undertaken to identify mustard genotypes with stable performance under late-sown conditions by evaluating genotype × environment interactions across multiple sowing dates in the Eastern Vidarbha region of Maharashtra. The experiment was carried out at the Research Farm of the All India Coordinated Research Project (AICRP) on Linseed and Mustard, College of Agriculture, Nagpur, Maharashtra. A study evaluated 164 Indian mustard germplasm lines to identify stress-tolerant genotypes. The lines, along with checks, were grown in RBD design during Rabi 2019-20 under normal (Oct 30 sowing) and stressed (Nov 30 sowing) conditions. Principal component and biplot analyses identified 8 genotypes as high-yielding and stress-tolerant. These eight genotypes, along with checks PM-26 and TAM 108-1, were evaluated over four years (Rabi 2020-21 to 2023-24) under four sowing dates (Oct 30, Nov 15, Nov 30, Dec 15), creating 16 environments. A randomized complete block design with three replications was used. Observations were recorded on seed yield and its contributing traits and physiological characters. Stability analysis using Eberhart and Russell (1966) model, AMMI and GGE Biplot models over four years (Rabi 2020-21 to 2023-24) revealed ACN-226 and ACN-237 as high-yielding and stable performers. The genotypes ACN 226 and ACN 237 showed less seed yield reduction under stress (Nov 30 sowing) across four years *vs* checks. Based on heat susceptibility index (S) and yield stability ratio (YS), these genotypes are moderately stress-tolerant with higher yield stability *vs* checks. In 2023-24, ACN 226 and ACN 237 outperformed checks (TAM 108-1 and PM 26) in seed yield and morpho-physiological traits like root-shoot length, proline content, relative water content, chlorophyll content, and lower canopy temperature under terminal heat stress. The mustard genotypes ACN-237 and ACN-226 proved to be stable, high-yielding genotypes across diverse environments (sowing dates). Their consistent performance makes them ideal for late-sown conditions of Eastern Vidarbha Region of Maharashtra and valuable for breeding of abiotic stress resilience mustard varieties.

Keywords: *Heat toleramce, Indian mustard, stress resilience*

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Genetic analysis of inheritance pattern of Alternaria blight resistance in Indian mustard (*Brassica juncea* L.)

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Resistance to Alternaria blight in Indian mustard (*Brassica juncea* L.) is governed by complex genetic mechanisms that necessitate detailed genetic analysis for effective utilization in resistance breeding. An investigation was conducted during the *Rabi* seasons of 2021–2022 and 2022–2023 at the Norman E. Borlaug Crop Research Centre (NEBCRC), GBPUAT, Pantnagar, to elucidate the inheritance pattern of Alternaria blight resistance under natural epiphytotic conditions. Six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2) derived from four crosses were evaluated using a Compact Family Block Design. Analysis of

variance revealed significant differences among generations and families for Alternaria blight severity and yield-related traits, indicating the presence of substantial genetic variability. Scaling test analysis showed significant deviations from the additive-dominance model in most families. For disease severity, significant scale effects were detected in three out of four families, while all families exhibited significant scale estimates in at least one scale, with values ranging from 0.13 to 2.12. These results confirmed the involvement of non-allelic interactions in governing resistance. Gene effect estimation through scaling and joint scaling tests revealed that both additive and non-additive gene actions contributed to resistance expression, with non-additive components, particularly dominance and dominance × dominance interactions, playing a predominant role. Overall, the study demonstrates that resistance to Alternaria blight in *B. juncea* is polygenically controlled with a strong influence of epistatic interactions, highlighting the need for breeding strategies.

Keywords: *Alternaria blight, disease resistance, Indian mustard, genetic inheritance*

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Emerging crop protection tools for insect pest management in mustard

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Mustard (*Brassica* spp.) is a key oilseed crop, yet its productivity is severely constrained by insect pests such as mustard aphid (*Lipaphis erysimi*), painted bug (*Bagrada hilaris*), flea beetles and mustard sawfly (*Athalia lugens proxima*). Conventional reliance on synthetic insecticides has led to insecticide resistance, pest resurgence, residue accumulation and ecological disruption and adverse effects on pollinators and natural enemies. Recent advances highlight eco-friendly and sustainable alternatives, including biopesticides (botanicals, entomopathogenic fungi, bacteria and viruses), semio-chemical based tools for monitoring and trapping and molecular innovations such as marker-assisted breeding and RNA interference (RNAi). Precision agriculture technologies- drones, smart sprayers and digital decision support systems, further enhance surveillance and site-specific interventions. Conservation biological control through habitat management and reduced chemical uses supports natural enemies, ensuring long-term pest suppression. Integrating these approaches within an Integrated Pest Management (IPM) framework reduces dependence on chemicals, improves control efficiency and safeguards environmental and human health.

Keywords: Biopesticides, crop protection tools, insect pest, integrated pest management, mustard, semiochemicals, RNA interference, precision agriculture

Keywords: *Brassica juncea, drought tolerance, genotypic variation, moisture deficit stress, physiological traits*

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Fertilizer and micronutrient strategies for managing aphid stress in mustard under climate variability

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Climate change is intensifying both biotic and abiotic stresses in agricultural systems, leading to increased pest pressure, altered crop pest interactions and reduced productivity. In oilseed crops such as mustard (*Brassica juncea* L.), rising temperatures, variable humidity, and imbalanced nutrient use have been

linked to outbreaks of aphid pests, particularly mustard aphid (*Lipaphis erysimi* Kalt.) and green peach aphid (*Myzus persicae* Sulzer). Excessive fertilizer application, especially nitrogen, is known to enhance plant succulence and nutritional quality for herbivores, thereby aggravating pest infestation under changing climatic conditions. Conversely, balanced nutrient management, including micronutrient supplementation and organic amendments, has emerged as a potential climate-resilient strategy to enhance plant tolerance and suppress pest populations. The present study aimed to evaluate the combined influence of fertilizer doses and micronutrient combinations on aphid infestation dynamics in mustard, while assessing their interaction with prevailing abiotic factors, to develop sustainable nutrient-based strategies for mitigating biotic stress under climate change scenarios. During the *Rabi* season of 2024–25, a split plot factorial design was employed with four levels of recommended dose of fertilizers (RDF: 0%, 100%, 125%, and 150%) as main plot treatments and four micronutrient combinations as sub-plot treatments. The micronutrient treatments comprised sulphur (S), zinc (Zn), boron (B) and farmyard manure (FYM) applied individually and in combinations, with the most comprehensive treatment including 40 kg S + 5 kg Zn + 1 kg B + 500 kg FYM. Aphid populations were recorded weekly from the 1st to 12th standard meteorological week (SMW), and population density was expressed as number of aphids per 10 cm plant stalk. Economic threshold levels (ETL) were used to identify critical infestation periods. Yield losses in siliqua and seed were estimated to assess economic impact. The results revealed that fertilizer management significantly influenced aphid population dynamics. Lower fertilizer levels (0% and 100% RDF) recorded reduced populations of both mustard aphid (35.02–36.35 aphids/10 cm stalk) and green peach aphid (0.56–0.59 aphids/10 cm stalk), whereas higher fertilizer doses (125% and 150% RDF) promoted aphid build-up. Among micronutrient treatments, the integrated application of 40 kg S + 5 kg Zn + 1 kg B + 500 kg FYM proved most effective in suppressing aphid populations, indicating the role of balanced nutrition and organic amendments in enhancing plant resistance. Green peach aphid populations remained below ETL across all treatments, while mustard aphid frequently crossed ETL under higher RDF levels. Abiotic factors showed significant correlations with aphid dynamics; mustard aphid populations were positively influenced by maximum temperature, evening relative humidity, wind speed and sunshine hours, whereas green peach aphid was mainly affected by minimum temperature and humidity. Yield loss analysis showed that excessive fertilization combined with poor micronutrient management resulted in severe losses, with siliqua and seed yield reductions reaching up to 16.50% and 14.00% respectively. In contrast, integrated nutrient management minimized losses to below 7%. Overall, the study demonstrates that judicious fertilizer use, combined with micronutrient and organic supplementation, serves as an effective strategy to mitigate biotic stress under climate variability, supporting sustainable and climate-resilient mustard production.

Keywords: *Abiotic stresses, micronutrient, population dynamics*

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Micro and secondry nutrient fortified farm yard manure to bio-stimulate Indian mustard yield and nutrient availability

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Field experiments were conducted during 2016-2021 to assess the impact of graded levels of FYM enriched with micro and secondary nutrients in calcareous soil under rain-fed ecology. The secondary and micro nutrients fortified FYM developed and evaluated its impact to address the issue of decreasing soil health, nutrient availability and yield levels in Indian mustard. FYM @ 10 t/ha and FYM (500 kg/ha) fortified with 20 kg S + 5 kg Zn + 2 kg B + 10 kg Fe significantly improved seed yield and growth parameters of mustard. However, highest benefit cost ratio (4.22) with seed yield of 28.72 q/ha was obtained under the application half dose of the recommended levels of secondary and micronutrient *i.e.* 2.5 kg Zn + 1 kg B + 5 kg Fe + 10 g S enriched FYM 500 kg/ha. It indicated that application of balance

amount of micro and secondary nutrients through 500 kg FYM improved mustard yield and economic return to the farmers. Nutrient enrichment with micro and secondary nutrient at the rate of 5.0 kg Zn + 2 kg B+ 10 kg Fe +20kg S enriched FYM @ 500 kg/hasignificantly increased the microbial biomass carbon (56.46% SMB-C), SOC (17.13%), and microbial biomass nitrogen (71.14% MBN) over the control. Similarly, nutrient fortification significantly improved the activity of dehydrogenase activity (56.27%), alkaline phosphatase (101.44%) and aryl sulphatase (73.7%) in soil over control. Availability of S, Zn Fe and boron also increased by 17.74, 127.68, 43.41 and 52.76 percent over control. It also aids in maintaining minerals in their naturally chelated state, which improves nutrition over extended periods of time and increases yields. The results showed that the maximum B:C ratio (4.22) was achieved with seed yield of 28.72 q/ha when fortified FYM including Zn, Fe, B, and S at the rate of 2.5 kg Zn + 1 kg B+ 5 Kg Fe + 10 kg S En- FYM @ 500 kg/ha. Additionally, the single practice of FYM fortification with secondary and micronutrients boosted stover and seed yield by 16.44% and 15.57 percent, respectively, compared to straight application. In the dry and semi-arid northwest of India, in the states of Rajasthan, Gujarat, Haryana, and portions of Uttar Pradesh and Madhya Pradesh, this research may yield a useful technique for raising mustard production.

Keywords: *Bio-stimulate, biomass, yield*

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Comparative analysis of heat-stress responses across Brassica species

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Heat is a major environmental stressor that restricts the growth, productivity, and geographical spread of oilseed brassica species in the world. Rising temperatures linked with climate change have increased the frequency and severity of heat stress incidents, posing major challenges for sustainable Brassica cultivation. Understanding the physiological and molecular mechanisms underlying heat stress tolerance is now considered important for developing climate-resilient Brassica cultivars. This study provides insight into heat stress adaptation mechanisms in *Brassica species*. A total of twenty genotypes of tolerant and susceptible groups from three rapeseed-mustard species were evaluated for flowering, maturity, and various yield components, such as plant height (PH), pods on the main shoot (PMS), main shoot length (MSL), pod length (PL), seeds per pod (SPP), and seed weight (SW) over two years. One heat-tolerant and one heat-susceptible genotype from *Brassica rapa, B. napus* and *B. juncea* were selected based on heat susceptibility indices for transcriptomic analysis. Three biological replicates were sampled, and paired-end RNA sequencing was employed for both control and stressed plants of tolerant and susceptible lines. Heat stress was applied during the flowering stage in a heat tent built using a clear polyethylene sheet to create a greenhouse effect. Temperature variations were monitored for both control and stressed conditions using the iButton miniature data loggers. A temperature difference of approximately 4.8–6.8°C during the day and about 2.4–4.8°C during the night between the control and stressed conditions was observed. *B. rapa* OP genotype, TL-17, exhibited the maximum tolerance, while PT-303 was very susceptible to heat stress. In *B. juncea* lines, JT-36 and Rohini revealed better heat tolerance. In *B. napus*, Mystic and Tilo were highly susceptible, while two, Garnet and GSC-6, had maximum tolerance to heat stress. Quality filtered reads from both control and stressed plants of tolerant and susceptible lines were mapped with the specific reference genome. The consequences of alignment depicted that 62.14–88.51%, 64.25–90.15%, and 48.3–93.02% of the total reads were mapped to the reference genomes of *B. rapa, B. napus*, and *B. juncea*, respectively. This study identifies candidate genes for developing heat-resilient Brassica cultivars under altering climatic conditions.

Keywords: *Brassica species, heat stress, transcriptomics, control and stressed*

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Characterization of intergeneric derivatives developed from the hybridization between *Brassica napus* and *Diplotaxis erucoides*

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Alternaria blight (Alternaria leaf spot), incited by fungi *Alternaria brassicae, A. brassicicola* and *A. raphani* individually or by mixed infection, is a devastating disease of Brassica oilseeds. The fungi produce chlorotic lesions on leaves, stems, and siliquae, thus, decrease photosynthetic area and cause early defoliation and senescence. Huge losses to seed yield varying from 47 to 70% and oil content occur under severe infection conditions. Limited genetic variation for disease resistance exists in the primary gene pool of crop Brassica. However, *Diplotaxis erucoides*, a wild crucifer, possesses high resistance to Alternaria blight. The present study characterized the A_2 derivatives developed from the cross between *B. napus* and *D. erucoides. Brassica napus* was crossed with *D. erucoides* to produce intergeneric hybrids. Morphological, pollen grain stainability and cytological studies were performed to confirm the true hybridity of test genotypes. Chromosome doubling was induced in the hybrid plants by placing cotton swabs soaked with 0.2% colchicine in 1% DMSO on apical or axillary meristems of plants for continuous five hours for four days. The resulting amphiploid plants were selfed to generate A_2 generation plants. The wide hybrids were morphologically inclined to *B. napus* parent. However, they produced white coloured flowers from *D. erucoides*. All hybrid plants were completely male sterile. Colchicine treatment helped to restore fertility of plants and produce A_2 generation seeds. Donor specific molecular markers for *D. erucoides* were used to genotype A_2 generation plants to estimate the proportion of alien chromatin from the wild crucifer. Screening of plants for resistance against Alternaria blight under artificial conditions identified three disease free plants. These selected genotypes are currently being advanced for further generation of introgression lines harbouring Alternaria blight resistance. The introgression lines will be used as donors to transfer Alternaria blight resistance into elite genotypes of rapeseed.

Keywords: *Alternaria blight, Brassica species, disease resistance, D. erucoides*

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Understanding yellow mosaic virus resistance in soybean

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The Mungbean Yellow Mosaic Virus has been impacting various Asian regions for nearly a century. This virus has led to significant yield reductions, with losses varying from 10% to 100% depending on the plant's genotype and the timing of the infection. Soybean is one of the most adaptable crops in Asia, contributing to balanced nutrition and sustainable agricultural practices. Consequently, it is essential to investigate potential sources of resistance in this crop. Whole genome resequencing of resistant and susceptible cultivars lead to the identification of potential candidate genes on chromosomes previously mapped for MYMIV viz, chr 2,6,8 and 14. After infecting the plants with MYMIV, potential candidate genes containing the SNPs were tested for differential gene expression using qRT-PCR. Quantitative assessment indicated differential regulation of these genes. The identified SNPs are utilized to develop molecular markers that can assist in crop breeding programmes and is currently under progress. This research addresses a significant gap in understanding the key genes that distinguish the source of resistance. Previous studies have not been able to identify specific R genes associated with MYMIV resistance in soybean. The genome-wide association study (GWAS) attempted to link the most prominent single nucleotide polymorphism (SNP) and its associated R gene, which was consistent across all studied varieties; however, further experimental validation is necessary to substantiate these findings. The present study aims to investigate the locus identified in all mapping studies related to MYMIV resistance to reach a definitive conclusion.

Keywords: *MYMIV resistance, GWAS, polymorphism*

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Application of RenSeq approach for accelerated discovery of disease resistance gene for prevalent diseases of soybean in India

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Soybean is a major oilseed crop in India contributes around 37% to the total oilseed and 20% to the total edible oil production in India. Though it is grown over 12.07 Mha. area with total production of 13.98 Mt., the national productivity of soybean has been stagnant since recent past and is lower than other soybean growing countries like China, Brazil and USA. One of the major reasons for this low productivity is moderate to severe incidence of various diseases namely Yellow Mosaic Virus (YMV), Anthracnose, Charcoal rot, Rhizoctonia Aerial Blight (RAB) etc. causing on an average yield loss of 25-30%. In case of severe incidence of anthracnose, YMV and RAB more than 60% yield losses have been reported. In order to prevent the yield losses from these destructive pathogens, it is the need of the hour to identify new sources of disease resistance genes (R) and deploy desirable R genes into elite soybean cultivars.

Though classical breeding methods have contributed significantly to the resistant cultivar development, these methods and identification, mapping and cloning of a new R genes through traditional methods are time consuming. The novel technique called Ren-Seq (Resistance Gene Enriched Sequencing), can specifically capture, enrich and sequence resistance genes, primarily NBS-LRR genes, to accelerate disease resistance gene discovery. This generally involves the preparation of long enriched libraries then target enrichment, size selection, assembly of Hi-Fi reads and finally candidate gene identification. It has already been successfully used in many crops for several diseases for instance, in wheat for stem rust, in potato for late blight, in canola for club root. Recently, researchers from different universities of USA have collaborated and initiated a project called "SoyRenSeq" with the aim to accelerated identification of candidate R genes conferring resistances to various soybean pathogens prevalent in the Mid-west region of USA and for accelerated development of disease-resistant soybean cultivars by precise R gene selection. Considering the humungous yield losses caused by different soybean disease in India, it is needed to apply RenSeq technique to accelerate discovery of disease resistance gene for various major diseases prevalent in India. This will lead to explore and optimize the rapid discovery of novel resistance genes against emergent soybean pathogens, enabling the introgression of these disease resistance genes into soybean cultivars quickly, precisely and accurately, ensuring sustainable production and profitability to the soybean growers in India.

Keywords: *Disease resistance gene, YMV, Rhizoctonia aerial blight, Ren-Seq technique*

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Regeneration plasticity in Indian soybean cultivars

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Soybean (*Glycine max* (L.) Merr.) is a major oilseed crop of global and national importance; however, its genetic improvement through biotechnological approaches is often limited by low and genotype-dependent in vitro regeneration efficiency. The present study aimed to evaluate regeneration plasticity among Indian soybean cultivars and to optimize a reliable multiple shoot induction protocol suitable for downstream genetic transformation studies. Cotyledonary node explants excised from five-day-old in vitro-germinated seedlings of four soybean cultivars (NRC-136, JS-335, CAT-2911, and NRC-128) were cultured on Murashige and Skoog (MS) medium supplemented with different combinations of plant growth regulators and polyamines. Direct organogenesis was induced using MS medium containing 6-benzylaminopurine (BAP) either alone or in combination with thidiazuron (TDZ) and spermidine. The synergistic application of BAP, TDZ, and spermidine significantly enhanced shoot induction frequency, shoot number per explant, and reduced the regeneration period compared to BAP alone. Regeneration efficiency ranged from 55.8% to 78.9%, with an average of 3.9 to 6.4 shoots per explant under optimized conditions. Significant genotypic variation was observed, with CAT-2911 and JS-335 exhibiting superior regenerative responses. The optimized protocol demonstrates a reproducible and efficient regeneration system based on direct organogenesis and provides a strong foundation for genetic transformation and genome editing applications in Indian soybean cultivars.

Keywords: *Cotyledonary, lasticity, regeneration*

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Harnessing multivariate trait architecture to identify charcoal rot resilient soybean genotypes under climate change

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Rising temperatures and moisture stress have intensified charcoal rot caused by *Macrophomina phaseolina* in soybean, causing severe yield instability. Identifying resistant genotypes and key yield-associated traits is therefore crucial for developing climate-resilient cultivars. This study aimed to characterize soybean genotypes for charcoal rot resistance using disease severity and yield-related traits through multivariate analysis. A diverse set of soybean genotypes was evaluated under natural charcoal rot stress conditions at research farm of JNKVV Jabalpur. It is a designated hot spot location for charcoal rot under AICRP on soybean. Observations were recorded for plant height (PH), number of branches per plant (NBP), number of pods per plant (NPP), number of seeds per pod (NSP), pod weight per plant (PWP), seed yield per plot (SYP), and root and stem severity index (RSI). Analysis of variance revealed highly significant differences (P d" 0.01) among genotypes for all traits, indicating substantial genetic variability. Coefficients of variation were low to moderate, confirming experimental precision. Hierarchical cluster analysis and principal component analysis (PCA) were employed to assess genetic diversity and trait interrelationships. Cluster analysis revealed substantial genetic variability among genotypes for charcoal rot response and yield performance. Genetic variability analysis showed high genotypic and phenotypic coefficients of variation, along with high broad-sense heritability (>85%) and high genetic advance as percent of mean for most traits, including SYP and RSI, suggesting the predominance of additive gene action and effectiveness of selection. PCA indicated that the first two principal components accounted for 56.6% of the total variation, with PC1 (35.4%) predominantly influenced by yield-related traits and PC2 (21.2%) associated with disease severity. The PCA biplot demonstrated a pronounced negative association between RSI and yield-contributing traits, confirming the detrimental effect of charcoal rot severity on soybean productivity. Based on RSI values, Genotypes IC18734, EC389148, SL 955, MAUS 710, and JS 20-94 were identified as charcoal rot resistant, exhibiting minimal root and stem infection along with stable yield expression under stress conditions. In contrast, Genotypes DSb18 and Pusa -37, SL 799, Dsb 15and JS 93-05 were classified as highly susceptible, recording severe disease symptoms and reduced yield performance. Moreover, these findings were further validated by sick pot experiment under greenhouse condition and the outcome was same. These contrasting responses validate RSI as a robust indicator for screening charcoal rot tolerance in soybean. In conclusion, the integration of RSI with yield related traits using multivariate approaches provides an effective strategy for identifying charcoal rot resistant soybean genotypes. The resistant genotypes identified in this study constitute valuable genetic resources for breeding climate-resilient soybean cultivars capable of sustaining productivity under increasing biotic stress pressure.

Keyword: *Charcoal rot resistance, climate change, genotype*

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Agro-climatic dynamics and their impact on soybean yield prediction using deep learning

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Rapid advancements in artificial intelligence (AI) are transforming modern digital agriculture, where precise soybean yield prediction is essential to meet rising edible oil demands, reduce protein malnutrition, enhance input efficiency, and promote sustainable productivity. Conventional empirical and statistical models often fail to capture the nonlinear and dynamic interactions among climatic, soil, and management variables, particularly under variable environmental conditions. To address these limitations, this study focuses on soybean-dominant districts of Madhya Pradesh, India, and proposes an advanced Hybrid Ensemble Feature Selection (HEFS) framework. The framework integrates Stepwise Multiple Linear Regression (SMLR), Least Absolute Shrinkage and Selection Operator (LASSO), and Random Forest Regression (RFR) to extract the most informative predictors from fine-grained, multi-source weekly datasets encompassing weather, soil moisture, and fertilizer variables. Feature importance analysis through XGBoost identified TMax28, TMax37, TMin30, SR34, TMin34, RF33, N, RF27, and K as key variables influencing yield across major growth stages. The proposed HEFS-CNN model demonstrated high predictive accuracy (R^2 = 0.95, MAE = 0.14, MSE = 0.04, RMSE = 0.20), effectively capturing complex nonlinear dependencies between climatic and management parameters. Findings emphasize the critical role of temperature, radiation, and moisture regulation during key phenological phases in maximizing yield. Despite data availability constraints, the proposed framework exhibits strong scalability and adaptability, enabling potential application to other crops and agro-climatic zones. Overall, the HEFS-CNN model establishes a robust, interpretable, and data-driven approach for early yield forecasting, supporting climate-smart agriculture and IoT-enabled decision-making systems for improved regional planning and sustainable productivity.

Keywords*: Soybean, hybrid ensemble feature selection (HEFS), CNN, weekly agro-climatic data, yield prediction*

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Antixenosis and antibiosis studies on some selected soybean genotypes against *Spodoptera litura*

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Soybean in its growth period is attacked by a number of defoliators viz. *Spodoptera litura*, *Chrysodeixis acuta*, *Gessonia gemma*, *Diachrysia orichalcea*, *Mocis undata* etc. Collectively they cause about 20% yield loss in soybean. As there are no defoliator resistant varieties, farmers use chemical insecticides for their control. Repeated and irrational use of these chemical insecticides is leading to development of insecticide resistance. Though some genotypes have been identified showing resistance through field screening, but genuine sources for resistance are lacking for using them in breeding programmes. Among various approaches for identifying sources for defoliator-resistant genotypes, use of digestibility indices are very promising and confirmative. Hence, the genotypes were assessed for resistance based on Antixenosis and Antibiosis parameters i.e., Approximate Digestibility (AD), Efficiency of Conversion of Ingested food (ECI) and Efficiency of Conversion of Digested food (ECD). Antixenosis and Antibiosis

studies have been done on 10 selected soybean genotype viz., NRC150, NRC 152, NRC 138, G5P22, JS 335, JS 25-03, JS 25-06, JS 20-34, JS 22-12 and JS 24-33 at Indore. Among evaluated 10 soybean genotypes, JS 25 03 was exhibited Strong antixenosis ('C' value-0.48). In Antibiosis studies against *S. litura* the lowest Approximate digestibility (AD) was observed in JS 25-03 (54.25%) soybean genotype while Efficiency of conversion of digested food (ECD) and Efficiency of conversion of digested food (ECD) was observed the lowest in JS 25-06 (ECD-72.19%; ECI 39.57%).

Keywords: *Antixenosis, resistant genotype, Spodoptera litura*

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Morphological, cultural and molecular variability in *Rhizoctonia solani* isolates causing aerial blight (RAB) of soybean

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A total of forty-two isolates of *Rhizoctonia solani*, the incitant of Rhizoctonia Aerial Blight (RAB) of soybean, were collected from major soybean-growing regions of India, encompassing Madhya Pradesh, Uttarakhand, Maharashtra, Delhi, Chhattisgarh, Karnataka, Gujarat, Rajasthan, Punjab, and Nagaland, to investigate their morphological, cultural, and molecular variability. The isolates exhibited pronounced polymorphism in colony morphology, pigmentation, growth pattern, and sclerotial characteristics. On potato dextrose agar (PDA), radial growth varied significantly from 1.36 cm (isolate RS21, Hoshangabad, MP) to 8.95 cm (isolate RS7, Kangra, HP). Mycelial pigmentation ranged from white to brown, with 32 isolates exhibiting whitish colonies and 26 showing uneven mycelial growth patterns. Aerial mycelium formation was observed in 28 isolates, whereas 14 exhibited submerged growth. Sclerotial initiation generally commenced between the second and third day of incubation, with the absence of sclerotia in eight isolates. The maximum sclerotial diameter (9.25 mm) was recorded in isolate RS38 (Nagaland), while the highest sclerotial count (177) was observed in isolate RS36 (Jabalpur, MP). Sclerotial coloration varied from rough black to light orange, with rough black predominating. Artificial screening of soybean genotypes under controlled glasshouse conditions using soil inoculation methods revealed significant variation in disease severity, based on Area Under Disease Progress Curve (AUDPC). Molecular characterization using ITS1 and ITS4 primers confirmed that the majority of isolates belonged to the *R. solani* AG1-IA anastomosis group. These findings reveal considerable morphological, cultural, and genetic heterogeneity among *R. solani* populations in India, providing valuable insights into pathogen diversity that can aid in the development of resistant soybean cultivars.

Keywords: *Mycelial pigmentation, polymorphism ,cultivars*

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Influence of sulfur-oxidizing bacteria and siderophore-producing bacteria in the soybean-mustard cropping system recovered from extreme habitats

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Sulfur and iron are critical nutrients required by oilseed plants, including soybean and mustard. Since the soils of predominantly oilseed-growing states are deficient in sulfur and iron, this deficiency negatively affects yield. We explored sulfur-oxidizing bacteria (SOBs) and siderophore-producing bacteria (SPBs) from extreme habitats, including coal mines, hot water springs, and iron mines located in Chhattisgarh. Furthermore, we also isolated SOBs and SPBs from the crop rhizosphere. These bacteria were further evaluated biochemically, plant growth promotion assay, biosafety, and antagonistic properties against soil-borne phytopathogens. These were then tested for their influence on soybean and mustard crops in pots and fields. We found that native bacteria did not provide the benefits of elemental sulfur application. SOBs isolated from extreme habitats showed higher yield promotion than those from crop rhizosphere. A field study showed that *Bacillus amyloliquefaciens*, applied with 20 Kg of sulfur, enhanced yield by 17.10% and 16.42% compared to uninoculated control and uninoculated plots with 20 Kg/ha sulfur, respectively. SOBs from the Alliaceae family: *Citrobacter freundii* + 20 kg/ha S application enhanced grain yield by 8.40 %, whereas *Enterobacter* sp. + S application enhanced grain yield by 6.69% in soybean. In mustard, B. pumilus + 30 Kg S enhanced grain yield by 26.35% and 10.68% compared to the absolute control T1 and the recommended practice of 40 Kg/ha sulfur dose, respectively. Similarly, yield enhancement with SPB *Priestia megaterium* was 11.41% higher than that of the un-inoculated control in field-grown soybeans. Similarly, SPBs *Pseudomonas* sp. achieved a 13.44% yield enhancement over the absolute control and 11.72% compared to the recommended practice of 50 Kg iron sulfate/ha. Overall, we concluded that SOBs and SPBs could enhance the yield by more than 15-20% with a 25% reduction in chemical inputs. Microbial consortia of SOBs and SPBs may significantly contribute to the sustainability of oilseed crops under a changing climatic scenario.

Keywords: *Edible oil, soybean, sulfur oxidizing bacteria*

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A hybrid modified ConvFormer and TransFormer architecture with ASPP integration for soybean leaf disease detection and multi-class classification

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Convolutional Neural Networks (CNNs) excel at capturing local spatial patterns but struggle to model long-range dependencies due to their inherently limited receptive fields. Conversely, Transformer-based architectures effectively learn global contextual relationships but often require large datasets, incur high computational costs, and may lose fine-grained spatial details. To overcome these complementary limitations, we propose a hybrid ConvFormer–ASPP architecture that integrates Modified ConvFormer Blocks, Transformer Blocks, and an Atrous Spatial Pyramid Pooling (ASPP) module within a four-stage hierarchical encoder. By combining CNN-driven local feature extraction with Transformer-based global representation learning and multi-scale contextual aggregation through ASPP, the proposed model achieves a balanced

and robust feature representation suitable for complex and highly variable leaf disease patterns. The model processes input images through progressive down-sampling stages, combining depth wise separable convolutions, spatial attention, channel MLPs, and multi-dilated feature aggregation to enhance both local and global feature representation. A lightweight classification head further ensures efficient inference without compromising accuracy. An experimental evaluation was conducted on the benchmark PlantVillage dataset and a newly developed SoyMulti-Class (SMC) dataset, which we generated to represent real-world variations in soybean leaf diseases. The SoyMulti-class dataset contains a total of 10,869 samples. It includes four classes of soybean leaves: aerial blight, bacterial pustule, yellow mosaic virus, and healthy leaf samples. Ablation studies confirm the contribution of each proposed component. On PlantVillage, the baseline ConvFormer achieved strong performance, which further improved with the integration of ASPP and Modified ConvFormer Blocks, resulting in up to 97.14% Top-1 accuracy on the PlantVillage Dataset. Similar to our SoyMulti-Class dataset, 91.25% were observed, where the complete model achieved notable accuracy gains and reduced loss compared to the baseline, demonstrating robustness on complex, field-level images. Importantly, these improvements were obtained with only a moderate overhead in model complexity. Overall, the proposed hybrid ConvFormer-ASPP framework effectively captures rich, multi-scale features and significantly enhances the performance of plant disease classification. The results highlight its strong potential for scalable and reliable deployment in real-world precision agriculture systems.

Keywords: *Convformer, leaf disease detector, soybean, Soymulti-class*

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CRISPR-Cas9 knockout of *GmERA1* isoforms to enhance drought tolerance in soybean

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Soybean [*Glycine max* (L.) Merrill.] growth and production are severely affected by drought stress, which continuously reduces yield and quality, constraining the productivity of this vital oilseed crop. CRISPR-Cas9 mediated genome editing offers a precise strategy to enhance abiotic stress resilience through targeted disruption of negative regulatory genes. The *ERA1* gene, encoding the â-subunit of protein farnesyltransferase, functions as a negative regulator of abscisic acid (ABA) signaling; its mutation leads to ABA hypersensitivity, enhanced stomatal closure, and reduced water loss. In order to enhance drought tolerance in soybean, two functional *ERA1* isoforms, *GmERA1A* and *GmERA1B*, located on chromosomes 6 and 13, respectively, were knocked out employing CRISPR-Cas9 genome editing tool. Both isoforms share a conserved genomic organization comprising 14 exons and 13 introns. A guide RNAs (sgRNAs) were designed to target a homologous region spanning exon 1 and exon 2 of both isoforms, enabling their knockout. The sgRNAs oligonucleotides were cloned into the shuttle vector pBlu/gRNA under the control of the *Arabidopsis* U6 promoter using the BbsI site and subsequently transferred into the binary vector pCas9MDC123 via the *Eco*RI site. The resulting constructs were mobilized into *Agrobacterium tumefaciens* strain GV3101. Cas9-expressing plasmids were used to transform soybean cultivar JS-335 through *Agrobacterium*-mediated and *In-planta* transformation. Putative T• transformants were selected using glufosinate and validated by PCR amplification of Cas9 and Phosphinothricin Acetyltransferase (PAT) genes. Targeted disruption of *ERA1* is expected to potentiate ABA signaling in guard cells, thereby enhancing stomatal closure, improving water-use efficiency, and conferring drought tolerance. This study demonstrates a promising genome-editing strategy for developing drought-resilient soybean cultivars.

Keywords: *CRISPR-Cas9, drought tolerance*

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In-vitro evaluation of fungicides against *Rhizoctonia solani* causing aerial blight of soybean

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Aerial blight caused by *Rhizoctonia solani* is an emerging and economically important disease of soybean, leading to rapid foliar necrosis, defoliation, and significant yield losses under warm and humid conditions. The present investigation was undertaken to evaluate the in-vitro efficacy of different fungicides against *R. solani* isolated from aerial blight infected soybean plants. Using the poisoned food technique, six fungicides, viz., Carbendazim (12%) + Mancozeb (63%), Hexaconazole 5% SC, Tebuconazole 25.9% EC, Picoxystrobin 22.52% SC, Pyraclostrobin 133 g/l + Epoxiconazole 50 g/l SE, and Tebuconazole 10% + Sulphur 65%, were tested at four concentrations (100, 250, 500, and 1000 ppm), and radial mycelial growth was recorded at 24 hour intervals. Carbendazim (12%) + Mancozeb (63%) and Pyraclostrobin 133 g/l + Epoxiconazole 50 g/l SE completely inhibited mycelial growth at all concentrations, indicating strong fungicidal activity. Tebuconazole 25.9% EC and Picoxystrobin 22.52% SC were also highly effective, achieving complete inhibition at e”250 ppm and near-complete inhibition at 100 ppm. Hexaconazole 5% SC showed moderate to high antifungal activity with 75.8–90.0 per cent inhibition, but failed to achieve complete suppression even at the highest dose. Tebuconazole 10% + Sulphur 65% was the least effective treatment, permitting considerable mycelial growth with only 60.9–84.7 per cent inhibition. Overall, the study demonstrates that Carbendazim (12%) + Mancozeb (63%) and Pyraclostrobin 133 g/l + Epoxiconazole 50 g/l SE are highly potent against *R. solani* under in-vitro conditions, while Tebuconazole 25.9% EC and Picoxystrobin 22.52% SC offer strong inhibitory potential.

Keywords: *Aerial blight disease, in-vitro evaluation of fungicide*

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Evaluation of herbicide and microbial strains on productivity and economics of soybean

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Soybean has been called as “Golden Bean” of twentieth century consisting 40-42% protein and 18-22% oil. Soybean ranks first both in area and production in India, occupying an area of 13.50 mha with production of 12.58 mt and productivity of 932 kg/ha. Soybean is an important leguminous crop with high nutritional value, plays an important medicinal role with derivatives like genistein (an isoflavone phytonutrient) used in cancer prevention. In soybean, weeds results in grain yield reduction compared to other biotic and abiotic stresses. Soybean is majorly grown in *kharif* season and suffers from severe weed crop competition due to continuous rain, which do not permit hand weeding operation timely, resulting

in yield loss to the tune of 30–80%. Weeds are major biotic factor responsible for poor soybean yield. Hence, a study was conducted at All India Co-Ordinated Research Project on Soybean, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka during *kharif*-2024. The experiment was replicated thrice in split plot design with five main plots and four sub plots. Soybean variety DSb-34 was used for sowing to know the compatibility of three different herbicides recommended for soybean along with weedy check and weed free check with plant growth promoting *rhizobacteria* (PGPR) including three microbial strains so that the tolerant microbes could be used as a potential herbicide and microbial culture to support the soybean crop nutritionally on growth performance of the soybean. In this study, soybean crop was inoculated by cultures of *Bacillus daqingense*, *Bacillus aryabhataii*, consortia of *B. daqingense* and *Bacillus aryabhataii*. Under main plot, results revealed that apart from weed-free check, application of diclosulam @ 26 g/ha + one hand weeding at 40 days after sowingrecorded significantly lower weed density (2.98 /m^2), weed dry weight (2.52 g/m^2), weed index (7.2), higher weed control efficiency (82.3 %)at 60 DAS, highest yield parameters *viz*., grain yield (2861 kg/ha), biological yield (4441 kg/ha),number of pods per plant (50.8), 100-seed weight (13.24 g) and economics *viz.*,net return (1,01,513 /ha) and B:C ratio (3.03) respectively followed by application of propaquizafop 2.5% + imazethapyr 3.75% at 2.0 l/ha at 15-20 DAS as compared to other treatment. Whereas, under microbial strains, *B. daqingense*@ 10 g/kg seed recorded significantly higher number of pods per plant (50.4), 100-seed weight (13.53), seed yield (2847 kg/ha), biological yield (4618 kg/ha), net return (1,02,831 /ha) and benefit cost ratio (3.13) as comparted to other strains.

Keywords: *Economics, herbicides, PGPR, productivity, soybean*

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Efficacy of herbicides with PGPR on growth, yield and weed dynamics of soybean (*Glycine max* L. Merrill)

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Weeds represent the most economically important pest complex to global food production and it has significantly impact on mankind at all levels, from health perspectives to the pursuit of recreation. Rainy season crops are more prone to weed infestation due to frequent rains which favour the flushes of weeds. The dominance of weed species varied from location to location. Among pest complex (insects, disease, weeds etc.), estimated contribution of 11.5% is from weeds, which is one-third of the total food production. Of the total loss in food production, the weed share maximum (45%). If weeds are not controlled, yield reduction of upto 75% can occur in soybean. So, efficient weed management is the major key in successful cultivation of soybean. Use of PGPR with herbicides in soybean may have synergistic effect boosting productivity and stress tolerance. However, the compatibility depends on the microbial strains and the herbicides used. So, an experiment has been conducted to study the herbicidal effect along with PGPR to find out the growth, yield and weed dynamics of soybean at CAU Research Farm, Andro, Central Agricultural University, Imphal during *kharif* season of 2023. The experiment was conducted in split plot design with three replications having five herbicidal treatments viz., Diclosulam @ 26 g/ha, Diclosulam @ 26 g/ha + One hand weeding at 40 DAS, Propaquizafop 2.5% + Imazethapyr 3.75% at 2.0 l/ha at 15-20 DAS, Weedy check and Weed-free check (2 hand weeding at 20 and 40 DAS under main plot and 4 microbial strains viz., *B. daqingense* @ 10 g/kg seed, *Bacillus aryabhataii* (Zn & P-solubilizing bacteria) @ 10 g/kg seed, *B. daqingense* @ 10 g/kg seed + *Bacillus aryabhataii* @ 10 g/kg seed (Consortia) and un-inoculated under sub plot. The tested cultivar was MACS 1460. From the experiment, it was observed that pre emergence application of Diclosulam + one hand weeding at 40 DAS recorded significantly higher no. of pods/plant (63), seed yield of 1639 kg/ha and harvest index of 42.7% over other herbicidal treatments. However, 100 seed weight was found to be non- significant. Weed control efficiency was maximum at Weed-free check (68.1%) which was closely followed by

Diclosulam + one hand weeding at 40 DAS (67.4%) at 60 DAS. Among the microbial strains, treatment with *B. daqingense* @ 10 g/kg seed + *Bacillus aryabhataii* @ 10 g/kg seed (Consortia) recorded highest no. of pods/plant, nodule dry weight, seed yield and harvest index. However, treatment combination of Diclosulam @ 26 g/ha + One hand weeding at 40 DAS with *B. daqingense* @ 10 g/kg seed recorded maximum seed yield (1781 kg/ha) followed by Weed-free check with *B. daqingense* @ 10 g/kg seed + *Bacillus aryabhataii* @ 10 g/kg seed (1756 kg/ha) and Diclosulam @ 26 g/ha + One hand weeding at 40 DAS with *B. daqingense* @ 10 g/kg seed + *Bacillus aryabhataii* @ 10 g/kg seed (1703 kg/ha).

Keywords: *Herbicides, PGPR, weed dynamics*

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Synergistic effects of moisture-stress-tolerant endophytic bacteria and AM fungi on growth, nodulation and yield of soybean under field conditions

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In the 21st century, climate change has become a global challenge to food security, significantly reducing the productivity of important oilseed crops such as soybean (*Glycine max* L.). Conventional mitigation strategies are often slow and limited, requiring the development of economic and sustainable alternatives such as beneficial plant-associated microorganisms. Endophytic bacteria, plant growth-promoting rhizobacteria (PGPR), and AM fungi enhance plant growth under abiotic stress by colonising plant tissues, improving nutrient solubilisation, phytohormone production, ACC 1-aminocyclopropane-1-carboxylate (ACC) deaminase-mediated stress ethylene reduction, and improved antioxidant defence mechanisms. AM fungi, through their extended hyphal networks, facilitate plants to draw water beyond the root zone and improve plant fitness through maintaining osmotic balance under moisture stress conditions. In this research, endophytic bacterial strains were recovered from soybean root, shoot, and seed tissues and screened for moisture stress tolerance under in vitro conditions using polyethene glycol (PEG 6000) at concentrations up to 30% (-1.3 MPa). Based on 16S rRNA gene sequencing, the most tolerant strains were identified as *Brevundimonas naejangsanensis*, *Bacillus amyloliquefaciens*, and *Bacillus nakamurai*. Multilocation field trials were conducted at ICAR-National Soybean Research Institute, Khandwa Road, Indore (MP) & Indira Gandhi Agriculture University, Raipur (CG). The selected endophytic strains were co-inoculated with *Bradyrhizobium liaoningense* and arbuscular mycorrhizal fungi (AMF) available at ICAR-NSRI, Indore. The co-inoculation of bacterial endophytes with soybean rhizobia and AM fungi has significantly contributed to drought stress alleviating parameters and improved plant fitness by improving morphological traits such as root-shoot length and plant biomass, as well as physiological and biochemical parameters including chlorophyll content, relative leaf water content, antioxidant enzyme activities (superoxide dismutase, catalase, and peroxidase), reduced ethylene production, and increased synthesis of plant growth-promoting metabolites such as indole-3-acetic acid (IAA). Also, the combined application as a consortia yielded the maximum increase in yield. Overall, the findings showed that integrated biological approaches using elite microbial strains offer an effective solution for managing drought stress in soybeans. Furthermore, the application of endophytic bacteria, alone or in combination with other PGPMs, holds significant potential for sustaining soybean productivity even under moisture stress conditions. Future research must focus on developing climate-resilient bio-inoculants, molecular modification of microbial strains using emerging technologies such as CRISPR-Cas9 and recombinant DNA tools, and the formulation of newly identified microbes as sole and consortia for large-scale agricultural applications.

Keywords: *ACC deaminase, endophytic bacteria, drought stress, plant growth-promoting rhizobacteria (PGPR), indole-3-acetic acid (IAA), AMF*

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Antixenotic effect of soybean on growth and development of tobacco caterpillar (*Spodoptera litura* Fab.) under Manipur conditions

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Soybean (*Glycine max* [L.] Mirrill), a crop of high nutritional and economic importance, plays a vital role in sustainable agriculture due to its rich composition of protein (40–42%), oil (20–22%), carbohydrates, and essential amino acids. Despite its significance, soybean cultivation, especially in the foothills and mid-hills of Manipur, suffers severe yield losses from insect pests, with the tobacco caterpillar (*Spodoptera litura* Fab.) identified as one of the most destructive defoliators. *S. litura*, a polyphagous noctuid pest, poses a major challenge to soybean production under tropical and subtropical conditions. Host plant resistance through mechanisms such as antixenosis provides an effective and eco-friendly strategy for pest management, reducing reliance on chemical insecticides. This study aimed to evaluate the antixenotic response of eight soybean genotypes (F4 P21, CAT 2503, G5 P22, CAT 146, CAT 47, F3 P18, DE 201, and MACS 1460) against *S. litura* under Manipur agroclimatic conditions, and to identify morphophysiological traits contributing to resistance. The experiment was conducted under laboratory conditions using free-choice test to assess non-preference behaviour of third-instar *S. litura* larvae. The degree of feeding deterrence was quantified using the Preference Index (C = 2A / (M + A)), where "A" and "M" represent the amount of leaf material consumed from a test genotype and the susceptible check (JS 335), respectively. Morphophysiological parameters including leaf length, leaf width, trichome density (adaxial and abaxial surfaces), leaf water content, and chlorophyll content were recorded to relate these features with resistance expression. The results revealed a clear genotypic variation in the levels of antixenotic resistance. Among the tested genotypes, DE 201 exhibited the highest level of resistance with a C-value of 0.49, categorized as strong antixenosis, while MACS 1460 was identified as the most susceptible genotype with a C-value of 0.95, being the preferred host for *S. litura*. The genotypes F4 P21 (C = 0.62), CAT 2503 (0.73), F3 P18 (0.70), and G5 P22 (0.75) showed moderate antixenotic response, whereas CAT 146 (0.79) and CAT 47 (0.84) displayed slight resistance. Resistant genotypes such as DE 201 and F4 P21 were characterized by shorter and narrower leaves, high trichome density, low chlorophyll content, and reduced leaf water content. These morphological and physiological traits were negatively correlated with insect infestation and leaf defoliation rate. Notably, DE 201 had the highest trichome density (513.33 trichomes per 25 mm² adaxially) and the lowest chlorophyll concentration (11.66 µmol chlorophyll/m²), indicating that dense pubescence and lighter green foliage might serve as physical and visual deterrents to *S. litura*. Overall, the study confirms that morphological features such as leaf area reduction, lower water content, and higher trichome density contribute significantly to antixenotic resistance in soybean. The identification of DE 201 as the most resistant genotype offers a valuable resource for breeding programme aimed at developing *S. litura*-resistant soybean genotypes suited to the agroecological conditions of Manipur. Incorporation of resistant varieties into integrated pest management (IPM) framework can sustainably reduce pest pressure, minimize yield losses, and decrease chemical pesticide dependence in soybean ecosystems.

Keywords: *Antixenosis, host plant resistance, soybean, sustainable agriculture, tobacco caterpillar*

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AI-enabled novel method for detection of groundnut foliar diseases using CNN

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Groundnut (*Arachis hypogaea* L.) is a major oilseed and food-legume crop cultivated in tropical and subtropical regions, playing a vital role in food security and farmers' livelihoods. However, groundnut production is severely affected by foliar diseases such as early leaf spot, late leaf spot and rust, which cause considerable yield losses if not detected and managed at an early stage. Traditional disease diagnosis relies mainly on visual inspection by farmers or experts, a process that is time-consuming, subjective and often impractical for large-scale cultivation. Delayed or inaccurate diagnosis frequently results in improper disease management and reduced crop productivity. To overcome these constraints, this study presents an AI-enabled framework for rapid and reliable disease detection and identification of major groundnut leaf diseases under real field conditions. The work evaluates the performance of a Convolutional Neural Network (CNN)-based object detection framework using the YOLO11 model, which enables simultaneous localization and identification of disease symptoms on groundnut leaves. Groundnut leaf images were taken using a digital camera from the research fields of the All India Coordinated Research Project (AICRP) on Groundnut, University of Agricultural Sciences, Dharwad, Karnataka, during the *Kharif* season of 2025. Image acquisition was carried out under natural field conditions to capture variability in illumination, background and disease severity, thereby improving real-world applicability. A comprehensive dataset consisting of 17,300 images of healthy and diseased groundnut leaves was developed. The dataset included samples affected by early leaf spot, late leaf spot and rust. Prior to model training, the images were subjected to standard pre-processing techniques, including resizing, normalization, data annotation and class balancing, to enhance detection robustness and minimize bias. The YOLO11 model was selected due to its lightweight architecture, high detection accuracy, and fast inference speed, making it suitable for deployment in resource-constrained agricultural environments. The experimental evaluation revealed that the proposed model attained an overall detection accuracy of 99.9% with an inference time of 0.3 milliseconds per image. The model effectively detected and localized disease-affected regions on groundnut leaves, enabling rapid and reliable diagnosis. The results obtained in this work demonstrate the practical relevance of the model for real-time field deployment through mobile-based advisory systems, handheld diagnostic tools or edge computing plat forms. This study contributes to precision agriculture by providing a practical, fast and accurate disease detection system for groundnut. Early identification of foliar diseases can support timely intervention, reduce indiscriminate pesticide use, and improve sustainable crop health management.

Keywords: *Foliar diseases, groundnut, YOLO11*

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Adaptive groundnut management using agromet advisory services to enhance climate resilience under erratic monsoon regimes

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Increasing climatic variability, particularly the rising frequency of extreme rainfall events and prolonged dry spells during the southwest monsoon, has emerged as a major challenge for rainfed groundnut cultivation in the Central Dry Zone of Karnataka. Under such conditions, traditional calendar-based farming practices are often unable to cope with rapid weather fluctuations, leading to inefficient input use, higher cost of cultivation, and yield instability. In this context, Agromet Advisory Services (AAS) issued under the Gramin Krishi Mausam Sewa (GKMS) programme through the Agro-Meteorological Field Unit (AMFU), Hiriyur, play a critical role in enabling farmers to adopt adaptive crop management strategies. These advisories are generated using IMD medium-range weather forecasts, interpreted at the local level and translated into Phenophase-specific, value-added recommendations using a scientifically developed crop weather calendar (CWC) based on more than 50 years of historical weather data for the region. The comparative evaluation of adaptive crop management using AAS-based advisories and traditional farming practices clearly demonstrated the superiority of AAS-based farming under conditions of pronounced rainfall variability during the 2025 kharif season at ZAHRS, Hiriyur, Karnataka. The rainfall pattern during the year was highly irregular, characterized by prolonged dry spells interspersed with a few high-intensity rainfall events, reflecting increasing monsoon instability in the Central Dry Zone of Karnataka. Extended dry conditions prevailed from January to April, followed by a brief pre-monsoon rainfall surge in May, uneven southwest monsoon progression during June to August, and a highly concentrated rainfall episode in September. Such erratic distribution, despite an overall positive annual rainfall deviation, created frequent moisture stress during critical growth stages of groundnut and increased the risk of runoff losses, nutrient leaching, and crop damage during extreme rainfall events. Under these challenging weather conditions, groundnut fields managed using GKMS–AMFU Hiriyur–based Agromet Advisory Services (AAS) recorded higher yields and improved economic performance compared to traditional farming practices. Timely advisories enabled farmers to optimize sowing windows, schedule irrigations during dry spells, avoid fertilizer and pesticide applications prior to heavy rainfall events, and adopt need-based plant protection measures. Consequently, AAS-based farming achieved pod yields in the range of 22–25 q/ha, compared to 15.0–17.0 q/ha under traditional practices, representing a yield advantage of approximately 25–40 per cent. In addition, improved input-use efficiency resulted in a reduction in cost of cultivation by 8–12 per cent, thereby enhancing net returns. These findings clearly demonstrate that Agromet Advisory Services delivered through the GKMS framework and AMFU Hiriyur, supported by IMD medium-range weather forecasts, significantly enhance climate resilience, productivity, and profitability of groundnut cultivation under increasingly erratic monsoon conditions in the Central Dry Zone of Karnataka.

Keywords: *Groundnut, agromet advisory services (AAS), crop weather calendar (CWC), central dry zone of karnataka*

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Host plant resistance for sustainable management of multiple foliar fungal diseases in groundnut

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Groundnut (*Arachis hypogea* L.) also called as "Peanut", Monkey nut (UK), Goober and Pindar (USA) is a leguminous plant that is widely cultivated in the tropics and subtropics. It is known for its high oil content and edible seeds. It is the fourth most important source of edible oil and third most important source of vegetable protein in the world. In India, groundnut occupies about 4.70 million hectares, producing 10.18 million tonnes with a productivity of 1777 kg/ha. Among biotic constraints that limit groundnut yield, foliar fungal diseases are important in globally. Late leaf spot (LLS) caused by *Phaeoisariopsis personata*, early leaf spot caused by *Cercospora arachidicola* and rust caused by *Puccinia arachidis* are important foliar fungal diseases of groundnut. Depending on genotype, time and stage of occurrence, losses in pod and fodder yield is to the extent of 50 -70 per cent and it also adversely affects the quality of the produce. Hence in order to exploit the host plant resistance for Sustainable Management of Multiple Foliar Fungal Diseases in Groundnut, the present investigation was carried out at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, during *Kharif* 2024 and 2025. Twenty-five groundnut genotypes including the released varieties have been evaluated under natural condition with DH 256 used as resistance check and JL 24 used as susceptible check. The disease incidence was recorded and based on their reaction; genotypes were categorized into Highly resistant, Resistant, Moderately Resistant, Susceptible and Highly Susceptible by using 0 to 9 scale. The experiment followed an augmented design with two replications. Results revealed that, among the twenty five genotypes such as GPBD 5, GPBD 4, DBG 3, Dh-256 and DBG 4 showed resistant reaction for LLS and other foliar diseases. , Nine genotypes showed moderately resistant reaction while nine entries were moderately susceptible to susceptible reaction to LLS and other foliar diseases. These resistant genotypes can exploited as potential donors in breeding programs for developing durable resistance to LLS and rust, there by contributing to sustainable groundnut production. Incorporating these resistance genes broadens the genetic base and minimizes resistance breakdown, while combining them with traits like high yield, oil content and adaptability enables the development of climate-resilient, high performing cultivars for diverse agro-ecological zones and ecofriendly sustainable management of multiple foliar fungal diseases in groundnut.

Keywords: *Groundnut; late leaf spot, rust, sustainable management*

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Management of insect pests through entomopathogenic fungus in *Kharif* groundnut

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An experiment was laid out during *Kharif*, 2023 at Main Agricultural Research Station, Dharwad in a

randomized block design with six treatments (Foliar spray of *Lecanicillium lecanii* (1x108cfu/ml) (accession number IOF1 KM215209) at 30 days after spray (DAS) followed by (fb) *Metarhizium rileyi* (accession number IOF1 KC776914) at 45 DAS @ 2 g/L each; *Lecanicillium lecanii* at 30 DAS fb *Beauveria bassiana* (accession number IOF1 KJ542522) at 45 DAS @ 2 g/L each; *Lecanicillium lecanii* @ 2 g/l at 30 and 45 DAS; *Beauveria bassiana* @ 2 g/L at 30 and 45 DAS; *Metarhizium rileyi* @ 2 g/L at 30 and 45 DAS and water as untreated check were sprayed at 30 and 45 days after sowing (DAS) on the Groundnut variety, JL-24)) and four replications. Observations on the number of sucking pest (leafhoppers and thrips), defoliators (Spodoptera and Helicoverpa), per cent foliage damage due to respective pests at 1 day before spray (DBS), 7 DAS and 15 DAS, number of predator (Coccinellids) and parasitoid (Campoletis) at 1 DBS and 15 DAS were recorded. Incremental cost benefit ratio was calculated, based on the cost of respective entomopathogens, pod yield and haulm yield. Results revealed that the foliar spray of *Lecanicillium lecanii* @ 2 g/L at 30 and 45 DAS recorded lowest population of leafhoppers (2.77 and 1.97 number / top 3 leaves/plant) and thrips (1.87 and 0.94 number /terminal bud / plant) after first and second spray at 15 DAS, respectively. Similarly, the lowest per cent foliar damage in the same spray by leafhoppers (13.19 & 6.58 per cent) and thrips (3.15 & 2.18 per cent) at 15 DAS after first and second spray, respectively. Whereas, foliar spray of *Metarhizium rileyi* @ 2 g/L at 30 and 45 DAS recorded lowest number of spodoptera (0.47 and 0.26 larvae/plant) and helicoverpa (0.67 and 0.42 larvae/plant) at 15 DAS after first and second spray, respectively. Similarly, in the same treatment lowest per cent foliar damage due to spodoptera (2.48 % and 2.02% at 15 DAS after first and second spray, respectively) and helicoverpa (4.25% and 3.21% at 15 DAS after first and second spray, respectively) were recorded. There was a non-significant difference in the number of predator and parasitiod a day before spray but after 15 DAS after each spray highest population was recorded in the untreated check. However, it was concluded that the foliar spray of *Lecanicillium lecanii* @ 2 g/L at 30 DAS followed by *Metarhizium rileyi* at 45 DAS @ 2 g/L recorded highest pod yield (2222.25 kg/ha) and haulm yield (2488.0 kg/ha) with 624.25 kg/ha pod yield and 890.0 kg/ha haulm yield increase over control which gave the maximum incremental cost benefit ratio of 0.62.

Keywords: *Beauveria bassiana, groundnut, insect, Lecanicillium lecanii, Metarhizium rileyi, pests*

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Extent of adoption of integrated white grub management practices in groundnut: evidence from Saurashtra region of Gujarat

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White grub (*Holotrichia* spp.) is one of the most destructive insect pests of groundnut, particularly in semi-arid regions, causing substantial yield and economic losses. Despite the availability of integrated management technologies, recurring infestations indicate limitations in farmers' adoption of recommended practices. Effective white grub management requires a life cycle–based approach, with timely interventions at both grub and adult stages. However, inadequate attention to adult-stage management may act as a critical hindrance. The present study aimed to assess the extent of adoption of integrated white grub management practices in groundnut and to identify stage-specific gaps limiting effective pest control in the Saurashtra region of Gujarat. The study was conducted across major groundnut-growing districts of Saurashtra, covering a representative sample of groundnut farmers. A structured and pre-tested interview schedule was used to collect data on the adoption of recommended white grub management practices, categorized into grub-stage and adult-stage interventions.Adoption was measured using a three-point continuum (regularly, sometimes, never) with corresponding scores. Weighted mean scores were computed to rank practices, and descriptive statistical tools were used to interpret adoption patterns and identify critical gaps. The results revealed that grub-stage management practices were relatively better adopted compared to adult-stage interventions. Among grub management practices, seed treatment with insecticides

recorded the highest adoption (weighted mean score: 2.35), followed by deep summer ploughing (2.33) and furrow application of insecticides (2.27). In contrast, crop rotation with non-host crops showed the lowest adoption (1.89), indicating limited acceptance of cultural management. Adult-stage management practices exhibited consistently lower adoption levels. Chemical spraying on host trees during evening hours was the most adopted adult management practice (2.15), while pheromone traps (Anisole-based) and light traps recorded the lowest adoption scores (1.94 and 1.99, respectively). A major knowledge gap was observed regarding the egg-laying behaviour of adult beetles on trees and shrubs located in and around farmers' fields. The study clearly indicates that poor adoption of adult-stage management is a major hindering factor in effective white grub control. Farmers prefer curative and chemical-based interventions over preventive, ecological, and community-level adult management strategies. The comparatively low adoption of adult beetle management practices, particularly pheromone traps and light traps, suggests a critical extension gap, as adult-stage control is essential for breaking the pest life cycle. The study underscores the need for targeted extension interventions, capacity building, and demonstration-based approaches focusing on adult beetle ecology, forecasting, and integrated lifecycle management to enhance the effectiveness and sustainability of white grub management in groundnut-based systems.

Keywords: *Groundnut, integrated management, pest life cycle, white grub*

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Effect of zinc on productivity and quality of groundnut (*Arachis hypogaea* L.) in arid region of Rajasthan

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A field experiment entitled "Effect of Zinc on Productivity and Quality of Groundnut (*Arachis hypogaea* L.) in Arid Region of Rajasthan" was conducted during *Kharif* 2024 at the Instructional Farm, College of Agriculture, Bikaner. The experiment comprised ten treatments viz., control, zinc @ 2, 4, 6 and 8 kg ha^{-1}, seed treatment with Zinc Solubilizing Bacteria (ZSB), and their combinations (2, 4, 6 and 8 kg ha^{-1} zinc + ZSB), laid out in a Randomized Block Design with four replications. Application of zinc and ZSB significantly influenced growth, yield attributes, yield, nutrient uptake, and quality parameters of groundnut. Among the treatments, application of zinc @ 6.0 kg ha^{-1} produced significantly higher kernel yield (3000 kg ha^{-1}), pod yield (4348 kg ha^{-1}), haulm yield (8793 kg ha^{-1}) and biological yield (13140 kg ha^{-1}) over the control, and was statistically at par with zinc @ 4.0 kg ha^{-1} + ZSB treatment. The highest yields were recorded with zinc @ 8.0 kg ha^{-1} alone and in combination with ZSB. Yield attributes such as number of pods per plant, kernels per pod, seed index, shelling percentage, and harvest index improved significantly with increasing zinc levels. Quality parameters including protein content (23.88%) and oil yield (1384 kg ha^{-1}) were significantly enhanced by zinc @ 6.0 kg ha{ ^{1}, which was statistically comparable with zinc @ 4.0 kg ha^{-1} + ZSB, while the maximum values were obtained with zinc @ 8.0 kg ha^{-1} alone and with ZSB. Uptake of nitrogen, phosphorus, potassium, and zinc by kernel and haulm was significantly higher under zinc @ 6.0 kg ha{ ^{1} and zinc @ 4.0 kg ha^{-1} + ZSB. Post-harvest soil zinc availability increased significantly, whereas available N, P, K, and organic carbon remained unaffected. Economically, zinc @ 6.0 kg ha^{-1} recorded significantly higher net returns (^{1} 2,24,101 ha^{-1}) and benefit–cost ratio (3.39), comparable with zinc @ 4.0 kg ha^{-1} + ZSB. The maximum net return (^{1} 2,32,933 ha^{-1}) and B:C ratio (3.45) were obtained with zinc @ 8.0 kg ha^{-1} + ZSB. Based on the results, application of zinc @ 6.0 kg ha^{-1} is recommended as the optimum dose for enhancing productivity, quality, and profitability of groundnut in zinc-deficient arid soils of Rajasthan, ensuring sustainable micronutrient management.

Keywords: *Groundnut, zinc, protein, oil*

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Unraveling seasonal insect pest dynamics in groundnut: evidence from fifteen years of monitoring data

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Groundnut (*Arachis hypogaea* L.) is an important oilseed crop, and insect pests significantly affect its productivity and profitability. Indiscriminate and untimely application of insecticides for pest management often increases production costs and leads to ecological imbalance. Long-term pest surveillance is essential to understand pest population dynamics and to facilitate real-time, need-based pest management strategies. In this context, pooled data from fifteen years (2010–2025) of insect pest monitoring in the groundnut ecosystem were analyzed to assess the seasonal incidence of major insect pests. The study was conducted at the Main Agricultural Research Station, University of Agricultural Sciences, Raichur, Karnataka during *Kharif* season. Major lepidopteran and sucking pests were monitored using pheromone traps, yellow sticky traps, and light traps installed at recommended densities. Weekly observations were recorded from the 31st to the 50th standard week, and mean catches per trap per week were computed using pooled data across years. The results indicated that *Spodoptera litura* (Fab.) was the predominant lepidopteran pest in the groundnut ecosystem. Its activity gradually increased from the early crop growth stages and reached peak levels during the 43rd to 46th standard weeks, with maximum mean catches of up to 97.8 moths per trap per week, followed by a sharp decline towards crop maturity. In contrast, *Helicoverpa armigera* (Hübner) incidence remained comparatively low throughout the season, exhibiting only minor peaks during the mid-season period. Among sucking pests, leaf miner incidence was largely confined to the early crop growth stage, with peak activity observed during the 38th standard week. Leafhopper populations increased from the 35th standard week onwards and attained peak activity during the 43rd standard week, causing notable foliage damage before declining. Thrips population also followed a similar trend, with peak incidence recorded during the 40th to 43rd standard weeks. The pooled long-term data clearly demonstrated distinct and predictable seasonal patterns in the occurrence of major insect pests in groundnut. These findings emphasize the importance of continuous, trap-based pest monitoring for accurate forecasting and timely implementation of integrated pest management practices. The study provides a robust baseline for developing region-specific pest advisory services and sustainable pest management strategies in the groundnut ecosystem.

Keywords: *Groundnut, Arachis hypogaea L., insect pest dynamics, long-term monitoring, pooled data, pheromone traps, integrated pest management*

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Spodoptera and leaf miner in groundnut: measuring the yield impact in hotspot regions

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Defoliating insect pests, particularly *Spodoptera litura* and leaf miner, are major constraints to groundnut (*Arachis hypogaea* L.) productivity in hotspot regions. A three-year Kharif study was conducted at Raichur to quantify yield losses caused by these pests. The susceptible variety TMV-2 was grown under protected and unprotected conditions in a Randomized Block Design with five replications. Uniform

agronomic practices were applied in all plots. Seed treatment with Imidacloprid 600 FS and need-based sprays of Thiamethoxam 25 % WG were applied in both treatments to minimize interference from sucking pests. Protected plots received additional defoliator management with Neem oil (2 ml/liter) as a prophylactic spray and one application of Emamectin benzoate 5 SG (0.4 g/liter), while unprotected plots received no defoliator-specific treatments. Leaf damage was recorded from 25 to 90 days after sowing, and pod and haulm yields were recorded at harvest. Percent decrease in defoliator damage and yield losses were calculated using standard formulas. Pooled results over three years revealed that unprotected plots suffered maximum foliar damage of 33.26 %, whereas protected plots showed significantly lower damage (5.47 %), corresponding to an 83.55 % reduction in defoliator damage. Pod and haulm yields were substantially higher in protected plots (1774.32 kg/ha and 5718.20 kg/ha) compared to unprotected plots (1292.55 kg/ha and 4657.64 kg/ha), representing 27.15 % and 18.54 % losses in pod and haulm yields, respectively, in unprotected conditions. The study demonstrates the significant economic impact of defoliators on groundnut productivity and underscores the importance of timely pest management interventions. These findings provide quantitative evidence to guide integrated pest management (IPM) strategies in groundnut hotspot regions.

Keywords: *Arachis hypogaea* L., *Spodoptera, leaf miner, defoliators, yield loss, integrated pest management*

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Influence of pre- and post-emergence herbicides on the productivity of groundnut (*Arachis hypogaea* L.)

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Groundnut (*Arachis hypogaea* L.) is highly vulnerable to weed infestation during its early growth stages due to its sparse canopy, resulting in yield losses from 54 to 71 per cent. Therefore, effective weed management is essential to minimize the impact of weed on groundnut. Hence, a field experiment was conducted during the *Rabi* season of 2024-25 at Regional Research Station, Tamil Nadu Agricultural University, Vriddhachalam. The research aims to find the effect of different weed management practices on the growth and productivity of groundnut. The study involves ten treatments arranged in a randomized block design (RBD) with three replications. Among the weed management practices in groundnut, lower weed density and weed dry matter production was observed in weed free check and hand weeding twice at 20 and 40 DAS and it was on par with pre-emergence application of diclosulam at 26 g/ha *fb* fenoxaprop-p-ethyl at 78 g/ha at 4-5 leaf stage of weed. The results indicated that the higher plant height, leaf area index, dry matter production, chlorophyll index and pod yield were observed in the weed-free check followed by hand weeding twice at 20 and 40 days after sowing. However, it is statistically on par with the application of diclosulam at 26 g/ha *fb* fenoxaprop-p-ethyl at 78 g/ha at 4-5 leaf stage of weed. On economic basis pre-emergence application of diclosulam at 26 g/ha *fb* fenoxaprop-p-ethyl at 78 g/ha at 4-5 leaf stage of weed recorded the higher net returns (1,16,703 ha^{-1}) and benefit-cost ratio (2.53), making it the most economically viable weed management option among the treatments and can be recommended for farmers. Higher weed density, higher weed dry weight, lower weed control efficiency was recorded in weedy check. Lower growth attributes, yield attributes, pod yield, haulm yield, net returns and benefit-cost ratio were recorded in application of topramezone 33.6% SC @ 20.6 g /ha at 4-5 leaf stage of weed due higher phytotoxicity to the groundnut crop. Hence it is concluded that pre-emergence application of diclosulam 26 g/ha *fb* fenoxaprop-p-ethyl 78 g/ha at 4-5 leaf stage of weed (ready mix) was an economically feasible weed management practices higher net returns and benefit-cost ratio, which could help the farmers to increase their productivity and profitability with effective weed management in groundnut.

Keywords: *Arachis hypogaea, herbicides, productivity, weed management*

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Influence of pre and post emergence herbicides on weed control, growth, yield and economics of Kharif groundnut

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Groundnut is the "King of Oil seeds," rich in minerals and essential vitamins contains 48-51% oil, 26-28% protein, and 11.5% starch, making it versatile for products such as roasted nuts and peanut butter. Groundnut suffers heavy competition from weeds especially in the initial stages of crop growth period up to 45 DAS where weed free environment aids in increased productivity. Hence, it is essential to determine most suitable combination of pre and post emergence herbicides for efficient control of weeds with low cost of cultivation and higher net returns in groundnut crop. A Field trial was conducted in the F.No.59 of Regional Agricultural Research Station, Tirupati of Acharya N.G.Ranga Agricultural University, Andhra Pradesh during kharif season of 2023 to study the effect of different herbicides for the control of weeds in Groundnut. Observations like Groundnut pod, haulm yields, yield attributes, weed dry matter were recorded. The predominant weed species observed in the experimental field were *Digitaria sanguinalis, Boerhavia erecta, Cleome viscose, Commelina benghalensis, Dactyloctenium aegyptium, Trichodesma indicum* and *Cyperus rotundus.* Different weed management practices significantly influenced weed dry matter, yield and yield attributes of kharif groundnut. Significantly higher per hectare pod yield (2012 kg), kernel yield (1415 kg) was recorded with Hand weeding twice treatment (T_8) over all other weed management practices but it was statistically at par with pre emergence application of Diclosulam @ 20 g (T_1) and 25 g (T_2) followed by hand weeding (T_3 and T_4), T_1 & T_2 followed by post emergence application of Quizalofop-p-ethyl @ 50 g/ha (T_5 and T_6) but significantly superior over Pre emergence application of Diclosulam @ 20 g (T_1) and 25 g (T_2) and Pre emergence application of pendimethalin fb post emergence application of Quizalofop-p-ethyl (T_7) and weedy check (T_9). Similar results were reported by Grichar et al., in peanut with the Diclosulam herbicide. Significantly lowest weed dry matter per m^{-2} of 6.6 g was recorded with Hand weeding twice treatment (T_8) at harvest which was comparable with pre emergence application of Diclosulam @ 20 g (T_1) and 25 g (T_2) followed by hand weeding (T_4 and T_4), T_1 & T_2 followed by post emergence application of Quizalofop-p-ethyl @ 50 g ai/ha (T_5 and T_6) but significantly superior over Pre emergence application of Diclosulam @ 20 g (T_1) and 25 g (T_2), pre emergence application of pendimethalin fb post emergence application of Quizalofop-p-ethyl (T_7) and weedy check (T_9). Higher weed control efficiency was recorded with Hand weeding twice 95.4 followed by pre emergence application of Diclosulam fb hand weeding (T_3) as 93.9 at harvest. Higher gross (Rs.1,20,700/-) and net (Rs.62,700) monetary returns per hectare were recorded with hand weeding twice treatment (T_8) followed by T_4 and T_3 but, higher BCR was recorded with T_4. Pre emergence application of Diclosulam @ 25 g followed by Quizalofop @ 50 g ha^{-1} was effective in control of weeds and resulted in higher pod yield at par with manual weeding twice and recorded the comparably lower weed dry matter. Diclosulam herbicide has effectively controlled Sedges up to 70-80%.

Keywords: *Groundnut, herbicides, growth, kharif, weed control, yield*

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Prevalence of soil-borne diseases in groundnut in Tamil Nadu and their management

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Groundnut (*Arachis hypogaea* L.) is an important oilseeds and ancillary food crop in Tamil Nadu with

0.88 million tones production from 0.32 million ha area with productivity of 2698 kg ha^{-1} (Season and Crop Report, Tamil Nadu 2023-2024). Higher productivity can be obtained by addressing the production constraints and damage caused by diseases which causes considerable yield losses in groundnut. Soil borne diseases incited by the fungal pathogens infest at various crop growth stages in groundnut and causes severe yield losses and impairing quality. Survey was conducted in the major groundnut growing area of Tamil Nadu during *Kharif* and *Rabi /Summer* season every year for the past ten years and the incidence of diseases were recorded periodically. The major soil borne diseases of groundnut were collar rot (*Aspergillus niger*), dry root rot/dry wilt (*Macrophomina phaseolina*) and stem rot (*Scletotium rolfsii*). During the *Kharif* season the dry root rot incidence ranged from 3 to 16 per cent, collar rot incidence ranged between 10 to 22 per cent. During the *Rabi/Summer* season the dry root rot incidence ranged from 5 to 21 per cent, collar rot incidence ranged between 7 to 15 per cent. Field trial was conducted for the management of soil borne diseases in Kharif season at Regional Research Station, Vriddhachalam with the susceptible variety revealed that integrated approaches including soil application of *Trichoderma* enriched in farm yard manure and seed dressing were found to be effective managing the soil borne diseases.

Keywords: *Groundnut, collar rot, soil-borne diseases, Trichoderma, Kharif*

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Bio-efficacy of sequential herbicide application on weed dynamics and productivity of groundnut in Saurashtra region of Gujarat

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Groundnut (*Arachis hypogaea* L.) is an important *kharif* oilseed crop in the semi-arid Saurashtra region of Gujarat, but its productivity is often reduced due to many biotic stresses especially severe weed infestation. Weed management through chemical means is by far the most efficient and cost effective means for season-long weed control. Besides pre-emergence (PRE) weed control there is a need of post-emergence (PoE) control of weeds too due to emergence of late flushes of weeds. Hence, there is a need to explore season-long weed control through sequential use of PRE & PoE herbicides providing an efficient and economical alternative to either PRE or PoE applied alone. Thus, a field experiment was conducted during the Spring–Summer 2023 (Feb to June) and *Kharif* 2023 (June to October) seasons at the ICAR–IIGR main campus, Junagadh. The experiments were laid out in a RCBD with three replications, using the groundnut variety 'TG 37A'. A total of nine weed management treatments were evaluated, which included, a weedy check (control), hand weeding plus interculture (HW + IC), diclosulam (PRE) *fb* clethodim (PoE), diclosulam (PRE) *fb* fenoxaprop-p-ethyl (PoE), oxyfluorfen (PRE) *fb* clethodim (PoE), oxyfluorfen (PRE) *fb* fenoxaprop-p-ethyl (PoE), pre-mix pendimethalin + imazethapyr (PRE), oxyfluorfen (PRE) *fb* quizalofop-p-ethyl (PoE) at recommended doses, and a weed-free. The study indicated the strong inverse relationship between weed dry matter and crop productivity as the weedy check recorded the highest average (of two seasons) weed dry weight (111.8 g/m²) and the lowest average pod yield (1058 kg/ha) due to severe crop-weed competition at critical stages. Among the weed management practices, sequential application of herbicides was more effective compared to pre-emergence herbicides or manual methods alone. The treatment involving diclosulam (26 g/ha, PRE) *fb* fenoxaprop-p-ethyl (78 g/ha, PoE) proved to be the most efficient chemical option, significantly reducing weed dry matter to 3.91 g/m² during *Kharif* and 25.0 g/m² during Spring-Summer at 60 days of sowing (DOS). The corresponding values for 90 DAS were 4.48 g/m² during *Kharif* and 21.1 g/m² during Spring-Summer. This enabled better overall resource availability to the crop thereby resulting in realization of higher pod yields of 3245 kg/ha during Spring-Summer and 2601 kg/ha in *Kharif* (at par with the best treatment of weed-free). From an economic perspective, the same treatment (diclosulam *fb* fenoxaprop-p-ethyl) also emerged as the most profitable practice with the higher net returns of (1,60,655/ha during

Spring-Summer and ¹ 1,46,352/ha during *Kharif*). Manual weeding, despite relatively effective weed control, showed comparatively lower net returns due to higher labour costs and relatively low yields. Thus, an increase of 16.7% in average yields and 20.5% in net returns (over two seasons) were accrued following the above herbicide treatment compared to manual weeding twice. The two years studies confirmed that diclosulam at 26 g/ha PRE– fenoxaprop-p-ethyl at 78 g/ha PoE (at 20-25 DOS) sequence could be the most efficient, productive and cost-effective weed management strategy for groundnut in both Kharif and Spring - Summer groundnut in the Saurashtra region of Gujarat.

Keywords: *Bio-efficacy, groundnut, herbicide, productivity, weed dynamics*

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Influence of weather on the occurrence of foliar diseases of Groundnut

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A study was conducted on influence temperature, relative humidity and rainfall on foliar diseases (early leaf spot, late spot and rust) of groundnut during kharif 2022, 2023 and 2024 at ARS, Kadiri. Weather parameters strongly influence the epidemiology of foliar diseases in groundnut, yet their relative contributions vary across seasons. The present study investigated the relationship between key meteorological variables and the incidence of early leaf spot (ELS), late leaf spot (LLS), and rust during three consecutive Kharif seasons (2022–2024). Pearson's correlation coefficients were estimated between disease intensity and major weather parameters, including rainfall, number of rainy days, maximum and minimum temperature, and relative humidity during morning and evening periods. The analysis revealed that rainfall and rainy days exhibited weak and largely non-significant correlations with ELS, LLS, and rust across all three seasons, indicating a limited direct role in disease development. In contrast, temperature and relative humidity emerged as critical determinants of disease incidence. Minimum temperature showed a strong and significant negative correlation with ELS, LLS, and rust during 2022 and 2023, suggesting that cooler night temperatures favored disease progression. Maximum temperature demonstrated a moderate negative association, particularly with ELS during 2022. Relative humidity, especially evening relative humidity, exhibited a strong positive and significant correlation with all three diseases, most prominently during the 2024 season. Morning relative humidity also showed a positive association with LLS and rust in certain years. The year-to-year variability observed in disease–weather relationships highlight the dynamic nature of pathogen responses to environmental conditions under Kharif cropping systems. Overall, the findings indicate that minimum temperature and relative humidity, particularly during evening hours, play a dominant role in influencing the incidence of ELS, LLS, and rust, while rainfall-related parameters are of secondary importance. The results underscore the need to prioritize temperature–humidity interactions in disease prediction models and in the development of weather-based forewarning systems. Such insights can aid in optimizing fungicide application schedules and improving integrated disease management strategies for groundnut under changing climatic conditions.

Keywords: *climatic conditions, foliar diseases, fungicide, groundnut, leaf spot*

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Estimation of yield losses and management of late leaf spot in groundnut (*Arachis hypogaea* L.) using tebuconazole

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India stands as a global leader in oilseed production, cultivating nine annual field crops, including soybean, rapeseed-mustard, and groundnut, which form the core of the nation's edible oil supply. Despite producing nearly 43 million tonnes annually, India faces a significant edible oil deficit, currently importing 55% of its requirements. The government has launched strategic interventions like the National Mission on Edible Oils–Oilseeds to boost domestic productivity. Biotic stresses, specifically foliar diseases like Late Leaf Spot (LLS), hampers groundnut productivity significantly. Study was conducted to quantify yield losses and evaluate the efficacy of systematic fungicidal intervention at hot spot locations to enhance edible oil security. Field experiment was conducted during three consecutive *Kharif* seasons 2021-2023 at Oilseeds Research Station, Jalgaon which is a hot spot location for late leaf spot. The groundnut variety SB-XI, susceptible to late leaf spot was used in the study. The experiment layout was in Randomized Block Design with three replications. Seven treatments with foliar sprays of Tebuconazole 25.9% EC at various intervals (50, 65, 80, and 95 days after sowing), while eighth one was untreated control. Disease intensity (PDI), pod yield, haulm yield, percentage yield loss and benefit-cost ratio (BCR) were recorded and pooled over years. The pooled data revealed that treatment T_4 (foliar sprays at 50, 65, 80, and 95 DAS) was the most effective treatment to reduce the yield losses due to leaf blight disease. Over the three-year period, T_4 maintained the lowest PDI of 19.97% (ranging from 19.10% to 20.57%), compared to the untreated control (55.44%). Treatment T_4 recorded a mean pod yield of 13.94 q/ha, which was found significantly superior over the untreated control (8.93 q/ha). Estimation of losses showed that unprotected plots suffered an average pod yield loss of 35.99% and haulm yield losses of 26.04%. Economic analysis consistently favored the T_4 schedule i.e. foliar sprays at 50, 65, 80, and 95 DAS, which achieved the highest BCR each year ranging from 4.23 to 5.41. Treatments with three sprays (50, 65 and 80 DAS or 65, 80 and 95 DAS) were the next best options. The study confirms that systematic fungicidal management with Tebuconazole 25.9% EC foliar sprays is essential for mitigating LLS severity and maximizing groundnut output. By preventing over one-third of potential yield losses, a schedule of foliar sprays of Tebuconazole 25.9% EC at 50, 65, 80 and 95 DAS effectively minimizes disease severity and ensures maximum economic returns in groundnut crop.

Keywords: *groundnut, late leaf spot, tebuconazole, yield losses*

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Impact of toxigenic *Aspergillus flavus* on the nutritional composition of groundnut kernels

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Groundnut (*Arachishypogaea* L.) serves as a critical source of plant-based protein and edible oil. However, its quality is frequently jeopardized by *Aspergillus flavus* infection, which triggers seed decay and produces dangerous aflatoxin B1. This research investigated how different toxigenic strains alter the proximate

constituents of groundnut seeds. The baseline nutritional values observed in the uninoculated kernals (control T1) were 1.21per cent moisture, 4.03 per cent ash, 26.44 per cent fat, 9.56 per cent fibre and 24.50 per cent protein. Significant deviations from these values were noted following fungal inoculation. Seeds treated with isolate AFG13 (T2) demonstrated a substantial drop in primary nutrients, yielding 0.83 per cent moisture, 3.02 per cent ash, 22.48 per cent fat, 7.41 per cent fibre and 15.62 per cent protein. This specific strain AFG13 caused the most dramatic depletion in protein and lipid levels. Conversely, seeds inoculated with AFG17 (T3) showed a distinct metabolic pattern, resulting in 1.36 per cent moisture, 1.21 per cent ash, 20.64 per cent fat and 20.12 per cent protein. A standout feature of the T3 treatment was the sharp rise in crude fibre content, which reached 21.03 per cent, alongside a significant decrease in ash and fat. These results emphasize that fungal contamination causes a profound loss in the caloric and dietary worth of groundnut kernals, beyond the mere presence of toxins.

Keywords: *Arachis hypogaea, Aspergillus flavus, fat, nutritional degradation, protein*

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Herbicide-based weed management in Kharif groundnut (*Arachis hypogaea* L.)

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Groundnut is a major oilseed crop globally, ranking fourth among oilseed crops. Despite, improved management practices, productivity in India remains low due to severe weed infestation, resulting in yield losses of 24–70%. The crop is highly vulnerable to weed competition during early growth stages because of its slow initial growth and poor canopy development. Weeds remove 30–40% of soil nutrients and compete for moisture, light, and space, besides hindering pegging and pod formation. Therefore, effective weed management requires the use of herbicides with different modes of action through pre- and post-emergence applications. The field experiment was conducted during summer (*Kharif*) seasons of 2024 and 2025 at Punjab Agricultural University, Ludhiana. Growth parameters, yield attributes, and pod and haulm yields were recorded at harvest. Among various treatments, significantly higher plant height, crop dry matter accumulation and yield attributes were recorded in weed free conditions and it was statistically at par to two hand weedings at 21 and 42 DAS, pendimethalin 750 g + pyroxasulfone 127.5 g a.i. ha^{-1} (tank mix), pendimethalin 750 g a.i. ha^{-1} + imazethapyr 50 g a.i. ha^{-1} (pre-mix) and imazethapyr 75 g a.i. ha^{-1} (post). Weed free enhanced pod yield by 74-118% as compared to unsprayed check. Also, two hand weedings at 21 and 42 DAS, pendimethalin 750 g + pyroxasulfone 127.5 g a.i. ha^{-1} (tank mix), pendimethalin 750 g a.i. ha^{-1} + imazethapyr 50 g a.i. ha^{-1} (pre-mix) and imazethapyr 75 g a.i. ha^{-1} (post) increased pod yield by 98.5-109.5 and 52-68% in both years, as compared to unsprayed check, showing statistical parity with weed free. Pendimethalin and pyroxasulfone interfere with normal cell development by inhibiting cell division in germinating seedlings. Imazethapyr is suitable for use in legumes due to its ability to inhibit acetohydroxy acid synthase, an enzyme essential for the biosynthesis of branched-chain amino acids. So, pre-mix and tank-mix application of herbicides provided broad-spectrum and efficient weed control due to their distinct modes of action, which interfere with multiple physiological pathways in weeds.

Keywords: *Groundnut, herbicide, Kharif, weed management*

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Ready-mix herbicidal application: a new approach to weed management in Kharif groundnut (*Arachis hypogaea* L.)

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Groundnut is considered the major oilseed crop in India, though the productivity of groundnut is not stable due to various constrains, among them weed infestation is most important restrictive factor to achieve potential crop yield. Keeping this background in view the field experiment was conducted during two consecutive rainy seasons of 2023 to 2024 at District Seed Farm (latitude: 22°58´N and longitude: 88°25'E with an altitude of 9.75m above mean sea level) Kalyani, Bidhan Chandra Krishi Viswavidyalaya, West Bengal to evaluate the efficacy and economics of different ready-mix herbicidal combination on weed management of groundnut during rainy season. The experiment comprising in a Randomized Complete Block Design (RCBD) with ten different weed management treatments replicated thrice. The different weed management treatments were T_1: Pendimethalin 30 % + Imazethapyr 2 % EC @ 800 g a.i ha^{-1} (Ready mix) as pre-emergence, T_2: Diclosulam 84 WDG @ 25 g ha^{-1} as pre-emergence, T_3: T_1 followed by Sodium Acifluorfen 16.5% + Clodinafop propargyl 8% EC @ 245 g a.i ha^{-1} (Ready mix) as post emergence, T_4: T_2 followed by Sodium Acifluorfen 16.5% + Clodinafop propargyl 8% EC @ 245 g a.i ha^{-1} (Ready mix) as post emergence, T_5: T_1 followed by Propiquizofop 2.5% + Imazethapyr 3.75% ME @ 125 g a.i ha^{-1} (Ready mix) as post emergence, T_6: T_2 followed by Propiquizofop 2.5% + Imazethapyr 3.75% ME @ 125 g a.i ha^{-1} (Ready mix) as post emergence, T_7: T_1 followed by hoeing at 25 DAS, T_8: T_2 followed by hoeing at 25 DAS, T_9: Weedy check and T_{10}: Weed free check. The groundnut cultivar TG-37A used in the experiment received 20:60:40 kg N, P_2O_5 and K_2O ha^{-1} irrespective of treatments. Result revealed that pod yield of groundnut increased about 52.5 to 56.3% with pre-emergence application of Diclosulam 84 WDG followed by ready mix post emergence application of Sodium Acifluorfen + Clodinafop propargyl (T_4) and Propiquizofop + Imazethapyr (T_6) respectively over weedy check (T_9), where the B:C ratio was increased a tune of 32.0 to 32.6% due to same herbicidal combination. Though, the highest pod yield and gross return was found from the weed free plot (T_{10}) but due to its tremendous treatment cost it had not produced the highest B:C ratio. Among the pre emergence herbicides diclosulam recorded its superiority over ready mix application of pendimethalin + imazethapyr weather applied solely or in combination with post emergence herbicides. Again, the ready mix post emergence herbicide propiquizofop + imazethapyr showed its supremacy over ready mix sodium acifluorfen + clodinafop propargyl in majority of cases. Different weed management practices of groundnut produced 16.8 to 63.1% higher pod yield over weedy check or control during rainy season.

Keywords: *Diclosulam, herbicide, groundnut, ready-mix, weed management*

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Pest surveillance and contemporary status of the major insect pests in groundnut

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Groundnut is one of the most important legume crops in the world, grown in a large scale in tropical and sub-tropical regions. It is mainly valued for its high quality edible oil and digestible protein. India ranks first in groundnut area and second largest producer in the world. Though many factors including climatic conditions are responsible for low productivity of groundnut, insect pests is one of the most significant

factors contributing to yield loss. Groundnut is attacked by about 60 species of insect pests including sucking pests and defoliators, caused substantial damage and poor seed quality of the crop. The pest damage varies with the critical stages in groundnut. Knowledge of status of insect pests at different growth stages of groundnut will be helpful in predicting the incidence in advance and evolving proper pest management strategies. Hence studies were conducted to find out population dynamics and distribution of major insect pests I relation to the influence of weather factors in groundnut. Pest monitoring trials at Research farm, Vridhachalam and surveys in farmers' fields at 20 villages were conducted during 2022 to 2024 in *Kharif* and *Rabi-summer*. Observations on insect pests population and extent of infestation were recorded at critical stages *viz.*,vegetative (20-30 DAS), pod formation (45-60 DAS) and pod development (90 DAS to week before harvest). In *Kharif*, 2023 & 2024, leafhopper infestation was high during 2nd week August to 1st week September with population of 3.2-4.7 Nos./top 3 leaves with damage of 10.5 -26.5 %. Thrips population was 1.5-3.1Nos./terminal bud with damage of 7.5 -16.5 % during 4th week of August to 1st week of September. Aphids population was 6.8 -32.1 in 2.5 cm length of plant stem. Among the defoliators, leaf miner incidence was noticed after 25 DAS with severe outbreak during 40 - 60 DAS in *Kharif*, 2023. Leaf miner peak population ranged from 10.4 to 11.8 larvae per plant with the defoliation damage of 67.5-72.5 % during 3rd week of August to 1st week of September. Defoliation by *Spodoptera* reached maximum in vegetative to pod formation stage during August to September with the damage of 18.5 to 42.5 %. In Rabi 2022-23 & 2023-24, leafhopper and thrips population was severe during vegetative to pod development stages of the crop, ranged between 3.8 to 5.4 Nos./ top 3 leaves with damage of 11.0 –35.5 % for leafhopper and 2.6 to 11.8 Nos./ terminal bud with damage of 7.5 – 11.5 % for thrips during February – March. Leaf miner damage reached maximum of 40.9 % at 45 DAS in farmer's fields. Among the pests, leafhopper, thrips, leafminer and *Spodoptera* occurred regularly in severe in all the seasons of groundnut cultivation. Correlation studies in groundnut revealed that, maximum and minimum temperatures had significant positive correlation with population and damage of leafminer and leafhopper. Relative humidity had significant negative correlation with leafminer and *Spodoptera* population.Rainfall had negative correlation with sucking pests. Sunshine hours negatively correlated with damage of *Spodoptera* and leafminer and positively correlated with the damage of leafhopper and thrips.

Keywords: *Groundnut, kharif, leafminer, rabi-summer, spodoptera, thrips*

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Integrated weed management strategies for productivity and profitability of *Kharif* groundnut (*Arachis hypogaea* L.)

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A field experiment was conducted at Agricultural Research Station, ANGRAU, Kadiri during three consecutive seasons of 2022, 2023 and 2024 in *Kharif* groundnut on sandy loam soils. To study the efficacy of diclosulam herbicide in managing weeds and enhancing the productivity of groundnut was tested in this experiment on weed management in *kharif* groundnut (*Arachis hypogaea* L.). The experiment was laid out in a randomized block design with nine treatments and replicated thrice. Pooled results over three years revealed that, lowest weed density and weed dry weight at 30 and 60 DAS was recorded with hand weeding twice at 20 and 40 DAS which was superior over all the chemical weed control treatments. Among different chemical weed control treatments, application of diclosulam @ 20 g a.i ha^{-1} & 25 a.i. ha^{-1} (PE) *fb* Quizalofop ethyl @ 50g a.i ha^{-1} at 18-20 DAS as post emergence recorded highest weed control efficiency, lowest weed density, weed dry weight, weed index which was on par with diclosulam @ 20 g a.i ha^{-1} & 25 a.i. ha^{-1} *fb* hand weeding at 25- 30 DAS. Diclosulam application did not show any phytotoxicity at either 20 or 25 g a.i. ha^{-1}. Higher mean pod yield over three years (1296 kg ha^{-1}) was recorded with hand weeding twice at 20 and 40 DAS over all other weed management practices, which was closely followed by diclosulam @ 20 g a.i ha^{-1} (PE) *fb* Quizalofop

ethyl @ 50 g a.i ha^{-1} (POE) at 18-20 DAS (1249 kg ha^{-1}), diclosulam 84 WDG @ 25 g a.i ha^{-1} (PE) *fb* Quizalofop ethyl @ 50 g a.i. ha^{-1} (POE) at 18-20 DAS (1233 kg ha^{-1}) followed by diclosulam @ 20 g a.i ha^{-1} (PE) *fb* HW at 25-30 DAS and Diclosulam @ 25 g a.i ha^{-1} (PE) *fb* HW at 25-30 DAS which are at par among them. This might be due to its increased concentration of diclosulam at deeper layers of the soil as a soluble herbicide due to higher half-life period coupled with higher leaching potential index and lower sorption coefficient lead to increased control of purplenut sedge, broad-leaved weeds and perennial sedges in groundnut on sandy soils. Higher values of groundnut yield attributes viz., number of pods per plant, hundred pod weight, shelling percentage was observed as a result of higher weed control efficiency leading to higher pod and kernel yield. Results further indicate that highest net returns and B:C ratio were recorded with diclosulam @ 20 g a.i ha^{-1} (PE) *fb* Quizalofop ethyl @ 50g a.i ha^{-1} (POE) at 18-20 DAS followed by diclosulam 84 WDG @ 25 g a.i ha^{-1} (PE) *fb* Quizalofop ethyl @ 50 g a.i. ha^{-1} (POE) at 18-20 DAS.

Keywords: *Groundnut, kharif, weed index, weed control efficiency*

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Nano-biotechnology-driven strategies for groundnut crop improvement

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Groundnut (*Arachis hypogaea* L.), a major oil seed crops widely cultivated in semi-arid and tropical regions. However, its productivity is often constrained by various abiotic and biotic stresses, posing a major challenge to sustainable cultivation. Therefore, for the management of these stresses several traditional and novel techniques are being used, but the success rate is still limited. Among the most advanced techniques, nano-biotechnology has been found to be one of the most innovative and promising viable solution to manage these challenging stress conditions. Several studies have clearly demonstrated that nano-biotechnological interventions can positively influence the physiological, biochemical, and molecular processes in groundnut plants exposed to stress. It has been reported that various engineered and decorated nanoparticles such as nano-fertilizers, nano-chelates, and nano-biostimulants are enough capable for targeted and control delivery of nutrients, hormones, and signaling molecules thereby improving nutrient uptake, minimizing yield losses, and also reducing environmental pollution. Further, application of nano-priming and various nanoformulations stimulate antioxidant defense systems, regulate osmolyte accumulation, and modulate stress-responsive gene expression, resulting in improved root architecture, water-use efficiency, nitrogen fixation, and yield stability. Additionally, nanomaterial's are also being explored for managing biotic stresses through nano-biosensors and nano-diagnostic tools which enable early recognition of pathogens, nutrient deficiencies, and stress signals, in groundnut cultivation. In nut cell, nano-biotechnological involvements present a transformative approach for sustainable groundnut production, however, challenges related to biosafety, nanoparticle fate, and regulatory frameworks remain and need further investigation.

Keywords: *Abiotic stress, biotic stress, groundnut, molecular traits, nano-biotechnological, seed*

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Identification of stable sources of late leaf spot resistance in groundnut through multi-generation cross evaluation

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Groundnut is a dynamic leguminous oilseed crop cherished for its high oil, protein and mineral content making it nutritionally crucial for humans and also as an animal feed. Late leaf spot (LLS), caused by *Phaeoisariopsis personata*, is a highly destructive foliar disease of groundnut, causing defoliation-induced yield losses of up to 50%, and exceeding 70% in India without fungicidal protection making it a major constraint to groundnut productivity. Reliance on chemical control for Late leaf spot (LLS) increases costs and environmental risks; therefore, developing genetically resistant varieties remains the most sustainable and effective long-term management strategy. The present study evaluated LLS resistance in 38 genotypes comprising six parents and their 8F, 8F, 8BC and 8BC, generations in groundnut during *Kharif* 2023 and 2024 at the Research Farm, Department of Genetics & Plant Breeding, RVSKVV, Gwalior, in Randomized Block Design with three replications. The assessment enabled effective genotypic characterization and identification of promising sources for resistance breeding and conservation planning. Disease scoring was done at 75 and 85 days after sowing (DAS) using a 1–9 disease scoring scale under field conditions. Among parents, GPBD-4, DGRMB-32, KDG-128 and NITYA HARITA consistently expressed resistance at both stages, identifying them as reliable resistance donors, whereas SUNOLEIC-95R remained highly susceptible and TG-86 showed moderate response. Across generations, most crosses exhibited strong early resistance at 75 DAS, particularly DGRMB-32 × GPBD-4 and DGRMB-32 × KDG-128, which maintained low disease scores in F , F, and backcross generations, indicating stable and heritable resistance. Resistance generally persisted up to 85 DAS, with only a marginal increase in disease severity as crop maturity advanced. Backcrosses involving resistant recurrent parents, especially GPBD-4 and DGRMB-32, showed superior and durable resistance, while backcrosses to the susceptible parent SUNOLEIC-95R recorded higher disease scores at later stages. Overall, the results highlight DGRMB-32, GPBD-4, KDG-128 and NITYA HARITA as dependable sources of LLS resistance and identify crosses such as DGRMB-32 × GPBD-4 and DGRMB-32 × KDG-128 as promising breeding materials for developing groundnut varieties with durable resistance to late leaf spot.

Keywords: *Groundnut, late leaf spot (LLS), susceptible, resistant and backcross breeding*

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Exploiting endophytic Bacillus strains GEB 1 and GEB 6 with antagonistic activity and antifungal metabolites against late leaf spot and rust in groundnut

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Groundnut is affected by various diseases among which late leaf spot and rust cause huge economic loss to the farmers. Various chemicals have been used for the management of the diseases infecting groundnut. However, repeated spraying of chemicals is hazardous, and pollute the environment. On the other hand, the defense system in the plant can be activated by means of application of Plant Growth-Promoting Rhizobacteria (PGPR) strains. In the present study, a total of 10 endophytic bacteria were isolated from different parts of groundnut plants and named as GEB 1 to GEB 10 (GEB-Groundnut endophytic bacteria). Among the ten isolates, GEB 1 and GEB 6 were shown to be effective in inhibiting the mycelial growth and spore germination of *Cercospora arachidicola* and *Puccinia arachidis*. The bacterial biocontrol

agent, *Bacillus* sp. GEB 1 and GEB-6 rely on various metabolic pathways essential for survival, adaptability, and plant interaction *viz*., Homocysteine degradation, ubiquinone biosynthesis, fatty Acid metabolism, phytanic acid, sphingolipid metabolism, methionine metabolism and steroidogenesis. These pathways help *Bacillus* combat rust and late leaf spot by boosting plant growth, enhancing disease resistance, and out competing these harmful pathogens. A virtual screening campaign was conducted to identify bioactive compounds from a pool of 45 metabolites produced by GEB1 and GEB6, using five modelled proteins: calmodulin, toxin biosynthesis protein, MAT-1 protein, USP2, and MAPK. Among the tested compounds, cyclodecene (E) demonstrated the highest binding affinity and the lowest binding energies. Cyclodecene (E) exhibited binding energies of -6.9 kcal/mol, -8.5 kcal/mol, -6.8 kcal/mol, -6.0 kcal/mol, and -7.0 kcal/mol for the pathogenicity proteins. These values were compared with those of gibberellic acid and 1,2-dihydro-2-methylpapaverine, which showed binding energies ranged from -2.6 to -8.3 kcal/mol among the same proteins. The efficacy of the isolated *Bacillus* spp. against late leaf spot and rust in groundnut was carried out under pot culture with five treatments replicated four times with five plants per replication in a completely randomized block design. The seeds were treated with the bioformulation @ 10 ml/kg of seed. For soil applications, 100 ml of the bioformulation/pot (2 ml/l) was dispensed into each pot 30 days after sowing, and foliar application @ 0.2 % was sprayed onto the leaves at 45 and 75 days after sowing. The pathogen was spray inoculated @ 1 x 10^6 CFU/ml. The effectiveness of the bioformulation on the incidence of disease was noticed 15 days after inoculation and the percent disease index was calculated. The results revealed that, seed treatment (10ml/kg) + soil application (100ml/pot) at 30 DAS + foliar application - GEB1 + GEB6 @ 0.2 % on 45 & 75 DAS recorded the lowest disease incidence of 5.03 and 6.00 PDI of late leaf spot and rust as against 30.20 and 25.95 per cent in the control accounting for 83.36 and 76.88 percent reduction over control. Thus it is concluded that, *Bacillus* strain GEB 1 and GEB 6 possessing antagonistic activity and antifungal metabolites can be exploited for the management of late leaf spot and rust in groundnut.

Keywords: *Antifungal metabolites, Bacillus strains, endophytic, groundnut, late leaf spot, rust*

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Groundnut (*Arachis hypogaea* L.) genotypes

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Groundnut is an important oilseed crop known for its several purposes including edible oil production, direct human consumption as food and for animal consumption in the form of silage, hay and oilcake. There is a need to find out high yielding as well as Water Use Efficiency (WUE) genotypes in groundnut. WUE is an important trait which contributes to productivity when there are limited water resources. The productivity of the crop can be enhanced by identifying the genotypes that utilise the scarce resources of water more efficiently. The research was undertaken to study the per-se performance for yield, yield attributes and water use efficiency related traits in 36 genotypes of groundnut. The present study for fourteen traits was carried out at the dry land farm of the S. V. Agricultural College, Tirupati, during *rabi*, 2021–2022. Analysis of variance (ANOVA) results showed highly significant differences for each character under study proving that genotypes vary greatly. Number of secondary branches plant^{-1} and number of primary branches plant^{-1} displayed greater GCV and PCV values. Number of primary branches plant^{-1}, number of secondary branches plant^{-1}, pod yield plant^{-1}, kernel yield plant^{-1}, plant height and specific leaf area at 60 DAS demonstrated high heritability coupled with high genetic advance as per cent of mean suggesting that additive gene action predominates in the expression of these characters and that selection would be successful in enhancing these traits. Using D^2 analysis, 36 genotypes of groundnut were divided into nine groups. Based on the distances between the clusters, it was found that the clusters VI-IX, VI-

VIII, I-IX, V-IX and VII-VIII were increasingly divergent in their magnitudes. In order to produce transgressive segregants, the genotypes of these clusters might be employed as parents in the hybridization scheme. To enhance features associated with water use efficiency, the cross combinations K-6 × TCGS-2053 and TCGS-2235 × TCGS-2053 may be suggested. By analysing the genetic divergence between clusters and genotype *per se* performance; Greeshma × TCGS-2053 and TCGS-2223 × TCGS-2230 could be recommended to obtain transgressive segregants for yield and yield attributes. Character association study demonstrated a highly substantial positive correlation between sound mature kernel per cent, harvest index, SPAD chlorophyll meter reading at 60 DAS, kernel yield plant^{-1} with pod yield plant^{-1} and between these traits at both the phenotypic and genotypic levels. Hence, it is important to place the appropriate emphasis on these qualities in order to enhance them and increase pod yield plant^{-1}. The path analysis showed that the direct effect of the kernel yield plant^{-1} on the pod yield plant^{-1} was extremely positive and it was followed by SPAD chlorophyll meter reading at 60 DAS, harvest index and plant height. The genotypes TCGS-2053, K-6, TCGS-2235, Greeshma, TCGS-2223 and TCGS-2230 were found to be promising for yield, yield related attributes and traits linked to water use efficiency by the overall analysis of the current study. These genotypes can therefore be used in the crossing programme to create high yielding cultivars with great water use efficiency.

Keywords: *Genetic divergence, yield traits, water use efficiency*

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Screening of groundnut genotype for cold and heat tolerance

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Groundnut (*Arachis hypogaea* L.) is an important self-pollinated oilseed, food and fodder crop. Groundnut is nutritious and contain rich source of oil (40–60%), protein (25–30%), and carbohydrate (10–20%). Summer/spring groundnut known for high productivity of groundnut due to low incidence of biotic and abiotic stress. Sowing of groundnut at low temperature (<20°C) during summer/spring results slow field emergence or poor plant stand. Delayed germination extending normal crop duration that expose crop to high temperature stress at reproductive phase. Therefore, this sowing condition is very ideal for identification of low and high temperature tolerant groundnut genotype suitable for summer/spring sowing season. A total 19 selected groundnut genotypes (Valencia-10; Spanish bunch-3; cultivars 6) screened for low and high temperature tolerance under field condition during summer 2023, 2024, 2025 at ICAR-Indian Institute of Groundnut Research, Regional Research Station, Bikaner, Rajasthan. Experimental trial was sown on 20, 29 and 27th January during 2023, 2024 and 2025, respectively when the soil temperature was 19 to 20 °C during 2023 to 2025. Weather parameters were recorded during crop season of three year. Each genotype was sown in single row of 2 m length at 30 cm spacing between rows and 10 cm between plants. Recommended package of practices was followed for rising of the good crop. Analysis of variance revealed non-significant difference among the all studied genotypes. Pooled mean of field emergence range 19 to 22 days, genotypes viz., NRCG 6402, NRCG 11349, NRCG 10894, NRCG 9943, NRCG 1286, NRCG 14367 recorded earliest 20 days to field emergence while high yielding varieties viz., TG37A, TAG 24 and Dh 86 emerge at 22 days. Based on three year screening above genotypes found to be cold tolerant in groundnut. Days to flower initiation was lowest in Pratap Moonfali 3 (52) followed by Dh 86 (53), Pratap Moonfali 3 (54), NRCG 14560 (54) and NRCG 6402 (54). Pooled mean pod yield (g pods/plant) range 1 to 8g, highest pod yield was recorded in Dh 86 (8g) followed by TG37A (7g) and TAG 24 (5g). Due to high temperature above 40 °C at flowering time during summer 2025, eleven entries could not bear pods. It indicates high temperature above 40 °C drastically reduced

pod yield in groundnut. Among the cultivars Dh 86 followed by TAG 24 and TG 37A had 1-2 g pods/plant while germplasm viz., NRCG 9943, 12367, 12436, 9168, 1286 had less than 1g pod yield/plant while rest 11 genotypes could not bear pods. This indicates these genotypes were found tolerant to high temperature stress in groundnut. Based on field emergence and pod yield results genotypes viz., NRCG 9943 and NRCG 1286 were found tolerant to cold and heat. Hence, these Valencia genotypes can be used in breeding programme to develop cold and heat tolerant groundnut varieties suitable for summer/spring season.

Keywords: *Cold, groundnut, genotype, heat tolerance*

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Evaluation of alternate hosts of groundnut bruchid, *Caryedon serratus* for their host suitability

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Groundnut bruchid, *Caryedon serratus* (Olivier) is a primary storage pest. Its infestation starts from the field and carried to godowns, where it assumes economic significance, provided favorable conditions. Bruchids lay eggs on exposed pods during post-harvest operations. A single pair of bruchids can inflict economic damage up to 80% within three months of storage. They are capable of infesting both pods and kernels, alike. During the off-season, bruchids survive on seed-bearing host trees belonging to genus *Acacia*, *Albizzia*, *Bauhinia*, *Caesalpinia*, *Cassia*, *Casuarina*, *Hardwickia*, *Helianthus*, *Pongamia*, *Prosopis* and *Tamarindus*. In this study, alternate hosts of *C. serratus* were evaluated for their host suitability. Study was conducted at the ICAR-Indian Institute of Groundnut Research, Junagadh during *Rabi*-spring 2024. Fallen pods and seeds of eight trees located around groundnut farm were collected. In the first study (natural infestation), bruchid eggs were counted on randomly collected 100 g pod/seed samples and incubated in laboratory conditions for 30 days to allow beetle emergence. In the second study (artificial infestation), 100 g bruchid egg-free pods and seeds were collected and 5-pairs of freshly emerged beetles were released. After 48 hrs of oviposition period, beetles were removed and eggs were counted. Beetle emergence was noted after 30-days of incubation in laboratory conditions. In the natural infestation study, results revealed that highest no. of bruchid eggs were noted on *Tamarindus indicus* (79.0 per 100 g of pod & seed sample) followed by *Bauhinia variegata* (26.0) and *Cassia fistula* (25.0). However, beetle emergence was highest in *T. indicus* (11.0 per 100 g of pod & seed sample) followed by *Acacia nilotica* (7.0) and *Prosopis julifera* (6.0). No egg laying and beetle emergence was noted from *Pongamia pinnata* and groundnut. In the artificial infestation study, significantly high number of eggs was recorded on *P. julifera* (39.3 eggs per 100 g of pod & seed sample) compared to that of groundnut (10.3), but at par with *T. indicus* (29.0). Similarly, significantly high number of beetles emerged from *P. julifera* (12.0 beetles per 100 g of pod & seed sample) which was at par with *A. nilotica* (9.0). For the first time, raintree *Samanea saman* was reported to be a host of *C. serratus*. Eggs were observed on raintree (6.0 and 12.0 per 100 g of pod, respectively) under natural and artificial infestation while, 7.0 beetles emerged from artificial infestation study. In natural infestation study, even though egg laying was noted on six alternate hosts but, beetle emergence was seen only in three alternate hosts of *C. serratus*. In artificial infestation study, egg laying was recorded on all alternate hosts but, adult emergence was absent in *P. pinnata* and *Albizzia lebbek*. Observations from this study, enlist *S. saman* as an alternate host of *C. serratus*. These insights into off-season survival and alternate hosts of groundnut bruchids will help in formulating both preventive and curative strategies for management.

Keywords: *Bruchid, caryedon serratus, groundnut, primary storage pest*

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Identification of differentially expressed genes (DEGs) responsible for defence against *Puccinia arachidis* and *Cercospora arachidicola* in groundnut (*Arachis hypogaea*)

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Groundnut (*Arachis hypogaea*) is a globally important oilseed crop, yet its productivity is severely constrained by fungal pathogens such as *Puccinia arachidis* (rust disease) and *Cercospora arachidicola* (early leaf spot). Despite their economic significance, the molecular basis of host–pathogen interactions in peanut remains poorly understood. In this study, we employed high-throughput RNA sequencing (RNA-Seq) to investigate transcriptomic responses of resistant (GPBD-4) and susceptible (JL-24) genotypes under infection by both pathogens, with the aim of identifying differentially expressed genes (DEGs) and elucidating defence-related pathways. A total of 86,380,930 reads (rust) and 91,734,735 reads (early leaf spot) were generated, yielding comprehensive transcriptome datasets. DEGs were annotated using Gene Ontology (GO) and Kyoto Encyclopedia of Genes and Genomes (KEGG) analyses, which revealed enrichment of pathways associated with plant defence, stress signalling, and secondary metabolism. Resistant plants exhibited exclusive up-regulation of defence-related genes including pathogenesis-related (PR) proteins, MLO-like proteins, ethylene-responsive transcription factors, thaumatin, F-box proteins, glutathione peroxidase, cinnamyl alcohol dehydrogenase, chitinase, cytochrome P450, glutathione S-transferase, and NBS-LRR resistance genes. These genes are implicated in pathogen recognition, signal transduction, oxidative stress mitigation, and reinforcement of cell wall integrity. In contrast, susceptible plants showed down-regulation of key defence-associated genes such as caffeate O-methyltransferase, beta-glucosidase, WRKY, bZIP, MYB transcription factors, cytochrome P450, leucine-rich repeat protein kinase, and terpene synthase, suggesting impaired activation of defence signalling cascades. Validation of RNA-Seq data by RT-qPCR using 15 primer sets confirmed strong correlation with transcriptome profiles ($R^2 = 0.82$ for rust; $R^2 = 0.92$ for early leaf spot), underscoring the reliability of the sequencing approach. Additionally, 4,511 (rust) and 8,591 (early leaf spot) EST-SSR markers were identified from unigenes, with several validated by PCR amplification. These markers provide valuable resources for genetic diversity assessment, QTL mapping, and marker-assisted breeding programs aimed at developing disease-resistant peanut varieties. Taken together, this integrated transcriptomic analysis provides novel insights into the molecular defence mechanisms of peanut against two major fungal pathogens. The identification of key DEGs, defence-related pathways, and EST-SSR markers not only enhances our understanding of host–pathogen interactions but also offers practical tools for crop improvement. This study establishes a foundation for future functional genomics research and breeding strategies to mitigate yield losses caused by rust and early leaf spot diseases in peanut.

Keywords: *Groundnut, marker-assisted breeding, QTL mapping, rust disease, transcriptomic*

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Integrated fungicidal approaches for the management of wilt (*Fusarium oxysporum* f.sp. *ricini*) in castor (*Ricinus communis* L.)

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Castor **(***Ricinus communis* L.) is an important non-edible oilseed crop majorly grown in arid and semi-arid regions of the world. Castor oil has gained significant global value because of its industrial uses. Several biotic and abiotic factors were causing major yield losses in castor crop. Among these biotic factors like fungal diseases have major impact in reduction of crop production and productivity. Castor wilt (*Fusarium oxysporum* f.sp. *ricini*) is one of the major biotic factors for low yields and sometimes the disease itself may cause 80% yield losses. Since the pathogen is soilborne in nature and control of the disease with single method may not possible. Hence using of new fungicide combination products is one of the strategies for effective management of castor wilt disease. The present investigation was conducted over three consecutive kharif seasons during 2018, 2019, and 2020 at the Regional Agricultural Research Station (RARS), Palem, under field conditions. The experimental field was artificially inoculated with the castor wilt pathogen, *Fusarium oxysporum* f. sp. *ricini*, to ensure uniform disease pressure. A total of seven treatments, including seed treatment combined with soil application of *Trichoderma harzianum*, along with a positive control, were evaluated for their efficacy against castor wilt. The experiment was laid out in a randomized design with three replications. Based on the pooled analysis of three years of experimentation, seed treatment with tebuconazole + trifloxystrobin 75 WG @ 0.4 g/kg seed proved to be the most effective treatment for managing wilt disease in castor. This treatment recorded the lowest wilt incidence (25.6%), which was statistically on par with seed (10 g/kg seed) and soil application of *Trichoderma harzianum*. In contrast, the control plot showed a significantly higher wilt incidence of 54.3%. Similarly, the highest seed germination percentage (90.0%) was observed with tebuconazole + trifloxystrobin seed treatment, followed by seed and soil application of *T. harzianum* (84.9%), with no significant difference between these two treatments. The lowest germination (76.0%) was recorded in the control. With respect to yield, the maximum seed yield (809 kg/ha) was obtained from seed treatment with tebuconazole + trifloxystrobin 75 WG @ 0.4 g/kg seed, followed closely by seed and soil application of *T. harzianum* (778.8 kg/ha), and these treatments were statistically comparable. The control plot recorded the lowest seed yield (320.5 kg/ha), while all other treatments performed significantly better than the control. Overall, seed treatment with tebuconazole + trifloxystrobin 75 WG @ 0.4 g/ kg seed was superior in reducing wilt incidence, enhancing germination, and improving seed yield in castor, while the bioagent *Trichoderma harzianum* also proved effective as an eco-friendly alternative for wilt management and yield improvement.

Keywords: *Castor, fungicides, integrated management, trichoderma harzianum, wilt*

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Field evaluation of newer insecticides for the management of leafhopper (*Empoasca flavescens*) in castor (*Ricinus communis* L.)

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Castor (*Ricinus communis* L.) is a high-value industrial oilseed crop with diverse applications. India is the leading producer of castor, contributing the major share to global production. Despite its importance, castor productivity is limited by several biotic stresses. Among them, insect pests cause considerable yield losses. Sucking pests, particularly leafhopper (*Empoasca flavescens*) are major constraints in castor cultivation in rabi season. Leafhopper infestation leads to hopper burn, reduced photosynthetic activity and poor crop yields. Chemical control remains the primary management strategy for sucking pests in castor. However, resistance development necessitates the evaluation of newer insecticides for effective management. A field experiment was conducted for three consecutive rabi seasons (2020–21 to 2022–23) at the Regional Agricultural Research Station, Palem, using castor cultivar PCH-111. The experiment was laid out in a randomized block design with five treatments, including an untreated control and three replications. Three newer insecticide, spinetoram 11.70% SC, thiacloprid 21.70% SC and cyantraniliprole 10.26% OD were compared with the conventional insecticide profenophos 50 EC. Two foliar sprays were applied at 15-day intervals during spike development stages. Leafhopper populations were recorded before spraying and at 7 and 14 days after application, while yield and economics were analysed using pooled data over three years. Cyantraniliprole 10.26% OD @ 1 ml/L proved to be the most effective treatment, recording the lowest leafhopper population (20.6 and 12.8 leafhoppers/3 leaves/plant at 7 and 14 DAT after the first spray) compared with 83.0–93.8 in the untreated control. It resulted in the highest reduction over control (86.3% after the first spray and 84.7% after the second spray), followed by thiacloprid and the standard check Profenophos. After the second spray, cyantraniliprole maintained the minimum population (20.9–16.6 leafhoppers/3 leaves/plant) as against 102.1–108.8 in the untreated control. All treatments significantly enhanced seed yield, with cyantraniliprole producing the highest yield (2257 kg/ha) and benefit–cost ratio (1:8.3), followed by profenophos and thiacloprid.

Keywords*: Castor, field efficacy, leafhopper, management, newer insecticides*

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Bio-efficacy of endophytes against soil borne diseases in castor

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Castor (*Ricinus communis* L.) is an economically important crop; however, its cultivation is severely affected by wilt caused by *Fusarium oxysporum* f. sp. *ricini*, and root rot caused by *Macrophomina phaseolina* which are destructive soil- and seed-borne pathogens widely reported in major castor-growing regions. The management of these diseases remains particularly challenging due to the polyphagous nature of the pathogens and its prolonged survival in the soil. In recent years, biological management of plant diseases has emerged as an effective, environmentally benign, and sustainable alternative to chemical control, especially in the context of organic agriculture. Among the various biocontrol strategies, the exploitation of beneficial endophytes as biological control agents remains relatively underexplored, despite their significant potential in crop protection. In this backdrop, the present investigation is undertaken to identify and evaluate endophytic microorganisms

for the effective management of wilt incidence in castor. Endophytes were isolated from castor plants of different genotypes at 15, 30, 45, and 60 days after sowing (DAS). Among the different sampling stages, the highest number of endophytes was recovered at 30 DAS, followed by 45 DAS. In addition, stem tissues yielded a greater number of isolates compared to root tissues. Further, eight castor genotypes collected from different fields of IIOR and RARS, Palem, were utilized for endophyte isolation. In total, 222 endophytic microorganisms were obtained, comprising 36 fungal and 186 bacterial isolates. In vitro evaluation using the dual culture technique demonstrated that the endophytic isolates inhibited *Macrophomina phaseolina* and *Fusarium oxysporum* f. sp. *ricini*, with percentage inhibition ranging from 7.78 to 83.30%. Among the 186 bacterial endophytes evaluated against *M. phaseolina*, isolate CERB 50 exhibited the highest mycelial growth inhibition (77.7% over control), whereas the lowest inhibition (7.78% over control) was recorded with isolate CERB 9. Among the 36 fungal endophytes tested, isolate CESF 16 showed the maximum growth inhibition (83.3% over control), while the minimum inhibition (36.11%) was observed with isolate CERF 11. Similarly, against *F. oxysporum* f. sp. *ricini*, among the bacterial endophytes, isolate CERB 4 recorded the highest growth inhibition (77.8% over control), whereas isolate CESB 80 exhibited the lowest inhibition (7.78% over control). Among the fungal endophytes, isolate CESF 16 again demonstrated the highest inhibitory activity (80.0% over control), while the lowest growth inhibition (50.66% over control) was observed with isolate CESF 18. Out of the 222 endophytic isolates screened, eleven demonstrated strong antagonistic activity (>60% inhibition) against *M. phaseolina* and *F. oxysporum* f. sp. *ricini*. These included four root endophytic bacterial isolates—CERB 50 (78.89%, 73.5%), CERB 58 (73.89%, 71.8%), CERB 87 (70.56%, 65.9%), and CERB 4 (70.0%, 77.8%); two stem endophytic bacterial isolates—CESB 43 (75.5%, 77.6%) and CESB 81 (68.8%, 75.3%); two root endophytic fungal isolates—CERF 6 (74.44%, 77.6%) and CERF 2 (73.33%, 78.8%); and three stem endophytic fungal isolates—CESF 16 (83.33%, 80.0%), CESF 6 (78.8%, 78.8%), and CESF 15 (75.5%, 76.5%). Endophytes are increasingly recognized as promising biocontrol agents owing to their superior colonization efficiency and adaptability within host tissues. In addition to providing effective disease suppression, endophytic microorganisms contribute to enhanced host fitness by promoting plant growth and improving yield potential.

Keywords: *Castor, endophytes, F. oxysporum f. sp. ricini, M. phaseolina, root rot, wilt*

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Seasonal incidence of insect pests and its natural enemies of castor in Salem district of Tamil Nadu

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Castor, *Ricinus communis* L. (Euphorbiaceae) is one of the important annual non-edible oilseed rainfed crops serving pharmaceutical and industrial needs. Castor seeds contain upto 42 per cent extractable oil which has multiple industrial, agricultural, domestic and medical uses. More than100 pest species infest castor crop, but only a few major pests are responsible for the crop losses and mite species account for yield loss of up to 40–89 per cent; from seedling till capsule harvesting, leaf sap-sucking insects and mites, defoliators, capsule feeding insects. Overuse and misuse of synthetic pesticides can result in harmful effects on humans and the environment and toxicity to non-target organisms. An insect population always fluctuates according to the dynamic condition of its environment. Both abiotic and biotic factors are believed to be the factors responsible for the change in a population. Knowledge of the seasonal abundance and trends in the population build-up of pest has become important for effective control schedules. This information helps in developing an efficient management model for the insect pests attacking at various growth stages of the crop. Seasonal population fluctuation of insect pests of castor and determines the influence of various environmental factors on its population in a castor crop. Insect pests of castor and their natural enemies were monitored at weekly intervals in Tapioca and Castor research station, Yethapur. Castor hybrid, YRCH-1 was sown on 30.08.2024 and monitored from 38th standard week to 6th standard week. Castor field was maintained under unprotected condition. Among the sucking pests, leafhopper, whitefly and thrips population were low during *kharif* 2024-25. Leafhopper incidence started during the second fortnight of September and the infestation of leafhopper was recorded throughout the crop period which ranged from 1.77 to 29.31 numbers/3 leaves/plant. Thrips population was low to moderate during October to January.Defoliator population *viz.,* semilooper (0.64 to 2.98 numbers / plant), *S. litura* (1.00 to 5.38 numbers/plant) were recorded, whereas hairy caterpillars ranged from 0.14 to 1.51 numbers / plant and spiny caterpillars ranged from 0.21 to 2.00 numbers / plant and the extent of damage made by the defoliators represented by visually score leaf area ranged from 0 to 2. The parasitisation of semilooper larvae by the parasitoid, *Snellenius maculipennis* was found during 43rd to 49th standard weeks with parasitisation ranged from 40.40 to 65.35 per cent. Capsule borer infestation was observed during 47th to 1st standard week with very low damage ranged from 1.45 to 4.61%. The natural enemies population *viz*., spiders ranged from 0.3 to 2.6 numbers /plant and cociinellids ranged from 0.4 to 2.4 numbers /plant and occurred throughout the cropping period. During the period, the relation between the pests, natural enemies population and weather variables such as Minimum temperature (°C), Maximum temperature (°C), Relative Humidity (Morning %), Relative Humidity (Evening %), Rainfall, Rainy days, Wind speed (Km/hr.) and Sunshine (hours) were correlated. Correlation studies revealed that Leaf hopper populations showed a significant negative correlation with maximum temperature, relative humidity was positively correlated. Semilooper and *Spodoptera* spp. incidence showed a highly significant positive correlation with relative humidity and negative correlation with wind speed Coccinellid populations showed multiple significant negative correlations, including with maximum temperature, number of rainy days and wind speed.

Keywords*: Castor, insect pests, natural enemies, seasonal incidence, weather factors*

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Niger diseases and their management strategies

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Niger (*Guizotia abyssinica*) is an oilseed crop which plays significant role in the food and nutritional security of the poor tribal. It is cultivated to limited extent in Ethiopia, South Africa, East Africa, West Indies and Zimbabwe. India ranks first in area, production and export of Niger in the world. In India it is grown in an area of 0.83 lakh hectare with the production of 0.27 lakh tones and the productivity of 323 kg/ha during 2024. It is grown mainly cultivated in tribal pockets of Odisha, Chhattisgarh, Madhya Pradesh, Maharashtra, Gujarat, Bihar, Karnataka and Andhra Pradesh. Niger is although considered as a minor oilseed, is very important in term of quality and taste of its oil and export potential. Niger is a crop of dry area grown mostly by tribal in interior places due to which desired attention has not been given on the biotic and abiotic stresses. Now the crop is gaining importance and studies are being made on major disease aspects. The important diseases of niger are wilt (*Ozonium texanum* var. *parasiticum* Thirum.), Collar rot (*Sclerotium rolfsii* Sacc.), *Macrophomina* root and stem rot (*Macrophomina phaseolina* (Maubl.) Ashby), *Cercospora* leaf spot (*Cercospora guizoticola*), Alternaria blight (*Alternaria sp.), Curvularia* leaf spot (*Curvularia lunata*) and Powdery mildew (*Sphaerotheca* sp.). Niger diseases damage seeds, seedlings, roots, stems, and foliage, resulting in significant yield losses. Hence management strategies are important component for production of good quality niger seed for higher oil yield. Seed treatment with Thiram (0.2%) + Carbendazim (0.1%) or *Trichoderma viride* @ 10g/kg seed and application of *Trichoderma viride* @ 2.5 kg/ha mixing with 50 kg FYM in the field before sowing can effectively manage the Root and Stem rot disease. Seed treatment with two foliar sprays of containing (0.1% Carbendazim + Mancozeb, 0.2%) for the management of foliar (*Cercospora* leaf spot, Alternaria leaf spot and Powdery mildew) diseases of Niger.

***Keywords**: Bioagents, diseases, fungicides, integrated management, niger*

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Sesame diseases and their management strategies

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Integrated and holistic disease management, which incorporates bio-control agents, botanicals, and organic amendments, can reduce the number of fungicide applications per season while combating diseases in an economically viable and ecologically safe manner. Among the many production constraints, the most important are the lack of improved cultivars and a poor seed supply system. The production and productivity of sesame are further constrained by various abiotic and biotic stresses, such as root rot, stem rot, bacterial blight, phyllody, powdery mildew, *Alternaria*, and *Cercospora* leaf spot. Sesame diseases damage seeds, seedlings, roots, stems, and foliage, resulting in significant yield losses.in case of powdery mildew, seed treatment with thiram (0.2%) + carbendazim 50WP (0.1%) and two foliar sprays with wettable sulphur (0.25%) proved most effective in minimizing incidence. For Alternaria and *Cercospora* leaf spot, two foliar sprays of mancozeb (2%) + carbendazim (1%) were effective. For phyllody, seed treatment with thiamethoxam 70% WS at 5 g/kg, followed by a foliar spray of fiproimida (fipronil 40% + imidacloprid 40% WG) at 2 g/l at 30 and 45 DAS reduced vector populations and disease incidence. In case of root and stem rot, seed treatment with *T. viride* @ 10 g/kg, furrow application of enriched *T. viride* (2.5 kg in 100 kg FYM) @ 250 kg/ha, followed by two foliar sprays at 45 and 60 DAS of the

combination product (tebuconazole 50% + trifloxystrobin 25%) @ 0.5 g/l, was found economical and effective.

***Keywords**: Diseases, bioagents, fungicides, integrated management, sesame*

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Bacterial diversity in healthy and phyllody infected sesame plants revealed through metagenomics and culturomics

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Sesame phyllody disease is a major constraint to sesame cultivation, frequently causing severe yield losses or complete crop failure due to the absence of resistant cultivars and the lack of effective chemical control measures. To identify sustainable disease management alternatives, this study investigated the foliar microbiome by comparing microbial communities associated with healthy and phyllody-infected sesame plants collected from severely affected fields. Using an integrated approach combining culture-dependent methods and high-throughput DNA sequencing, a total of 3,108 bacterial operational taxonomic units (OTUs) were identified, representing several dominant genera, including *Pantoea*, *Pseudomonas*, *Allorhizobium*, and *Xanthomonas*. The phytoplasma, the established causal agent of phyllody disease, was detected exclusively in symptomatic plants. Co-occurrence network analysis revealed marked differences in microbial interactions between healthy and infected plants. Healthy plants exhibited relatively balanced and stable microbial networks, with *Pantoea*, *Pseudomonas*, and *Sphingomonas* acting as key hub taxa. In contrast, phyllody-infected plants displayed denser and more complex microbial networks, suggesting substantial phytoplasma-induced alterations in foliar microbial community structure. From culture-based isolation, 72 bacterial strains were recovered, with *Pantoea* being the predominant genus in both healthy and diseased plants. Functional prediction analyses indicated that the foliar microbiome is strongly associated with nutrient metabolism and the biosynthesis of alpha-linolenic acid, a naturally abundant and biologically important compound in sesame. To our knowledge, this is the first comprehensive study of the sesame foliar microbiome under phyllody disease pressure. The findings provide new insights into plant–microbiome–phytoplasma interactions and offer a foundation for developing microbiome-based, eco-friendly strategies for the sustainable management of sesame phyllody disease.

Keywords: *Bacterial communities, culturomics, metagenomics, phyllody, sesame*

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Unraveling sesame resistance to *Antigastra catalaunalis* Duponchel (Lepidoptera: Crambidae): insights from morphological, physiological, and biochemical traits

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Sesame (*Sesamum indicum*) is a vital oilseed crop, but its productivity is severely impacted by *Antigastra catalaunalis* infestation, leading to significant yield losses. Understanding resistance mechanisms in sesame genotypes is crucial for developing pest-resistant cultivars. This study aimed to evaluate resistance

levels among different sesame genotypes and identify key morphological, physiological, and biochemical traits associated with resistance. Ten sesame genotypes along with resistant check (Swetha), susceptible check (Prachi), and highly susceptible germplasm (PI 170726) were screened under controlled conditions for resistance to *A. catalaunalis*. IC-500343 and Swetha exhibited the lowest leaf damage (7.32%, 7.76%) and capsule infestation (1.50%, 2.20%), classifying them as highly resistant (HR). Conversely, Prachi and PI 170726 recorded the highest damage (40.74%, 45.64% leaf; 31.90%, 32.10% capsule), confirming high susceptibility (HS). Resistant genotypes showed delayed larval and pupal development, reduced fecundity, and lower adult emergence, indicating antibiosis effects. Principal Component Analysis (PCA) revealed trichome density, antioxidant enzyme activity, and specific leaf weight as key resistance traits, with PC1 explaining 63.184% of the variance. Hierarchical clustering grouped genotypes into HR, MR, and HS categories, validating their resistance classification. This study identifies key resistance traits and genotypes that can be used in breeding programs for pest-resistant sesame cultivars. Selecting genotypes with high trichome density, enhanced antioxidant activity, and reduced relative water content (RWC) could help develop sustainable pest-resistant varieties, reducing pesticide dependency and improving sesame yield.

Keywords: *Antigastra catalaunalis, biochemical defense, host plant resistance, morphological traits, principal component analysis, sesame*

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Assessment of sesame genotypes for *Macrophomina* stem and root rot resistance and eco-friendly management practices

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Sesame (*Sesamum indicum* L.) is a vital oilseed crop known for its high dietary protein and oil content, rich in oleic and linoleic acids. Despite its potential, sesame productivity is hindered by poor management and susceptibility to stresses; particularly diseases like *Macrophomina* stem and root rot. This disease, caused by *Macrophomina phaseolina*, thrives in warm climates and dry conditions, causing significant yield losses. The pathogen's resistant microsclerotia can persist for 2 to 15 years, germinating under high temperatures and low moisture, and invading the plant's vascular system. Symptoms include stem lesions, wilting, chlorosis, and root blackening, often leading to plant death. *Macrophomina phaseolina* causes yield losses between 15% and 100%, presenting a global economic threat. Conventional chemical fungicides, while common, pose environmental and health risks, contribute to pathogen resistance, and harm ecosystem biodiversity. They can also impair crop physiology, particularly photosynthesis. The study aimed to evaluate the sesame genotypes against *Macrophomina* stem and root rot and to explore eco-friendly management strategies using biocontrol agents and organic amendments. The genotypes were screened in sick plot at the Agricultural Research Station, Mandor, Jodhpur Rajasthan, and categorized based on disease incidence. Notably, 12 genotypes exhibited low disease incidence and high yield potential. Field experiments were also carried out at same station during kharif seasons of 2022-2023 and 2023-2024 years with different eight treatments and three replications in randomized block design. The treatment combining seed treatment with *Trichoderma harzianum* @ 10 g/kg of seed – Furrow application of enriched *T. harzianum* (2.5 kg *Trichoderma* + 100 kg vermicompost) @ 250 kg/ha followed by Rhizosphere inoculation of *T. harzianum* at thinning, and spray at flowering and capsule stage @ 5g/l showed the lowest disease incidence (6.56%) with highest disease control (75.70%). This treatment also resulted ~2.6 fold and ~1.4 fold higher yield over the untreated check and carbendazim like chemical pesticides, respectively. Maximum net return (¹ 45,480/ha), and B:C ratio (3.33) were also recorded with the same treatment. This study highlights the effectiveness of integrated biocontrol strategies for managing *Macrophomina* stem and root rot, providing

a sustainable approach for sesame cultivation.

Keywords: *Disease incidence, macrophomina, stem and root rot, sesame, Trichoderma harzianum*

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Impact of meteorology variable on the incidence of sesame insect pests in Bundelkhand region of Madhya Pradesh

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Sesame (*Sesamum indicum* L.) is an important oilseed crop of India, valued for its edible oil and nutritional significance. Its productivity, however, is affected by a complex of insect pests at different growth stages, with incidence largely influenced by weather conditions. To understand pest dynamics in relation to meteorological variables, a field study was conducted during the kharif seasons of 2021 and 2022 at the AICRP on Sesame, College of Agriculture, JNKVV, Tikamgarh, Madhya Pradesh. Weekly observations on major pests and natural enemies were recorded from 10 randomly selected plants at five spots, based on Standard Meteorological Weeks (SMWs). Corresponding weather data were collected from the college observatory, and pooled two-year data were analyzed for correlations between pest incidence and meteorological parameters. The population of leaf webber and capsule borer (*Antigastra catalaunalis*) varied across SMWs, starting at 0.01 larvae/plant in the 29th SMW (16–22 July) and peaking at 0.56 larvae/plant in the 37th SMW (10–16 September). Plant damage increased from 2.50% to a maximum of 41.00% in the 33rd SMW and remained high (39.50%) in the 37th SMW, indicating severe infestation during flowering and capsule formation. Bud fly (*Asphondylia sesame*) appeared in the 36th SMW (3–9 September) with 0.06 maggots/plant and 11% flower damage, peaking at 0.45 maggots/plant and 14.27% damage in the 37th SMW, while maximum flower damage (20%) occurred in the 39th SMW. Among sucking pests, jassid (*Orosius albicinctus*) peaked at 1.28/plant in the 37th SMW, whitefly (*Bemisia tabaci*) at 1.63/plant in the 36th SMW, and mirid bug (*Nesidiocoris tenuis*) at 1.27/plant in the 36th SMW. Semilooper (*Thysanoplusia orichalcea*) reached 2.92/plant in the 38th SMW, while sting bug (*Nezara viridula*) peaked at 0.71/plant in the 37th SMW. Natural enemies showed distinct seasonal trends. Chrysoperla spp. peaked at 0.04 adults/plant in the 37th SMW, coinciding with peak pest incidence, while Coccinella spp. reached 0.36 adults/plant. Dragonfly population was highest (0.12 adults/plant) in the 32nd SMW, and honey bee activity peaked at 0.65 bees/10 cm²/5 minutes during the 35th–36th SMW, corresponding to peak flowering. Correlation analysis (pooled 2021–2022) showed that abiotic factors significantly influenced pest incidence. Leaf webber and capsule borer were negatively correlated with minimum temperature (r = –0.53), rainfall (r = –0.39) and evaporation (r = –0.50). Bud fly showed highly significant negative correlations with minimum temperature (r = –0.66**), relative humidity (morning r = –0.76**, evening r = –0.66**) and rainfall (r = –0.86*), indicating reduced incidence under humid and rainy conditions. Jassid, whitefly, mirid bug, and semilooper were negatively influenced by rainfall and evaporation (r = –0.43 to –0.59). Sting bug showed weak positive correlations with rainfall (r = 0.41) and morning RH (r = 0.32). Among natural enemies, dragonfly had highly significant negative correlations with minimum temperature and RH (r = –0.84*), while Chrysoperla, Coccinella, and honey bee showed weak positive associations with humidity and slight negative correlation with rainfall and evaporation. The study concludes that maximum pest pressure occurred during August to mid-September, coinciding with flowering and capsule formation stages and favorable climatic conditions. Weather parameters played a crucial role in regulating pest and natural enemy populations. The findings are valuable for developing weather-based pest forecasting models and implementing need-based IPM strategies for sustainable sesame production in Bundelkhand region of Madhya Pradesh.

Keywords: *Bundelkhand, insect pests, IPM, natural enemies, sesame, seasonal incidence, weather parameters*

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Integrated management of major diseases of sesame

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Sesame (*Sesamum indicum* L.) is one of the oldest edible oilseed crops, belongs to the family Pedaliaceae. Sesame seeds are rich in protein and lipids having many health benefits. Sesame crop yields are affected by biotic and abiotic stresses. Among the biotic stresses fungal, bacterial and phytoplasma diseases significantly reduce sesame crop yields. Major diseases such as *Macrophomina* stem and root rot, *Alternaria* leaf spot and phyllody diseases remain key challenges in sesame cultivation. In view of this, field trials were conducted during two consecutive kharif seasons in 2024 and 2025 under AICRP on sesame scheme at Regional Agricultural Research Station, Jagtial, Telangana with main objective to evaluate different integrated disease management strategies for effective control of major diseases of sesame. The trial results revealed that, among the tested six treatments, T3 (Seed treatment with carbendazim @ 3g/kg and tank mix spray of tebuconazole 50%+ trifloxystrobin 25% @ 1g/l at 45 DAS + spray of thiamethoxam 25% WG @ 0.5g/l of water and spray of sulphur @ 2g/l at 65 DAS treatment showed least mean *Macrophomina* stem and root rot incidence (22.38%), phyllody (12.50%) and Alternaria leaf spot (45.00%) with seed yield 602.38 kg/ha followed by treatment T1 (Seed Treatment with *Trichoderma* sp. @10g/kg of seed and furrow application of enriched vermicompost (2.5 kg *Trichoderma* sp. + 100 kg vermicompost) @150 kg/ha at the time of sowing followed by spray of nimbicidine @ 5ml/l at 45 DAS and spray of sulphur @2g/l at 65 DAS) with stem and root rot incidence (33.95%), Phyllody(17.25%) and Alternaria leaf spot (66.50%) with seed yield 506.08 kg/ha. Hence, this integrated management strategy *viz*., seed treatment with carbendazim @ 3g/kg and tank mix spray of tebuconazole 50%+ trifloxystrobin 25% @ 1g/l at 45 DAS + spray of thiamethoxam 25% WG @ 0.5g/l of water and spray of sulphur @ 2g/l at 65 DAS can be used for effective management of major diseases of sesame.

Keywords*: Integrated disease management, phyllody, sesame, stem and root rot*

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Influence of weather parameters and management strategies for phytophthora blight in sesame caused by *Phytophthora parasitica* var. *sesame*

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Phytophthora blight in sesame, caused by *Phytophthora parasitica* var. *sesami*, is a destructive pathogen with a wide host range. Phytophthora blight can cause up to 80% yield loss. Plant mortality due to this disease can reach as high as 72–79%. The disease is particularly fatal at the seedling stage, with plant mortality ranging from 72–80%. Under highly favourable conditions, it can lead to total crop loss when seedlings are severely infected. The pathogen is both seed-borne and soil-borne, making the crop highly vulnerable at all growth stages. The initial signs of Phytophthora blight include water-soaked lesions on the leaves and stem, which first appear brown and later darken to black. This disease can attack plants at any stage of growth and causes the most harm when environmental conditions support the pathogen's rapid development. The fungus attacks all parts of the plant, including roots, stems, leaves, flowers, pods, and seeds. Severe infection occurs during

prolonged rainfall or waterlogging, leading to root and basal stem infections due to poor aeration, which results in high plant mortality. In later stages, the pathogen spreads from diseased plant parts to pods, causing rotting. While some infected pods may still produce seeds, these are typically diseased, have low viability, and can spread contamination to healthy seeds. The present investigation on *impact of weather parameters and management of phytophthora blight in sesame caused by Phytophthora parasitica var. sesami*, was conducted during *kharif* 2024. Laboratory experiments were carried out in the Department of Plant Pathology, and field experiments were conducted at the AICRP on Sesame and Niger, JNKVV, Jabalpur. The progression of Phytophthora blight in sesame cultivar RT-351 was studied under natural field conditions. Disease incidence increased from 3.45% (34th SMW) to 3.69% (43rd SMW), with faster progression between 9–16 September (36–37 SMW). Data showed positive correlations of disease incidence with relative humidity, soil moisture, rainfall, and rainy days, while minimum temperature was negatively correlated. In the present study, different fungicides were evaluated under field conditions. The maximum percentage of disease reduction over control was observed in T5 (seed treatment with carbendazim 12% WP + mancozeb 63% WP), followed by foliar application of the same fungicide.

***Keywords**: Fungicides, management, phytophthora blight, sesame, weather parameters*

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Climate-resilient management of powdery mildew in sesame through ready-mix fungicide strategies under changing climatic conditions

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Sesame (*Sesamum indicum* L.) is an important oilseed crop cultivated across diverse agro-climatic regions of India. In Gujarat, sesame productivity is severely affected by powdery mildew caused by *Erysiphe cichoracearum*, which appears regularly under favourable weather conditions and may result in heavy yield losses. The disease initiates as white powdery patches on leaves, leading to defoliation and reduced seed yield. Although farmers use conventional fungicides for disease management, the efficacy of newly available ready-mix fungicide formulations against sesame powdery mildew under field conditions remains inadequately documented. Therefore, the present study was undertaken to evaluate the field efficacy of different ready-mix fungicides for effective management of powdery mildew in sesame. The field experiment was conducted during *kharif* 2023–24 at the Agricultural Research Station, Junagadh Agricultural University, Amreli, situated in the North Saurashtra Agro-climatic Zone (VI). The experiment was laid out in a Randomized Block Design with three replications, using sesame variety Gujarat Sesame-3. Eight ready-mix fungicide treatments along with water spray and untreated control were evaluated. A common seed treatment with thiram @ 3 g/kg seed was applied. Fungicides were sprayed at disease initiation followed by a second spray after 15 days using 500 L water/ha. Disease intensity was recorded using a 0–9 scale and converted to percent disease intensity. Seed yield was recorded at harvest and data were statistically analysed. All fungicide treatments significantly reduced powdery mildew intensity and improved seed yield compared to the control. The results revealed that fluxapyroxad 167 g/l + pyraclostrobin 333 g/l SC (0.030%) was most effective, recording the lowest disease intensity (9.94%) and the highest seed yield (732 kg/ha). This was followed by pyraclostrobin 12.5% + epoxyconazole 4.7% SE, which also significantly reduced disease severity and improved yield. In contrast, untreated control plots showed high disease intensity (71.91%) and the lowest yield (290 kg/ha). The study demonstrates that climate-responsive fungicide combinations can effectively mitigate biotic stress, stabilize yield and enhance the resilience of sesame production under changing climatic conditions, thereby contributing to sustainable oilseed production in climate-vulnerable regions.

***Keywords**: Diseases, management, powdery mildew, ready-mix fungicide, sesame*

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Combined application of *Trichoderma asperellum* and AM fungi reduces root rot disease incidence (*Macrophomina phaseolina*) in sesame

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Sesame is liable to be infected by various pathogenic fungi like leaf blight and root rot at all the stages of crop growth. Therefore, the present study was carried out to evaluate the effect of bio agents on managing the diseases. Seed treatment with *Trichoderma asperellum* @ 4 g/kg of seed + soil application of *Trichoderma asperellum* (2.5 kg/ha) mixed with FYM @150 kg and VAM 10 kg as basal application resulted in minimum root rot incidence (14.87) and maximum per cent reduction of disease over control. Population of *Trichoderma* from rhizosphere of soil from different treatments by dilution plating technique. From these soil samples, *Trichoderma* was isolated and estimated on TSM medium by using dilution 10^4. The number of colonies of *Trichoderma* was 38.30 x 10^4 CFU and 21.48 x 10^4 CFU/g of soil from T_1 where as in T_2 the population was 02.24 x 10^3 CFU, 05.89 x 10^3 CFU, 16.68 x 10^3 CFU and 11.70 x 10^4 CFU /g of soil at 40 and 80 days after sowing when compared to control which is recorded to 12.98 x 10^4 CFU and 5.42 x 10^4 CFU /g of soil. The population density of AM enumerated by wet sieving and decanting method from rhizosphere of soil from different treatments. The number of AM spores was maximum in T_1 with 42.14 and 35.87/100g of soil as compared to control with 15.66 and 13.27/100g of soil. The maximum seed yield of 678 kg/ha was observed in the effective treatment; whereas minimum seed yield of 446 kg/ha was observed in the control.

Keywords: *AM fungi, management, root rot, sesame, trichoderma asperellum, yield*

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Plant growth regulator mediated crop growth responses, physiological efficiency and seed yield of sesame

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A field experiment on plant growth regulator mediated crop growth responses, physiological efficiency and seed yield of sesame was conducted during *kharif* season of 2025-26 at the Research Farm, All India Coordinating Research Project Unit (Sesame and Niger), JNKVV, Jabalpur. The experiment was conducted in a randomized block design with three replications and eleven treatments. The treatment comprised of T1 : Control, T2 : Salicylic acid @ 200 ppm at 60 DAS @ 300 L/ha,T3 : Salicylic acid @ 100 ppm at 45 & 60 DAS @ 300 L/ha, T4 : Paclobutrazol @ 200 ppm at 60 DAS @ 300 L/ha, T5 : Paclobutrazol @ 100 ppm at 45 & 60 DAS @ 300 L/ha, T6 : Mepiquat chloride @ 200 ppm at 60 DAS @ 300 L/ha, T7 : Mepiquat chloride @ 100 ppm at 45 & 60 DAS @ 300 L/ha, T8 : Chlormequat chloride @ 200 ppm at 60 DAS @ 300 L/ha,T9 : Chlormequat chloride @ 100 ppm at 45 & 60 DAS @ 300 L/ha, T10: KCL @ 2% at 60 DAS @ 300 L/ha, T11: KCL @ 2% at 45 & 60 DAS @ 300 L/ha. The sesame variety RT-372 was sown in the experimental field with recommended package of practice at a spacing of 30x10 cm row to row and plant to plant. The results revealed that the application of plant growth regulators had substantial influence on plant growth and physiology, productivity and quality of sesame as compared to the control treatment. The plant height varied between 105.56-115.11 cm under different treatment, however maximum

plant height was recorded in the treatment T11 KCL @2% at 45 and 60 DAS (115.11cm). The application of PGRs resulted in improved physiological efficiency led to enhanced yield attributes which reflected in terms of final yield of the crop. The treatment T8 (Chloremequat chloride @ 200ppm 60 DAS) recorded the highest number of capsules per plant (68.33), and seed yield (692.03 kg ha{ ¹), while the treatment T9 (Chloremequat chloride 100ppm at 45 and 60 DAS) recorded the highest number of seeds per capsule (68.83). The differences in yield attributes and the seed yield could not attain the level of significance and varied between number of capsule/plant (55.78-68.33), number of seed/ capsule (55.67-68.83), and seed yield (511.86-692.3 kg/ha). Hence it can be concluded that there is effect of PGRs on crop growth and yield but it could not attain the level of significance. Among various treatments T8 i.e. Chloremequat chloride @ 200ppm at 60 DAS was found best.

***Keywords**: Chloremequat chloride, growth attributes, PGRs, sesame, yield attributes*

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Survey, epidemiology, physiology for sesame phyllody and its ecofriendly management

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India, the 4th largest vegetable oil economy in the world, stands first in the production of castor, sesame, safflower, and niger oils, whereas second in groundnut. India ranks first in world with 19.47 lakh ha area and 8.66 lakh tonnes production. The average yield of sesame (413 kg/ha) in India is low as compared with other countries in the world (535 kg/ha). In India, infected sesame crop becomes partially or fully sterile resulting in complete yield loss and incidence ranges from 10-100%. Sesame Phyllody has become a potential threat to sesame cultivation itself. The main reasons for low productivity of sesame and heavy yields losses due to phyllody and root rot in Tamil Nadu. Survey for three years during 2023-2025 revealed that the disease severity ranged from 1.3% to 25.8% phyllody. The phyllody infected plants recorded less photosynthetic rate (8.46 µmol $CO_2 m^{-2} s^{-1}$), transpiration rate E (Trmmol) (3.24 mmol H_2O m^{-2} s^{-1}), stomatal conductance to H_2O (gs gsw) 0.45 mol H_2O $m^{-2} s^{-1}$, intercellular CO_2 concentration Ci Ci 360 µmol $CO_2 mol^{-1}$ comparing to healthy plants (12.0, 3.97, 0.85 and 336) using portable photosynthetic measuring equipment and also reduced the chlorophyll content for SPAD meter. Field experiment was conducted during 2024-25 to evaluate management strategies against phyllody. Seed treatment with thiamethoxam 70% WS @ 5 g/kg seed and foliar spray of fiproimida (fipronil 40%+imidacloprid 40% WG) @ 2g/l at 45 and 60 DAS (T_6) which recorded low phyllody disease incidence (10.29%) with yield of 616 kg/ha. Control recorded the maximum phyllody disease incidence (30.23%) with minimum yield of 402 kg/ha. The BCR varied significantly among the treatments. Higher BCR was recorded with T_6 (2.47) which includes seed treatment with thiamethoxam 70% WS @ 5 g/kg and foliar spray of fiproimida (fipronil 40%+imidacloprid 40% WG) @ 2g/l at 45 and 60 DAS whereas it was lower with control (1.4).

***Keywords**: Phyllody, physiology changes, management, sesame*

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Exploring novel chitosan based nano particles for antimicrobial activity against *Macrophomina phaseolina* causing stem and root rot in sunflower

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Agricultural productivity has long benefited from use of agrochemicals in plant disease management; however, excessive, and indiscriminate application of chemical pesticides has led to serious environmental and health concerns, including soil degradation, ecological imbalance, and the development of resistance in major crop pests. These limitations highlight the need for safe and sustainable alternatives for plant disease management. Chitosan is an eco-friendly and biodegradable biopolymer, with broad-spectrum antimicrobial activity against pathogens. Advancements in nanotechnology further enhance its applicability, as nano-formulations enable improved delivery, controlled release and increased efficacy. Copper-based nanoparticles are well known for their antifungal activity, and their combination with chitosan may offer synergistic effects in supressing plant pathogens. *Macrophomina phaseolina*, the causal agent of stem and root rot in sunflower, is a persistent soil-borne pathogen that is difficult to manage using conventional fungicides. This study, therefore, focuses on the evaluation of chitosan-based copper nanoparticles for their antifungal efficacy against *M. phaseolina* under *in vitro* conditions. Chitosan and chitosan-based Cu-nanoparticles were synthesized and characterized at ICAR-IIOR following standard protocols. Twenty-five isolates of *M. phaseolina* were isolated from infected sunflower samples collected from Telangana, Andhra Pradesh, Ludhiana, Maharashtra and Haryana. Pathogenicity tests against sunflower were conducted using the rolled paper towel method (*in vitro*) and soil inoculation (pot experiment) and the most virulent *M. phaseolina* isolate was identified for further bio-efficacy studies using agar well diffusion method and poisoned food technique. The results of the bio-efficacy assay showed significant inhibition in mycelial growth of *M. phaseolina*, in a dose-dependent response to chitosan concentration recording upto 90% inhibition at 1500 ppm, while Chitosan nanoparticles showed approximately 60% inhibition at 10,000 ppm and 80% at 15,000 ppm, which needs further validation, whereas Cu-chitosan nanoparticles achieved 90% inhibition at 10,000 ppm. The enhanced efficacy of Cu-chitosan nanoparticles highlights the potential synergistic effect in combination of metal nanoparticles with biopolymers. These findings demonstrate that chitosan-based nano formulations can be used as a novel alternative to chemical fungicides by reducing chemical load and increase its antifungal efficiency. Further research may support the development of biopolymer-based nano formulations for advanced application systems, including drone-based spraying.

Keywords: *Antifungal efficacy, chitosan, copper nanoformulations, macrophomina phaseolina, sunflower*

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Screening of sunflower genotypes for moisture stress tolerance based on physiological and biochemical parameters

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Moisture stress induces a range of physiological and biochemical changes in plants, which plays a key role in regulating water relations, photosynthesis and osmotic responses under stress conditions, forming the basis for differential stress tolerance among genotypes. Therefore, present study evaluated 42 sunflower pre-breeding lines derived from *Helianthus argophyllus* along with two checks *i.e.* RSLP-14 and R-127-1 under different moisture stress conditions in a factorial RBD design with two replications. Moisture stress was imposed by withholding irrigation at three critical growth stages; T_1: 20 to 40 DAS (vegetative stage), T_2: 40 to 60 DAS (flowering stage) and T_3: 60 to 80 DAS (seed filling stage) along with well-watered control plot. Results revealed that imposed moisture stress treatments had a distinct influence on the physiological and biochemical responses indicating substantial genetic variability existed among the genotypes studied. Relative water content declined from 96.2% (PBM-4) under control conditions to 54.1% (PBM-9) in Tf , while the rate of water loss decreased from 7.4 g/g (PBM-13) in the control to 1.1 (PBM-26) g/g in Tf . Specific leaf area also reduced markedly from 264.5 (PBM-13) cm²/g in the control to 74.2 cm²/g (PBM-24) in Tf. In contrast, specific leaf weight increased from 3.8 mg/cm² (PBM-13) in control to 13.5 (PBM-24) mg/cm² in T_3 and proline accumulation rose substantially from 1.0 µmol /g tissue (R-127-1) in the control to 48.1 µ/mol g tissue (PBM-3) in Tf. For traits like RWC, RWL, SLA and SCMR per cent reduction was high at 75 DAS in comparison with control by 9.4 per cent, 43.2 per cent, 22.3 per cent and 19.2 per cent, respectively whereas SLW and proline content increased in comparison with control by 30 per cent and 47.4 per cent, respectively. Rank sum analysis based on physiological and biochemical traits identified PBM-18, PBM-24, PBM-35, PBM-6 and PBM-33 as moisture stress tolerant genotypes.

***Keywords**: Moisture stress, physiological traits, pre-breeding lines, sunflower*

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Cultural and morphological variation of *Alternaria species* causing leaf blight of sunflower

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Sunflower (*Helianthus annuus* L.) is one of the important oilseed crops in the world and it ranks third in area after groundnut, mustard and rapeseed. Among the major diseases of sunflower, Alternaria leaf blight caused by *Alternaria helianthi* (Hansf.) Tubaki and Nishihara is most devastating disease in Karnataka. In this study total 24 phytopathogenic isolates from Alternaria leaf blight samples were collected from different locations of Karnataka to study the variability in term of morphological and cultural *viz*., growth rate, colony colour, aerial mycelium colour, growth pattern, sporulation, conidial size, conidial septation. In case of growth rate RCA2, VJA2 and VJA3 were observed very fast growing it cover up to 84 mm growth within 10 days of inoculation on PDA media. With respect to Colony colour isolates BGA1, BGA2, BGA3, GDA, GDA4, RCA1, VJA1 have shown whitish with brown centre to whitish with grey centre remaining isolates have shown brown to grey colour. Zonation was present in the isolates viz., BGA1, BGA2, BGA3, CHA2,

CHA4, RCA1, RCA4, VJA2, VJA3 and VJA4 and Zonation was absent in remaining isolates. Further with respect to sporulation maximum sporulation was observed in the isolates viz., BGA3, KPA1, KPA2, KPA3 and KPA4 isolates. In case of conidial size GDA3 isolate has shown maximum conidial length of 79.25 ìm and width of 24.51ìm and also having highest transverse septa of 5-7 and longitudinal septa 3-4. Isolate KPA3 has recorded lowest conidial length 25.36 ìm and width 12.56 ìm.

***Keywords**: Alternaria species, cultural and morphological variation, leaf blight, phytopathogenic isolates, sunflower*

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Influence of weather parameters on charcoal rot incidence in sunflower

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Sunflower (*Helianthus annuus* L.) is an important oilseed crop in Punjab during the spring season. It is affected by charcoal rot, which is brought on by the polyphagous fungus *Macrophomina phaseolina.* A field study was carried out at Punjab Agricultural University in Ludhiana to determine how different sowing dates and weather parameters affected the charcoal rot disease, seed yield, and other growth parameters in sunflower. The experiment was set up using a randomized block design, with three replications and four different dates of sowing—January 31, February 14, February 29, and March 15. Delays in sowing from January 30 to March 15 resulted in higher disease incidence and severity as well as lower seed yield. Sunflower sown on March 15th reported the highest mean disease severity (62.67%), while sunflowers sown on January 31st showed the lowest mean disease severity (33.50%). Since sowing was postponed from January 31 to March 15, the mean seed yield dropped from 20.10 to 16.00 q/ ha. Plant height, sunflower head and stem girth at various locations (top, middle, and bottom), all tend to decline as sowing is postponed from January to mid-March. With a correlation coefficient of 0.71 and 1.00 for mean temperature and sunshine hours, respectively, the incidence of charcoal rot and weather parameters showed a positive relationship. The incidence of charcoal rot, on the other hand, had a negative correlation ($r = -0.54$) with rainfall. The results demonstrated a strong correlation ($r = 0.89$) between mean temperature, relative humidity, and sunshine hours and the incidence of charcoal rot. Therefore, exposure of late sown sunflowers to high temperature, low relative humidity, and more sunshine hours at flowering stage predisposed them to charcoal rot.

***Keywords**: Charcoal rot, dsease incidence, regression, seed yield, sunflower, weather parameters*

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Nano double-emulsion of crude metabolites of *Bacillus subtilis* BST8 and BST18 as a potential strategy to control Alternaria leaf blight in sunflower

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Sunflower (*Helianthus annuus* L.) is a major oilseed crop whose productivity is increasingly threatened by *Alternaria* leaf blight, caused by *A. alternata*. Conventional fungicides provide effective suppression but raise environmental concerns and contribute to resistance development, necessitating safer and more sustainable disease management approaches. Among biological solutions, *Bacillus* spp. is promising due

to their diverse antifungal metabolites; however, field efficacy is often constrained by rapid degradation and poor environmental stability. With this background, the present study focused on isolating potent *Bacillus* strains, characterising their crude metabolites, and developing a stable nano-formulation to enhance their antifungal performance. Bacterial isolates collected from sunflower rhizospheres and the TNAU culture repository were screened against *A. alternata* using dual-culture assays. Strains BST8 and BST18, which exhibited superior antagonism and were selected for detailed evaluation. The crude metabolites were isolated from these two isolates and tested *in vitro* against the leaf blight pathogen at different concentrations (20,000, 40,000, 60,000, 80,000 and 1,00,000 ppm) using the agar well diffusion method, which resulted in successful control of the pathogenic fungus. Metabolite profiling *via* GC-MS revealed an upregulation of antifungal compounds like Clindamycin and Pyrrolo pyrazine, upon pathogen confrontation, supported by enrichment of fatty acid and folate biosynthesis pathways. Molecular docking predicted a multi-target mode of action, with metabolites showing strong binding affinity to key fungal pathogenicity proteins like Major allergen Alt a1, Large ribosomal subunit protein P1, MFS type transporter MFS19, Transcription activator ACTTR and Dioxygenase ALT11. To improve metabolite stability and delivery, a W/O/W nano double-emulsion was formulated using the crude extract as the core phase, an oil carrier, and a biopolymeric outer phase. The optimised formulation recorded a mean particle size of 152 nm, a zeta potential of +22 mV, confirming good colloidal stability, and successful encapsulation as evidenced by UV–Vis spectroscopy and FTIR. SEM imaging revealed uniformly spherical droplet morphology. Glasshouse studies demonstrated that the metabolite-loaded nano-emulsion reduced disease severity by 61.6%, significantly outperforming unformulated crude metabolites and approaching the efficacy of the chemical fungicide difenoconazole (78.3%). Biochemical profiling of treated plants showed marked enhancement of defence-related enzymes, *viz*., PAL, PPO, PO, and CAT, indicating robust induction of host defence mechanisms and improved oxidative stress management. Overall, the nano double-emulsion of *Bacillus*-derived metabolites presents an efficient and environmentally compatible strategy for controlling *Alternaria* leaf blight in sunflower. The formulation enhances metabolite stability, improves delivery, and strengthens host defence activation, offering a promising biocontrol platform for sustainable disease management in oilseed crops.

***Keywords**: Alternaria leaf blight, bacillus subtilis, management, metabolites, nano double-emulsion, sunflower*

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Screening of sesame germplasms against major insect pest shoot and capsule borer – *Antigastra catalaunalis* duponchal (Crambidae: Lepidoptera)

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Sesame, *Sesamum indicum* L. is one of the traditional and auspicious oilseeds crops widely grown in Asia for its high-quality nutritional seeds and oil. In general yield potential of crop plants are not fully realized due to the challenged forced by abiotic and biotic factors, particularly insect pests. Among the different insect pests infesting sesame crop, *Antigastra catalaunalis* is the major one, since its damaging right from the vegetative stage of the crop to till capsule maturity stage. To manage this biotic stress, farmers Soley depend on insecticides as first resort. However, indiscriminate use of insecticides leads to 3R problems to mother planet earth. Therefore, host plant resistance may serve as a alternate insect pest management strategy and also be a sustainable and environment-friendly one. In light of this, screening experiment was conducted during kharif 2024 a field experiment was conducted at RRS, Vriddhachalam, Cuddalore District, Tamil Nadu, India. A field experiment was conducted to evaluate 150 sesame

germplasms which were received from Project Coordinating Unit, AICRP on sesame and niger, Jabalpur along with a susceptible check (TC 25) and a resistant check (SI 250) to know their relative susceptibility and resistance to Antigastra under field condition. Observations were made on damage (%) done by *A. catalaunalis* during vegetative (30 DAS), flowering (45DAS) and Capsule stage (60 DAS). Observation on sucking pests like whiteflies and mirid bug population also made during vegetative to flowering stage. During vegetative stage, out of 150 germplasms 5 entries showed resistant (R) reaction, 45 entries showed (MR) reaction, 96 showed Moderately susceptible (MS) reaction, 3 entries showed susceptible (S) reaction and one entry showed highly susceptible reaction by recording more than 50% damage. During flowering stage, the damage caused by *A. catalaunalis* is was ranged between 3.5 to 20.76% in various germplasms. During flowering stage 133 entries showed resistant (R) reaction and 17 entries showed MR reaction by recording 10-20% damage. During reproductive stage, damage to capsule was recorded in all the germplasms. Out of 150, IC-23274 recoded moderately resistant (MR) reaction by showing 6.92% damage to capsules (Table 01). Remaining 149 germplasms showed resistant reaction during capsule formation stage by recording less than 5% damage done by *A. catalanaulis*. Whereas, six entries viz., NIC-8059-B, SI-7618-A, NIC-16403, ES-106-B, NIC-7902, NIC- 16410 were showed moderately resistant (MR) reaction by registering 10-20% damage during vegetative and flowering stage. Though the sesame germplasms supplied from PC unit, Jabalpur was white in seed colour none of them was preferred by Mirid bug at RRS, Vriddhachalam. Whereas the released white seeded sesame varieties VRI 3 and VRI 5 showed Mirid bug population (2.8/leaf) under RRS, Vriddhachalam condition. The six entries showed MR reaction both in vegetative and flowering stage may be exploited in resistance breeding against insect pests in sesame.

***Keywords**: Antigastra catalaunalis, shoot and capsule borer, sesame*

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Safeguarding the oilseed frontier: A decade and a half of quarantine interceptions in imported oilseed germplasm (2011–2025)

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The global exchange of Plant Genetic Resources (PGR) is fundamental to achieving national food security and diversifying the genetic base of domestic breeding programs. However, the transboundary movement of seeds also serves as a primary pathway for the inadvertent introduction of exotic pathogens. In the context of oilseed crops such as soybean, mustard, sunflower, and safflower, the risk is particularly high due to the potential for seed-borne transmission of pathogens that do not yet exist in our local agro-ecosystems. This report presents detail of the systematic testing protocols employed for the interception of fungal and bacterial pathogens of quarantine significance in imported oilseed germplasm. Over a sustained period of quarantine testing from 2011 to 2025, diverse consignments were subjected to a battery of rigorous diagnostic procedures. Our findings highlight the interception of high-risk fungal pathogens, including various species of *Peronospora mashurica*, *Diaporthe longicolla*, D. *phaseolorum* in soybean, *Puccnia helianthi* in sunflower, *P. carthemi* in safflower alongside devastating black leg (*Leptosphaeria maculans*) and black rot (*Xanthomonas campestris* pv. campestris) pathogens in mustard. The methodology integrates traditional mycological and bacteriological techniques - such as blotter tests, agar plate methods, and seedling symptom tests - with advanced molecular diagnostics to ensure the highest sensitivity in pathogen detection. A primary focus is placed on pathogens listed under national quarantine regulations, where the goal is ‘zero tolerance’ to prevent the establishment of diseases that could lead to significant yield losses and economic trade barriers. The study underscores the necessity of a robust quarantine framework. Infected samples were subjected to mandatory salvaging treatments or,

in cases of high-risk pathogens with no known cure, total rejection to safeguard the national biosecurity. This lecture will discuss the current trends in intercepted pathogens, the evolving challenges of "hidden" infections, and the critical role of plant quarantine as the first line of defense in protecting our oilseed economy. By ensuring that only pathogen-free germplasm reaches the hands of researchers/ stakeholders, we effectively fortify the biosecurity, long-term sustainability and preserve the integrity of our national agricultural landscape.

***Keywords**: Disease resistance, plant quarantine, oilseed, yield*

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Effect of weather parameters on the incidence and progression of amphobotrys gray mold in Tamil Nadu

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Castor (*Ricinus communis* L.) is a major non-edible oilseed crop in India, contributing over 4,500 crores annually. India is the world's leading producer, accounting for about 73% of global castor output, with 1.19 MT produced from 7.6 lakh ha and an average yield of 1520 kg/ha (2018–2019). Gujarat, Rajasthan, and Andhra Pradesh are the major producing states. Gray mold, caused by *Botryotinia ricini* (Godfrey) Whetzel. is a serious disease that causes severe yield loss, especially during prolonged rains at the spike and capsule formation stage. High humidity, free moisture, and wet conditions during flowering favour disease development. The pathogen requires free moisture for spore germination and growth, making the disease most severe from September to December when humidity is high and decaying vegetation increases spore load. Current management relies on timely fungicide applications such as carbendazim before and after rains, based on weather forecasts. Cultural practices are also essential: reducing moisture on plant surfaces, avoiding overhead irrigation during bloom (or irrigating early), increasing spacing for better ventilation, removing infected plant debris and old flowers, and minimizing conditions that favour condensation and prolonged leaf wetness. These practices help reduce both disease incidence and severity.

***Keywords:** Castor, gray mold, epidemiology, weather parameter*

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Technology assessment and yield gap analysis of Indian mustard (*Brassica juncea*) affected by Sclerotinia rot through on-farm testing (OFT) under farmers' fields of STCs.

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Mustard (*Brassica juncea*) is one of the major oilseed crops of India, contributing 27.8% to the total Indian oilseed economy and accounting for nearly 80% of Rabi oilseed production. It is cultivated over an area of 5.96 million ha, with a total production of 8.32 million tonnes and an average productivity of 1,397 kg ha^{-1} (GOI, 2018). Among the mustard-producing states of India, Rajasthan is the premier producer, contributing about 45% of the total national and Alwar district was which under improved management practices can exceed 2,138 kg ha^{-1}.

To achieve self-sufficiency in edible oils by 2047, India aims to substantially enhance mustard productivity, targeting an average yield of 20 quintals ha^{-1} (2,000 kg ha^{-1}) by 2030, with further increases envisioned by 2047 to bridge the existing yield gap of more than 900 kg ha^{-1} compared to the global average, Sclerotinia rot, in mustard may hindered in achieving this goal because Sclerotinia rot, caused by *Sclerotinia sclerotiorum* (Lib) de Bary, is a highly destructive fungal disease of mustard (rapeseed–mustard) that leads to severe yield and economic losses can reach 50–80% under favorable environmental conditions, The organism is most ubiquitous, wide host range (> 400), soil-borne and destructive plant pathogen distributed worldwide and makes management difficult, as it affects many common rotation crops. In Alwar district is one of the major mustards producing district of Rajasthan of having more than 2.5 lac ha area is under mustard cultivation and already available technology for management of SR not much effective. Hence, it is important that assessment and refinement of technology should be done through on-farm testing. The technologies developed by ICAR–IIRMR was evaluated/assessed through On-Farm Trials (OFTs) during the 2020–21, 2021–22, and 2022–23 cropping seasons at Krishi Vigyan Kendra (ICAR- IIRMR) Gunta Bansur Alwar Rajasthan. The result recoded during the crop season and found that the treatment (T_3) i.e. Seed treatment with carbendazim 50% WP @ 2 g/kg seed and Foliar spray of tebuconazole @ 0.5 ml/litre of water (40 DAS and 70 DAS) was found minimum disease incidence (6.08, 7.17% and 7.67%) higher disease control (76.39, 77.29 % and 71.41 %) during the three years, respectively was which at bar with T_2 (Seed treatment with Carbendazim 50% WP @ 2 g/kg seed and foliar spray of carbendazim @ 1 g/litre of water (40DAS and 70 DAS)) and recorded disease incidence 8.75%,9.33 % and T2: 8.33 % and disease control 66.03%, 66.88% and 69.06%, respectively whereas disease incidence was recorded in FP(T_1) were 25.76, 28.17 and 26.83% during the 3 years. The per cent increase in yield recorded in T_3 were 31.1%, 35.42% & 25% during the years which was at bar with treatment T_2 21.0%, 27.78% and 20.51% over the FP(T_1) and recorded the yield 1429.1, 1440, and 1560 Kg per ha, respectively. The Scocio-economic of mustard production was also recorded and found that the maximum gross return and B:C ration were higher in T_3 ranges Rs 101400-126750 per ha and B; C ratio 3.69- to 4.57 during the crop season and there is no irrigation during 25 December to15 January was also followed during the management.

Key words: *Mustard, Sclerotinia rot, management, disease incidence, yield*

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THEME - III

RESOURCE UTILIZATION AND ENHANCING PRODUCTION

Triple superphosphate as an efficient alternative phosphorus source for higher productivity and profitably of mustard under a maize–mustard cropping system

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In India, phosphorus (P) fertilization largely relies on Di-ammonium Phosphate (DAP); however, its frequent scarcity necessitates an alternative P sources. Triple superphosphate (TSP), a high-analysis P fertilizer, has potential as an effective substitute, though limited information is available on its performance across crops and agro-ecological conditions. Therefore, a field experiment was conducted during the *rabi* season of 2024–25 under a maize mustard cropping system at the ICAR–Indian Agricultural Research Institute, Pusa, New Delhi, to evaluate the agronomic and economic performance of TSP in mustard. The study comprised thirteen nutrient management treatments, including a control (N and K only), farmer's practice (urea-N and DAP-P), recommended N–P–S (without K), and recommended N–P–K–S with phosphorus supplied through DAP, SSP, TSP, or a complex NPK fertilizer. Additional treatments included TSP supplemented with phosphate-solubilizing bacteria, farmyard manure (10 t ha^{-1}), foliar mono-ammonium phosphate (5.0 kg ha^{-1}), or nitrogen-fixing microbial inoculation, as well as nitrogen-omission treatments receiving either Azospirillum inoculation or foliar nano-urea along with recommended P (TSP), K, and S. The experiment was laid out in a randomized complete block design with three replications. Phosphorus management significantly influenced growth, yield, nutrient uptake, and economics of mustard. Application of recommended NPK through TSP along with sulphur and FYM produced the highest mustard growth parameters, yield attributes, seed yield (2.83 t ha^{-1}), stover yield (8.00 t ha^{-1}), biological yield (10.83 t ha^{-1}), and nutrient uptake, and remained statistically comparable with other TSP based integrated nutrient management treatments. Nitrogen omission treatments consistently resulted in inferior performance. Although FYM application increased cultivation costs, maximum net returns (123,301 ha^{-1}) and benefit–cost ratio (2.56) were achieved with foliar MAP application. Overall, TSP proved to be an efficient and economically viable alternative P source for mustard under the maize–mustard cropping system.

Keywords: *Brassica juncea, economics, integrated nutrient management, maize–mustard system, triple superphosphate, phosphorus management*

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Effect of different planting methods on resource utilization and productivity of Gobhi Sarson in Pigeonpea-Gobhi Sarson cropping system under sub-tropical conditions

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Gobhi sarson (*Brassica napus* L.) is an important *rabi* oilseed crop in northern India, contributing significantly to edible oil production. Pigeonpea, a deep-rooted legume, enhances soil fertility through biological nitrogen fixation and conserves residual soil moisture, making it a suitable succeeding crop for *Gobhi sarson*. However, delayed harvest of pigeonpea often restricts timely sowing of Gobhi sarson, resulting in poor crop establishment and yield losses. Adoption of suitable planting methods such as relay cropping, direct seeding and transplanting may improve crop establishment, resource utilization and productivity. Hence, the present study was undertaken to evaluate the performance of planting methods of *Gobhi sarson* in a pigeonpea-Gobhi sarson cropping system under Sub-tropical zone. A field experiment was carried out during the *rabi* 2023-24 and 2024-25 at Punjab Agricultural University, Ludhiana. The experiment was laid out in a randomized complete block design with three replications. Treatments consisted of three planting methods of Gobhi sarson; relay cropping, direct seeding and transplanting in standing

pigeonpea and after uprooting of Pigeonpea in respect two different genotypes (PAU 881 and AL 882). In relay cropping, Gobhi sarson was sown in standing pigeonpea prior to its harvest. Under direct seeding method, sowing was done immediately after pigeonpea harvest, whereas in the transplanting method, 30 days old seedlings raised in a nursery were transplanted after pigeonpea harvest. Standard agronomic practices for raised bed cultivation of Gobhi sarson were uniformly followed across all treatments during both the crop seasons. Relay cropping in pigeonpea-based systems recorded highest growth parameters, including plant height, dry matter accumulation and LAI, due to better moisture conservation, improved soil structure and residual fertility from the preceding legume crop. Relay cropping also enhanced yield attributes, including number of siliquae plant^{-1} and seeds siliquae^{-1}, while test weight remained non-significant. The highest seed yield was obtained under pigeonpea (AL 882) + cowpea (F) - Gobhi sarson (relay cropping) - summer moong (23.97 q ha^{-1}) in *Rabi* 2023-24 and (24.54 q ha^{-1}) in *Rabi* 2024-25 which was statistically at par with T_1: Pigeonpea (PAU 881) + Cowpea (F) - *Gobhi sarson* (relay cropping) - Summer Moong (23.93 q ha^{-1}) during *Rabi* 2023-24 and (24.32 q ha^{-1}) during *Rabi* 2024-25 but significantly higher than direct-seeded and transplanted treatments. Improved yield under relay cropping resulted from timely establishment, better plant stand, efficient resource use and an extended effective growth period. Overall, relay cropping proved to be the most suitable, efficient and sustainable establishment method for maximizing productivity of Gobhi sarson in pigeonpea-based cropping systems, followed by direct seeding and transplanting.

Keywords: *Direct seeding, gobhi sarson, transplanting, pigeonpea-gobhi sarson system, relay cropping*

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Evaluating the impact of different management interventions on water use in canola in Central Punjab

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Canola (*Brassica napus* L.) is an important oilseed crop, valued for its high-quality edible oil and its potential to enhance water productivity in resource-constrained agroecosystems. The availability of modelling-based studies on canola crop, its yield, and water productivity is scanty. Therefore, the resource optimization and the broader applicability of field-based findings in canola become limited. A field experiment was conducted at the Soil Research Farm, Punjab Agricultural University, Ludhiana, by adopting a combined field-modelling approach under split-plot design with sowing dates as main levels and irrigation regimes as sub-levels. The study comprised three sowing dates (10 October, 30 October, and 20 November) and four irrigation schedules; stage-based irrigation, 1.2, 1.0, and 0.8 of IW/CPE irrigation, respectively. Building on the field framework, complementary CROPGRO simulations extended the analysis across five sowing dates (10 October-20 November at 10-day intervals), four soil textural classes, two crop establishment methods (direct seeding and transplanting), and the same set of irrigation schedules. The model was calibrated and validated for seed yield and irrigation water productivity using the field study and an independent dataset, with evaluation based on multiple performance indicators, showing strong agreement between simulated and observed values (NRMSE generally <20% and R^2 up to ~0.9). The results of field study indicated that early sowing (10 and 30 October) significantly increased seed and stover yield and improved siliqua number (13-40%) compared to delayed sowing, while seed number per siliqua and thousand-seed weight remained largely unaffected. Further, the real water productivity (RWP) was maximum in early sowings. Growth stage-based irrigation and the IW/CPE ratio of 1.2 consistently produced the highest yield, with progressive decline under lower IW/CPE ratios. Simulation results identified 20 October as the optimum sowing date, with yield penalty of about 0.1-0.6 t ha^{-1} associated with successive sowing delays. However, across treatments, simulated seed yield was recorded highest in sandy loam and loam soils, and under IW/CPE-based irrigation of 1.2. Among establishment methods, transplanted

canola produced approximately 15% higher yield and 0.7 kg ha^{-1} mm^{-1} greater RWP than direct seeded crop. In simulation study, the RWP decreased progressively after the optimum sowing date (20 October) and it was maximum in restricted irrigation (IW/CPE 0.8) and decreased with the increasing irrigation amount. Water stress analysis indicated that maximum stress observed under restrictive irrigation (IW/CPE 0.8), in loamy sand soil type, and slightly higher stress in transplanted crop, despite their higher yield and water productivity. Overall, the integrated field-modelling approach offers a reliable decision-support basis for improving canola yield and water productivity through optimized sowing time and irrigation management in water limited agro-ecosystems.

Keywords: *Split-plot design, resource optimization, productivity*

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Precision nitrogen management strategies for enhancing productivity, profitability and nitrogen use efficiency in mustard (*Brassica juncea* L.)

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Current agricultural production systems face challenges of poor economic returns, soil fatigue and negative environmental outcomes from excess use of nitrogenous fertilizers in mustard crop. To overcome these challenges, the current study was conducted to optimize nitrogen management using different N modules with precision nitrogen management tools and approaches. The experiment included nine nitrogen management strategies plus one unfertilized treatment as control, arranged in a randomized complete block design in three replicates. Results demonstrated that sensor guided nitrogen application using Greenseeker (GS) significantly augmented mustard yield by 21.7% and 85.0%, and proved more profitable, boosting net monetary returns and benefit-cost ratio by 34.4% & 162.2% and 23.9% & 74.2%, respectively in comparison to the recommended dose of fertilizer (RDF) and control, and saved 20.0% of nitrogen. The per cent variations in mustard seed yield varies from a minimum of -34.28% (in control) to a maximum of 21.67% (in GS) over RDF. The cost per kilogram (CPK-Rs 16.9) and crop production efficiency (CPE-19.9 kg ha-1 day^{-1}), agronomic efficiency of NPK (AEnpk- 18.7, 30.4 & 30.4kg kg^{-1}), partial factor productivity (PFPn-40.7 kg kg^{-1}) was achieved superior on NDVI based N application using Greenseeker with greater oil content and oil yield (42.5% & 1122 kg ha-1), respectively. The change in the SOC per cent varies from -32.8 (RDN_{75} + 2% NCU FS) to 52.6 8 (RDN_{100} + 2% Urea FS) from their initial values before experimentation. Further, N foliar spray treatments at N_{100} level registered for per cent negative changes in N efficiency (-1.46 to -6.90%) over RDF. These findings provide valuable insights for optimizing N in mustard production and implementing these precision nitrogen management techniques to enhance productivity, profitability, and environmental sustainability and supports oil security.

Keywords: *Brassica juncea L., GreenSeeker, NDVI, nitrogen management, yield*

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Resource conservation technologies for enhancing rapeseed-mustard productivity in arid and semi-arid region

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Oilseed constitutes the second largest agricultural commodity after cereals in country; India is one of the largest producer, consumer and importer of edible oilseeds in the world. The import has increased mainly due to increasing consumption of edible oils with the rising population and changing lifestyle of the people. The major part of oilseed growing regions cover under the arid and semi-arid regions in India, which are now under multiple threat of increasing population pressure, depleted water reserve, degradation of other natural resource base, and above all the anthropogenic warming of the climate. Conventional blanket fertilizer and irrigation practices often fail to address field-level heterogeneity, leading to inefficient input use and yield gaps. Resource conservation technologies (RCTs) which includes, conservation agriculture practices (minimum tillage, residue retention, crop rotation) soil and water conservation measures (raised bed planting, contour farming, in-situ moisture conservation). Precision water management (soil moisture–based irrigation scheduling, limited and timely irrigation) have emerged as effective interventions. The reviewed literature clearly indicates that resource conservation technologies improve soil health, conserve moisture, enhance nutrient use efficiency, and increase resilience to climate variability. Furthermore, It is observed that CA-based crop management practices are mostly being scaled-out in major cereal based cropping system like, rice/maize-wheat systems in India, and very less efforts being made in oilseed/pulse systems thus by adopting these technologies in oilseed cultivation can remarkably improve the overall productivity.

Keywords: *Conservation agriculture, oilseed crops, rapeseed-mustard, resource conservation technologies*

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The potential applications of rapeseed mustard protein isolates

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With the burgeoning global population, the demand for protein is also increasing. In the realm of global food security, protein is likely to become the limiting macronutrient, requiring that the global population has access to sufficient high-quality protein. Rapeseed mustard, ranking as the second most produced oilseed globally, offers a promising alternative protein source due to its exceptional nutritional profile, which includes a balanced amino acid composition and advantageous technical and functional properties. Additionally, the production of plant-based proteins is more cost-effective and environmentally sustainable compared to traditional dairy and meat production methods. Rapeseed mustard protein isolate can fulfil various roles in food systems, such as serving as an emulsifier, binder, foaming and gelling agent, thickener, texturizer, or simply as a protein source. The main challenge in making these proteins available to consumers lies in the extraction and isolation processes, which must preserve the proteins' native state and functionality while being economically viable on a commercial scale. Other challenges in rapeseed mustard processing include potential issues such as dark coloration, undesirable flavours, the presence of anti-nutritional compounds, and protein damage due to heat during oil extraction. In conclusion, rapeseed mustard protein isolates represent a sustainable and nutritionally valuable alternative to conventional protein sources. Continued research aimed at improving extraction efficiency, functionality, and sensory quality will support their wider application in food systems.

Keywords: *Food security, amino acid, anti-nutritional, protein isolates, rapeseed mustard*

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Evaluation of drip irrigation water in Indian mustard (*Brassica juncea* L.) under different crop geometry

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Water is a critical input for irrigation in agriculture and plays an important role in food production. Application of water directly to the root zone through micro-irrigation system can reduce the water, fertiliser and labour requirements by improving their availability and use-efficiency. The study was conducted at CCS HAU, Regional Research Station, Bawal, Rewari to To evaluate the different levels of drip irrigation under different crop geometry of Indian mustard during *rabi* 2022-23 and 2024-25. The main plot treatments included Three crop geometry viz. 30 cm R-R, 45 cm R-R and 30:60 cm (Paired row sowing) and in sub plot four level of irrigation water through drip system viz., two irrigation through flooding (120 mm), ten irrigation through drip at 7 days interval (120 mm), eight irrigation through drip at 9 days interval (96 mm) and six irrigation through drip at 12 days interval (72 mm). The each irrigation was given with 12 mm water for all treatments. The mean analysis of two years of experimentation showed that the Plant height at different growth stages, days to 50% flowering, number of seed/siliqua and 1000 seed weight did not influence with any of the irrigation levels through drip and flooding irrigation; however, the lower plant height and higher branches/plant were observed under 45 cm row-row spacing. Drip application of 80% recommended water produced statistically similar no. of siliqua/plant (256.7) and seed yield (26.04 q/ha) with 100% water application through drip (263.1, 26.10 q/ha) and flood irrigation (261.2, 26.27 q/ha), respectively. The 60% of recommended water application through drip produced significantly less no. of siliqua/plant and seed yield as compared to 80% and 100 % of recommended water through drip and flooding irrigation. The highest water use efficiency was observed under paired row sowing and 60% irrigation water applied through drip irrigation method. On the basis of two year results it is concluded that the application of 80% water through drip produced statistically similar seed yield with 100% water application through drip and flooding irrigation in loamy sand soils at RRS Bawal. The maximum seed yield was observed with 30 cm row spacing with drip irrigation in comparison to 45 cm and 30:60 cm paired row sowing under drip irrigation system.

Keywords: *Indian mustard, crop geometry, drip irrigation, productivity*

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Role of bee attractants in enhancing pollinator activity in *Brassica campestris* (BSH-1)

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Brassica campestris, belonging to the family *Brassicaceae*, is a vital oilseed crop extensively cultivated for edible oil production and protein-rich animal feed. It is a cross-pollinated crop that depends entirely on insect pollinators, and successful pollination is crucial for optimal seed set, yield, and crop productivity. A field experiment was conducted during 2023–24 to 2024–25 at the Norman E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, to evaluate the effect of different bee attractants on bee density in *B. campestris* (variety BSH-1). The treatments included essential oils of basil, lemongrass, rose and geranium, combinations of basil + lemongrass and

rose + geranium essential oils, sugar solution, liquid jaggery, molasses and a control where only water was applied. The highest bee density was recorded in plots sprayed with the combination of rose and geranium essential oils (0.79 bee density/m²/5min), followed by lemongrass essential oil (0.74 bee density/m²/5min), basil + lemongrass essential oil (0.71 bee density/m²/5min), rose essential oil (0.66 bee density/m²/5min), geranium essential oil (0.62 bee density/m²/5min), sugar solution (0.58 bee density/m²/5min), basil essential oil (0.56 bee density/m²/5min), liquid jiggery (0.54 bee density/m²/5min) and molasses(0.51 bee density/m²/5min). The lowest bee density was observed in the control plots (0.36 bee density/m²/5min). This study demonstrates the potential of essential oils, particularly the combination of rose and geranium oils, as effective bee attractants for improving pollination efficiency and yield in *Brassica campestris* (BSH-1).

Keywords: *Brassica campestris, bee attractant, pollinator, seed yield*

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Impact of nutrient management practices and sowing time on yield, quality, and sustainability of Indian mustard (*Brassica juncea* L.) under climate variability

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Indian mustard is a crucial crop that requires precise timing for sowing; otherwise, it may experience adverse morphological, physiological, and biochemical changes, as well as increased vulnerability to insect-pest attacks. Given the shifting patterns of rainfall and temperature, it is necessary to adjust the sowing period to a new optimal timeframe. Recently, the incorporation of various nutrient sources into farming practices has become increasingly important. The use of organic amendments alongside chemical fertilizers not only maximizes yield but also enhances labile microbial biomass, increases nutrient availability, and improves soil properties. A field experiment was conducted during two consecutive winter (*Rabi*) seasons of 2022-2023 and 2023-2024 at Agronomy Farm, Institute of Agricultural Sciences, BHU, Varanasi (UP). The treatments consisted of four sowing windows for Indian mustard D_1, 1st November; D_2, 10th November; D_3, 20th November; D_4, 30th November during both the years and five nutrient management practices N_1, 100% RDF (120, 60, 60, 25 kg NPKS ha^{-1}); N_2, 70% RDF + 15% RDN through poultry manure + consortia of biofertilizers @ 10 ml kg^{-1} seed; N_3, 70% RDF+ 15% RDN through poultry manure + *Panchagavya* @ 30 ml L^{-1} (2-spray); N_4, 70% RDF+ 15% RDN through poultry manure + seaweed extract @ 2 ml L^{-1} (2-spray); N_5, 70% RDF+15% RDN through poultry manure + consortia of biofertilizers @ 10 ml kg^{-1} seed + *Panchagavya* @ 30 ml L^{-1} & seaweed extract @ 2 ml L^{-1} both as tank mix (2-spray) thereby making twenty treatment combinations were tested in split plot design with three replications. Among the sowing windows, plant growth parameters, yield attributes and yield were observed higher from 1st November sown crop over two consecutive years. Furthermore, the results indicated that among the nutrient management practices, the application of 70% RDF+15% RDN through poultry manure + consortia of biofertilizers @ 10 ml kg^{-1} seed + *Panchagavya* @ 30 ml L^{-1} & seaweed extract @ 2 ml L^{-1} both as tank mix (2-spray) significantly enhanced growth parameters, yield and quality. Conversely, the application of 100% RDF yielded the lowest values during the respective years.

Keywords: *B. juncea, climate change, nutrient management, yield*

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Performance of nitrogen and phosphorus nano-formulations on growth, yield and quality of Indian mustard (*Brassica juncea* L.)

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A field experiment was conducted during *rabi* 2024-25 at the Oilseed experimental area, Research Farm, Chatha of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu during the *rabi* season of 2024-25. The experiment consisted of two factors, factor A (F_0 - No application, F_1 - 50% recommended dose of nitrogen and phosphorus (RDNP), F_2 - 75% RDNP, F_3 - 100% RDNP) and Factor B (N_0 - No spray, N_1 -2 sprays of Nano-Urea, N_2 -2 sprays of Nano-DAP, N_3 -2 sprays of Nano-Urea and Nano-DAP) which were arranged in Factorial Randomized block design with three replications. The experimental results revealed that among different fertility level treatments 100% RDNP recorded significantly higher growth and yield attributes, net returns, BC ratio and nutrient uptake than other treatments and control in comparison. Furthermore, significantly higher quality attributes like protein content and oil content were recorded with application of 100% RDNP which was however found to be at par with 75% RDNP. However, in case of oil yield 100% RDNP recorded significantly higher than 75% RDNP. Among different Nano-fertilizer treatments, 2 sprays of Nano-Urea and Nano-DAP simultaneously recorded better performance. Similarly, significantly higher oil yield was recorded by application of 2 sprays of Nano-Urea and Nano-DAP than 2 sprays of Nano-DAP and other treatments. However, application of 2 sprays of Nano-Urea and Nano-DAP together resulted in significant increase in quality attributes *viz.*, protein content (17.06 %) and oil Content (40.44 %) which was found to be at par with 2 sprays of Nano-DAP (16.59 % and 39.94). The interaction effect between fertility levels (A) and Nano-fertilizer application (B) was found to be significant w.r.t. number of seeds per siliqua and no. of siliquae per plant respectively. Therefore, 100 % RDNP (80:40:20 kg N: P_2O_5:K_2O) along with two sprays of Nano Urea and Nano DAP simultaneously at 30 and 50 DAS may be recommended for obtaining maximum crop yield, nutrient uptake, B:C ratio and quality of Indian Mustard in Jammu region.

Keywords: *Brassica, nano-formulations, nano-urea, yield*

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Economics of predominant rabi crops (mustard, linseed) in post-paddy cropping systems in rice fallow areas of Eastern Vidarbha, Maharashtra

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Paddy-based cropping systems dominate Eastern Vidarbha, Maharashtra, where inclusion of *rabi* crops after kharif paddy is essential for enhancing farm income and resource use efficiency. The present study evaluated the economics and productivity of predominant *rabi* crops grown under post-paddy conditions. The experiment was conducted during 2019-20, 2020-21, and 2022-23 using ancillary observations collected over three consecutive years. Early, mid-late, and late duration paddy varieties were transplanted during *kharif*, followed by zero-till sowing of *rabi* crops viz., mustard, linseed, and lathyrus at 30 cm row spacing after paddy harvest. Two protective irrigations were applied at critical growth stages. The interaction effect of paddy maturity duration and *rabi* crops significantly influenced yield attributes and system productivity across all years and in pooled analysis. The highest number of siliquae per plant was recorded in mustard sown after early-maturing paddy, which was statistically at par with mustard after mid-late

paddy. Mustard sown after early paddy also produced the highest seed yield per plant, followed by linseed, while lathyrus recorded comparatively lower yields. System yield analysis revealed that mustard and linseed performed significantly better under early and mid-late paddy, whereas lathyrus showed significant yield only under early paddy, with a decline in mid-late and late paddy conditions. Economic analysis indicated that early paddy significantly enhanced monetary returns of succeeding *rabi* crops. The highest net monetary returns were obtained with linseed after early paddy, primarily due to higher seed yield under favorable sowing time. Early paddy recorded the highest seed yield, followed by mid-late paddy, while late paddy showed substantial yield reduction due to increased temperature and reduced soil moisture. The benefit–cost ratio was highest in mustard, which was at par with linseed under early paddy conditions. Based on pooled data, it is concluded that sowing mustard after early-maturing paddy and linseed after early to mid-late paddy offers maximum economic returns in the paddy-based cropping system of Eastern Vidarbha.

Keywords: *Mustard, rabi, paddy, yield*

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To study the genetic heritability and genetic advance of an Indian mustard *(Brassica juncea)*

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The present investigation was carried out to assess genetic variability, heritability and genetic advance for yield and related traits in *Brassica juncea* (L.) Czern & Coss using 24 genotypes evaluated in a replicated field experiment. Analysis of variance revealed highly significant differences among genotypes for most of the traits studied, indicating the presence of substantial genetic variability in the experimental material. Traits such as days to 50% flowering, days to maturity, number of primary and secondary branches, spike length, seeds per spike, seed yield per plot, seed yield per plant and seed yield per hectare showed significant genotype effects, while test weight exhibited non-significant variation. For all characters, phenotypic variance exceeded genotypic variance, suggesting the influence of environmental factors. High broad-sense heritability coupled with high genetic advance was observed for seed yield per plant, seed yield per hectare, number of secondary branches, seeds per spike and days to 50% flowering, indicating the predominance of additive gene action and greater scope for improvement through direct selection. Moderate heritability was recorded for plant height, days to maturity and spike length, whereas test weight and maximum root length exhibited low heritability and genetic advance, reflecting strong environmental influence. The study emphasizes the potential of yield and yield-contributing traits for genetic improvement in *Brassica juncea.*

Keywords: *Brassica juncea (L.), genetic advance, genetic variability, genotypes, heritability, yield and related traits*

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Enhancing rapeseed–mustard productivity and farmer confidence through certified seed availability, quality assurance and high yield performing varieties in India

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High-quality seed is a critical driver of improved productivity, yield stability, and farmer confidence in Rapeseed–Mustard cultivation. Oilseed cropping system plays a vital role in India's edible oil economy. Total area and production under the nine oilseeds crops grown in India, rapeseed-mustard accounts for 30.3% of the acreage and 33.2% of the production (2023-24). Based on the production of 13.2 million tons during 2023-24, rapeseed-mustard became the first largest oilseed crop in India. Despite this significance, the seed replacement rate (SRR) in Rapeseed–Mustard remains moderate to high at around about 65%, while SRR levels in other major oilseeds such as soybean (35–40%) and groundnut (25–30%) are comparatively lower, indicating continued dependence on farm-saved seed and slow varietal turnover across oilseed systems. In many mustard-growing regions, farmers commonly use mixed or heterogeneous seed lots, resulting in poor genetic uniformity, uneven crop establishment, and a yield penalty of about 15–25% compared to crops raised with pure, certified seed. Replacement of such mixed seed with genetically pure, certified seed alone can bridge a major share of this yield gap, enabling realization of the full yield potential of improved mustard varieties even without additional external inputs. Institutional research efforts such as those by the ICAR-Indian Institute of Rapeseed-Mustard Research (IIRMR) have led to the development and release of high-yielding and high-oil content varieties suited to semi-arid and other agro-ecological regions of India. Notable examples include DRMRIJ 31 (Girraj), DRMR1165-40, DRMR150-35, NRCHB101, BPM-11, Brijraj, Radhika, NRCDR 02 and DRMR 601 are high-yielding Indian mustard varieties licensed for cultivation in Rajasthan, Uttar Pradesh, Haryana, and adjoining states, and NRCHB-506, the first public-sector mustard hybrid with broad adaptation and excellent performance in timely sown conditions with enhanced yield potential. These trends underscore the need for strengthening formal seed systems through robust seed certification and quality assurance mechanisms that ensure genetic purity, physical quality, germination capacity, and seed health—key determinants of uniform crop establishment and yield realization. Under institutional initiatives such as the Seed Hub programme, concerted efforts are undertaken to strengthen the Rapeseed–Mustard seed value chain by integrating participatory and organized seed production with formal certification and quality assurance mechanisms, thereby improving the availability of reliable, performance-assured seed across diverse agro ecological regions. In parallel, quality assurance mechanisms focus on continuous monitoring, documentation, and traceability at different stages of seed production, processing, and distribution, thereby reinforcing transparency and accountability within the seed system. From a farmer-level perspective, timely access to affordable certified seed offers one of the most cost-effective interventions for increasing mustard yields and profitability without increasing input use or production risk. From a policy perspective, improving SRR through scaled-up certified seed production, Seed Hub expansion, and strengthened quality assurance frameworks emerges as a strategic intervention to accelerate varietal replacement, enhance oilseed productivity, improve farmer incomes, and support national goals of edible oil self-reliance.

Keywords: *Oilseed crops, rapeseed–mustard, quality assurance, seed certification, seed hub, seed replacement rate, yield gap*

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Relative contribution of area and yield to the total output growth of rapeseed-mustard crop in Rajasthan

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Rapeseed-mustard production in India forms the backbone of the oilseed sector, supporting millions of farmers and the nation's growing demand for edible oils. Rajasthan is the leading state in rapeseed-mustard production, contributing 46 percent of the country's total output. According to the Ministry of Agriculture and Farmers Welfare, Rajasthan recorded about 34.7 lakh hectares under rapeseed-mustard cultivation with a production of approximately 52 lakh tones in 2024-25. Assessment of current status of rapeseed-mustard production helps in determining major strategies to reduce the country's dependence on edible oil imports. There have been several factors that were responsible for the increase in production of rapeseed-mustard. There is need to analyze the area effect and yield effect on rapeseed-mustard output to understand the true drivers of production growth and to implement required agricultural policy. A study was done to analyze the area effect, yield effect, and interaction effect that lead to the change in production of rapeseed-mustard in Rajasthan. Time series data for 3 decades from 1990-91 to 2019-20 were analyzed. Additive decomposition method has been used to determine area, yield, and interaction effect. Results revealed that during period I (1990-91 to 1999-00) 68.08 percent change in production was due to the area effect, which was more than the offset of the yield effect of 24.48 percent and interaction effect of 7.43 percent. During the period II (2000-01 to 2009-10) expansion in area was the main source of output growth. Area effect resulted in a 40.45 percent change in production. Next to area effect, yield effect (32.66%) was a major factor responsible for the change in production followed by the interaction effect (18.89%). The major contributing factor for the change in production during Period III (2010-11 to 2019-20) was the area effect, which was 56.52 percent. The contribution of yield effect and interaction effect was recorded 35 and 8.48 percent respectively. Expansion in the area under rapeseed production played a significant role in the growth of rapeseed-mustard production. This area expansion was due to the concerted efforts of the implementation of the Technology Mission on Oilseed. This study reveals that overall change in production was mainly due to the area effect and yield which states that increase in the area under production of rapeseed-mustard and adoption of high yielding varieties resulted into increase in production.

Keywords: *Rapeseed-mustard, area effect, yield effect, interaction effect, oilseeds*

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Evaluation of combined effect of convetional and nano fertilizers to increase the producitivty of *Brassica juncea* L.

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Indian mustard (*Brassica juncea* L.) is a major oilseed crop of India; however, its productivity is often limited by poor nutrient use efficiency associated with excessive reliance on conventional fertilizers. Nano fertilizers have emerged as a promising tool for improving nutrient availability while minimizing losses. A field experiment was conducted during the *rabi* season of 2023-24 at the Norman E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, to evaluate the effect of nano urea and nano DAP in combination with varying levels of nitrogen and

phosphorus on growth, yield, quality, and soil biological properties of Indian mustard. The experiment was laid out in a factorial randomized block design with three replications, comprising three fertility levels (50, 75 and 100% recommended NP) and foliar application of nano fertilizers, along with an absolute control. The results indicated that integrated application of nano fertilizers with conventional NP levels significantly improved growth parameters of mustard. The treatment receiving 100% RD-NP combined with two sprays each of nano urea and nano DAP recorded the highest plant height (214.7 cm), number of branches (25.0), SPAD value (46.0), dry matter accumulation (89.8 g plant^{-1}), and leaf area index (2.80). Yield attributes such as seeds per siliqua (15.53), siliquae per plant (271.45), and test weight (5.78 g) were also maximized under the same treatment, resulting in the highest seed yield (2396.9 kg ha^{-1}). However, this treatment remained statistically at par with 75% RD-NP combined with two sprays of nano urea and nano DAP, which produced a seed yield of 2218.6 kg ha^{-1}, demonstrating that a 25% reduction in conventional NP fertilizers is possible without compromising productivity. Oil content was significantly influenced by fertility levels, with higher oil percentage recorded under reduced NP application. The maximum mean oil content (44.8%) was observed at 50% RD-NP, while combined application of nano urea and nano DAP further improved oil quality across fertility levels. Soil biological properties responded positively to nano fertilizer application, as evidenced by significantly higher dehydrogenase, acid phosphatase, and alkaline phosphatase activities under 100% and 75% RD-NP treatments combined with nano fertilizers, indicating enhanced microbial activity and improved soil health. Integration of nano urea and nano DAP with 75% recommended NP fertilization is an efficient and sustainable nutrient management strategy for Indian mustard. This approach not only enhances growth, yield, and oil quality but also improves soil biological health while enabling a substantial reduction in conventional fertilizer use under *Tarai* conditions of Uttarakhand.

Keywords: *Brassica juncea L., nano fertilizers, soil health, yield*

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In-vitro effect of bio-agents for control of Alternaria blight of Indian mustard incited by *Alternaria brassicicola*

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Indian mustard [*Brassica juncea* (L.) Czern and Coss.] is one of the most popular *rabi* oil seed crop in India. It's belonging to family Cruciferae (Brassicaceae). It is mostly cultivated *rabi*, crop of Northern as well as North eastern region of India. Indian mustard contributes about 85 per cent of total rapeseed-mustard production in India. Crucial Indian mustard growing states are Rajasthan (50%), Uttar Pradesh (12.3%), Haryana (11.2%), Madhya Pradesh (9.8%), Gujrat (6.5%) and West Bengal (5.1%). Indian mustard is affected by many major diseases like Fungal, Bacterial, Viral, and also parasitic nematode. In mustard maximum losses in yield occurs due to microbial diseases. Among the major disease viz., Alternaria blight (*Alternaria brassicae*, *Alternaria brassicicola*, *Alternaria alternata*), White rust (*Albugo candida*), Downey mildew (*Peronospora parasitica*) Powdery mildew (*Erysiphe cruciferarum*), Bacterial blight (*Pseudomonas cannabina*), and Sclerotinia stem rot (*Sclerotinia sclerotiorum*) Alternaria blight of Indian mustard is one of the most important disease which reduce quantity and quality of seed yield. Alternaria blight disease is one of the damaging disease among the major diseases of mustard causing up to 70 per cent losses in yield with no proven source of resistance against the disease reported till date in any of the hosts. To control the losses caused by pathogens many farmers are using fungicides to obtain very good yield. The present study was carried out to recognize the effect of different bioagents on control against *Alternaria brassicicola* under *in-vitro* condition. Four antagonists viz., *Trichoderma*

viride, Trichoderma harzianum, *Pseudomonas fluorescens* and *Bacillus subtilis*, checked the growth of *Alternaria brassicicola* at point of their contact on culture medium. Among these, maximum inhibition (78.05%) of *Alternaria brassicicola* was observed in *Trichoderma harzianum.*

Keywords: *Alternaria, bioagent, Indian mustard, Trichoderma harzianum*

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Optimizing nutrient management for yield, water productivity and profitability in maize–mustard cropping system under semi-arid conditions

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A two-year field experiment was conducted during the winter seasons of 2020–21 and 2021–22 at the ICAR–Directorate of Rapeseed–Mustard Research, Bharatpur, Rajasthan, to assess the impact of integrated nutrient management on crop productivity, water-use efficiency, and economic returns of a maize–mustard cropping system under semi-arid conditions. The experiment was laid out in a split-plot design comprising five nutrient management practices in the main plots, including recommended dose of fertilizers (RDF), farmyard manure (FYM), biofertilizer, mustard straw, and Jivamrit, and three nitrogen levels (100, 125, and 150% of the recommended dose of nitrogen, RDN) in sub-plots, with three replications. The combined application of RDF + FYM @ 2.5 t ha{ ¹ + Azotobacter + mustard straw @ 2.5 t ha{ ¹ significantly enhanced physiological traits, yield attributes, and seed yield of mustard, reflected in higher SPAD chlorophyll readings, leaf area index, number of siliquae per plant, seeds per siliqua, and test weight. The highest mustard seed yield (3.22 t ha{ ¹) was recorded with 150% RDN. A similar trend was observed in maize, where integrated nutrient management resulted in superior leaf area index, cob length, grains per cob, 100-grain weight (25.09 g), and grain yield (3.73 t ha{ ¹). System productivity (4.84 t ha{ ¹) and water productivity (2.14 kg seed m{ ³) were maximized under RDF + FYM @ 2.5 t ha{ ¹ + Azotobacter + mustard straw @ 2.5 t ha{ ¹ in combination with 150% RDN. This treatment also produced the highest net returns (¹ 51,715 ha{ ¹ from maize, ¹ 81,040 ha{ ¹ from mustard, and ¹ 1,32,755 ha{ ¹ for the system) along with superior benefit–cost ratios. The results indicate that integrated application of organic and inorganic nutrient sources along with higher nitrogen levels substantially improves productivity, water-use efficiency, and profitability of the maize–mustard cropping system in semi-arid regions of Rajasthan.

Keywords: *Leaf area index, maize-mustard cropping system, profitability, scmr, system productivity, water productivity, yield*

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Role of sulphur oxidizing bacteria and phosphate solubilizing bacteria in mustard crop

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Sulphur is an essential element for both plants and animals. Sulphur scarcity is a global concern due to variety of factors such as intensive agriculture, lower sulphur returns from farmyard manure, growing high yielding varieties and the widespread use of chemical fertilizers containing very little sulphur, such as urea and di-ammonium phosphate. Phosphate is also an essential element involved in a wide range of physiological processes in plants, including cell division, photosynthesis, respiration, energy transfer, nucleic

acid, protein and carbohydrate synthesis. Plants absorb phosphorus as phosphate from soil, but P readily forms low-solubility complexes with soil materials. As a result, even when P concentration in soil is high, it has low mobility and availability to plants. In India, mustard (*Brassica juncea* L.) is the most important rabi oilseed crop, ranking second only to groundnut in the oilseed economy. Sulphur is an important constituent of mustard oil and leaves hence its deficiency causes a significant reduction in yield and oil. Sulphur oxidizing bacteria oxidize sulphur as principal metabolic process and fulfill an important role in the conversion of reduced sulphur (sulfide) and partially reduced sulphur (thiosulphate and sulphite) into sulphate. In this study mustard seeds were treated with sulphur oxidising bacteria (SOB N & SOB 20) and Phosphate solubilizing bacteria (PSB 1) and their effect was observed on seed germination and yield parameter under pot house conditions. These bacteria increase the germination rate as well as increase the shoot and root length of mustard in treated plants. The yield was also higher in treated plants as compare to control. So, it can be concluded that Sulphur oxidizing bacteria (SOB N & SOB20) and phosphate solubilizing bacteria (PSB01) have shown significant effect on the mustard crop and can be further studied for biofertilizer development for mustard crop.

Keywords: *Biofertilizer, mustard, nutrient, phosphate solubilizing bacteria, sulphur oxidizing bacteria*

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Effect of organic sources on mustard yield and soil health parameters in saline soils

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Saline soils are characterized by excessively high salt concentrations that severely restrict crop growth and reduce mustard yields by limiting the availability of essential plant nutrients. Reclaiming such salt-affected lands through improved soil management is crucial for addressing the broader challenges of global food security. This study hypothesized that the application of organic amendments could effectively reduce harmful salt ions while simultaneously enhancing mustard crop productivity. To test this, nine different treatment combinations were evaluated, integrating organic sources-such as farmyard manure (FYM), pressmud (PM), and vermicompost (VC)-with the recommended dose of fertilizer (RDF), and these were compared against RDF alone and an unamended control. The mustard variety DRMR IJ-31 was grown in saline soil under standard recommended agronomic practices. All organic amendments were applied at a total rate of 5 and 10 t/ha, either singly or in various combinations alongside RDF. Post-harvest assessments included seed yield, nutrient uptake (nitrogen, phosphorus, potassium, and sulfur), soil organic carbon (SOC) content, and soil enzymatic activities (alkaline phosphatase and dehydrogenase). The results demonstrated that the combined application of organic amendments significantly improved crop performance. The highest seed yield of 34.2 q/ha was recorded in treatment T9 (RDF + FYM 2.5 t/ha + PM 5 t/ha + VC 2.5 t/ha), which significantly outperformed all other treatments (p d" 0.05). Treatments T7 (RDF + PM 5 t/ha + VC 5 t/ha) and T5 (RDF + FYM 5 t/ha + PM 5 t/ha) also produced notably high yields, clearly surpassing those obtained from RDF alone or FYM alone. Furthermore, nutrient uptake of N, P, K, and S was markedly enhanced depending on the type, quantity, and combination of organic materials applied. Soil organic carbon increased by 0.29–0.68% across the treatments receiving 10 t/ha of organic matter. Soil enzymatic activities, including alkaline phosphatase and dehydrogenase, were also substantially improved, with the extent of enhancement varying according to the specific organic source and application rate. Overall, these findings highlight that integrating a balanced combination of organic amendments-particularly the T_9 treatment at a total rate of 10 t/ha along with RDF offers a highly effective and sustainable strategy for boosting mustard yield, improving nutrient availability, and restoring soil health in saline environments, thereby supporting better crop productivity in salt-affected agricultural regions.

Keywords: *Saline soils, dehydrogenase, oil organic carbon (SOC)*

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Role of improved Brassica varieties in enhancing oilseed production in Jammu & Kashmir

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Brassica oilseeds, particularly rapeseed–mustard, constitute an important component of agricultural production systems in Jammu & Kashmir, contributing to edible oil availability, farm income and cropping system diversification under diverse agro-ecological conditions. Despite their significance, oilseed productivity in the Union Territory has remained below national averages due to the predominance of traditional varieties, sub-optimal crop management practices and region-specific biophysical constraints. In recent years, focused efforts by state agricultural universities, ICAR institutions and extension agencies have emphasized the development, evaluation and dissemination of improved Brassica varieties through frontline demonstrations (FLDs), cluster frontline demonstrations (CFLDs) and KVK-led interventions. This article synthesizes evidence from demonstration-based studies, regional performance analyses and on-farm evaluations conducted since 2020 to assess the impact of improved oilseed varieties on production in Jammu & Kashmir. Across locations and production environments, improved varieties consistently outperformed local cultivars under farmers' field conditions, recording seed yield advantages generally ranging from about 18 to 27 percent, with even higher gains reported under favourable temperate conditions. These productivity gains were further supported by improved crop management practices demonstrated under FLD and CFLD programmes. In addition to yield enhancement, adoption of improved varieties resulted in higher farm profitability, as reflected by increased net returns and favourable benefit–cost ratios. However, the full realization of varietal potential continues to be constrained by persistent technology and extension gaps, including limited availability of quality seed, partial adoption of recommended production packages, pest pressure and climatic variability. Overall, the reviewed evidence highlights varietal improvement as a key driver of enhanced oilseed production in Jammu & Kashmir and underscores the need for strengthened seed systems, region-specific climate-resilient breeding and integrated extension approaches to achieve sustained gains in oilseed productivity.

Keywords: *Brassica species, FLDs, production, Rapeseed-mustard*

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Changes in phosphorus fractions and soil microbial activities amended with compost and mineral fertilizers

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The low availability of phosphorus (P) in soil affects crop growth and yield of crops. Therefore, an understanding of P transformation and availability in soil, using different sources of P, is crucial for adopting appropriate P management practices to improve the productivity of mustard (*Brassica juncea*). A field experiment comprising five treatments replicated into four was conducted for three consecutive years during 2021–24. Treatments consisted of control (Ct), recommended dose of N-P-K-S fertilizers at 80-40-40-40 kg ha^{-1} (RDF-100%), enriched compost at 6 Mg ha^{-1} (EC-6), EC at 6 Mg ha^{-1} + RDF-100% (EC-6 +RDF-100%) and EC at 6 Mg ha^{-1} + RDF-50% (EC-6 + RDF-50%), laid out in a randomized block design. Among different phosphorous fractions across the years; saloid-P (S-P), iron-P (Fe-P), aluminium-P (Al-P), and calcium-P (Ca-P) increased markedly after 2021–22, with a constant increase in subsequent years among the treatments compared to Ct. However, EC-6 + RDF-100% resulted in a

significant build-up in all P fractions, including Olsen-P, total-P (Pt) and inorganic-P (Pi), compared to RDF-100%. EC-6 + RDF-100% had 14, 16 and 15% higher Pt, Pi and organic-P (Po) respectively, during 2023-24 over 2021-22 in comparison to RDF-100%. Walkley Black carbon (WBC) was also increased with RDF-100% over Ct across the years as well as within the year; however, a significant concentration of WBC was observed with EC-6 + RDF-100% over the years compared to Ct. Results revealed that better P availability and soil microbial activities with EC-6 + RDF-100% resulted in significantly higher mean (3 years) seed (2.89 Mg ha^{-1}) and stover (4.90 Mg ha^{-1}) yield of mustard over RDF-100%. Nevertheless, EC-6 + RDF-50% produced 12% higher mean seed yield of mustard, than RDF-100%. EC-6 + RDF-100% also resulted in higher P uptake by seed and stover of mustard as compared to RDF-100%. This study hypothesises that the integration of enriched compost (EC-6) and mineral fertilizers (RDF-100%) is a beneficial alternative option for improving P availability, crop yield and soil fertility.

Keywords: *Microbial, phosphorus, mustard*

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Study for nutraceutical traits in leafy mustard landraces of Manipur

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Leafy mustard (*Brassica juncea* var. *rugosa*), commonly known as broad leaf mustard, is an important winter leafy vegetable in Manipur and is traditionally consumed as the popular boiled dish hangam thongba. The crop is reported to be rich in minerals and antioxidants, contributing to health promotion and disease prevention, and its inclusion in diets can help alleviate nutrient deficiencies. However, scientific information on its nutritional value remains limited, largely due to its relatively small area of cultivation and historically low research focus. With growing consumer interest driven by its health benefits, there is an increasing need to systematically evaluate and document the nutritional composition of leafy mustard. Thirty five (35) leafy mustard landraces randomly collected from 5 districts of Manipur were evaluated for seven nutritional traits viz. protein, phosphorus, potassium, sulphur, iron, manganese and zinc content in tender palatables leaves during *rabi* 2022-23 at CAU Research Farm, Andro in Randomized Block Design. Four (4) promising genotype in terms of the seven nutritional traits under study were identified. LM 1 exhibited highest sulphur (153 mg/100g) and iron content (4.8 mg/100g) with comparatively higher values for potassium, zinc and manganese content. LM 7 recorded maximum phosphorous content (117.9 mg/100g) along with comparatively higher values for protein, sulphur and iron content. Similarly, LM 11 exhibited maximum content for protein (3.6%) with higher values for potassium zinc and manganese while, LM 21 exhibited maximum manganese content (1.18 mg/100g) with comparative desirable values for potassium, sulphur, iron and zinc. Hence, these genotypes may be used as donor parents for their respective nutritional content in future improvement programmes. To get a better picture of the importance of leafy mustard from the nutritional point of view, a comparative study was made for nutritional content of the 7 nutritional traits studied with 5 other commonly consumed vegetables viz. Spinach, Lettuce, Broccoli, Cabbage and Kale. Values for the traits under consideration for these vegetables were taken from USDA Food Composition Database. The comparative study revealed leafy mustard to be an excellent source of protein, sulphur, iron, zinc, phosphorous and manganese and support its recommendation for dietary inclusion to help address nutrient deficiencies.

Keywords: leafy mustard, landraces, nutraceutical,

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Sustainable crop intensification through oilseeds for efficient resource utilization in western red and lateritic dry region of West Bengal

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Field experiments were carried out at farmers' field of Chhatna, Sonamukhi, Bishnupur and Khatra block of Bankura district of West Bengal, India to study the performance of various newly introduced crop sequences by replacing the upland and medium land paddy in the decades long rice based cropping system under diverse topographical and irrigation condition of red and lateritic belt of west Bengal with the objective of providing additional remuneration to the farmers by avoiding the risk of kharif paddy under delayed and erratic rainfall condition of the district through introduction of low water and input management requiring crops being profitable and having market demand with ultimate goal of increasing cropping intensity of the dryland agriculture of the district and state as well. The result showed that the highest benefit cost ratio (B: C ratio 3.44) was recorded in crop sequence 8 comprising redgram-sunflower-maize crop in the system followed by the value (BC ratio 3.40) recorded in the crop sequence 3 comprising maize-mustard-blackgram in the system.

Keywords: *Profitable alternative crop sequence, alternative land use strategies, rice, groundnut, maize, red gram, mustard, sunflower, cropping intensity*

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Optimization of crop residue in conservation agriculture-based maize-mustard system for improving productivity, profitability and soil health

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Conservation agriculture (CA), characterized by minimal soil disturbance, continuous soil cover through crop residues, and diversified cropping systems, has become a prominent strategy for promoting agricultural sustainability and conserving natural resources. In intensive cereal–oilseed systems such as maize–mustard, challenges including declining soil health, inefficient resource utilization, and increasing production costs threaten long-term productivity and farm profitability. Crop residue retention, a fundamental aspect of CA, significantly enhances soil physical, chemical, and biological properties by reducing erosion, regulating soil temperature, increasing soil organic carbon, and improving moisture retention. Nevertheless, the optimal level of crop residue retention required to maximize system productivity and profitability, without hindering crop establishment, remains insufficiently understood, especially within CA-based maize–mustard cropping systems. Optimizing crop residue management is therefore critical to fully realize the benefits of conservation agriculture. Appropriate residue levels enhance nutrient cycling, suppress weed growth, improve water-use efficiency, and stimulate beneficial soil microbial activity, collectively contributing to improved crop performance and soil health. This study was conducted to assess the effects of varying crop residue retention levels on productivity, profitability, and soil health parameters in a conservation agriculture-based maize–mustard system, with the aim of identifying an optimal residue management strategy for sustainable system intensification. The study concluded that the application of zero-tillage in combination with 50% crop residue in maize-mustard cropping systems may be recommended for higher

yields and system productivity in the northwestern plains zone of India.

Keywords: *Conservation agriculture, nefficient resource utilization, productivity*

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Growth and productivity of Indian mustard (*Brassica juncea* L.) as influenced by integrated nutrient management options

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India is the major producer of oilseeds both in terms of area and production and also biggest consumer of oilseeds. Rapeseed-mustard are the primary oilseed crops of India, occupying important place next to groundnut in area and production. Indian mustard (*Brassica juncea)* is the most important among all ecotypes due to its high seed yield and oil content. It can play an important role in crop diversification from rice-wheat mono-culture in Punjab which is depleting the natural resources viz. groundwater and soil health. The mustard crop needs less water than wheat and due to its deep-rooted system can explore deeper soil depths for nutrients which remain unutilized and hence, can both perform better and conserve the natural resources. But the major challenge is to match the economics of this crop with wheat, which can be accomplished by either enhancing productivity or decreasing the cultivation cost. Keeping this in view, an experiment was conducted in the PAU, Ludhiana to evaluate the performance of Indian mustard under 10 different integrated nutrient management options with an objective to find best nutrient management option for rearing maximum productivity of Indian mustard. The treatments comprising of T_1: control, T_2: 100% PK, T_3: 100% NPK, T_4: 150% NPK, T_5: 100% NPK + S @ 40 kg ha-1, T_6: 100% NPK + $ZnSO_4$ @ 25 kg ha-1, T_7: 100% NPK + B @ 1 kg ha-1, T_8: 100% NPK + FYM @ 2.5 t ha-1, T_9: 100% NP and T_{10}: 100% NK were arranged in Randomized Complete Block Design and were replicated thrice. The results of the study revealed that treatment T_4 recorded maximum plant height (182.1 cm) which was statistically at par with treatments T_3, T_5, T_6, T_7, T_8 and T_9 and significantly higher as compared to rest of the treatments. However, the yield parameters like number of primary branches per plant (4.8), number of secondary branches per plant (8.7) and number of silique per plant (301.5) were maximum in treatment T_5 which were significantly higher as compared to treatment T_1 and T_2 but statistically at par with rest of the treatments. Contrastingly, maximum biomass yield (9000 kg ha-1) and seed yield (1900 kg ha-1) was recorded in treatment T_4 with 150% NPK application and this was significantly higher as compared to all the other nutrient management options. The treatment also recorded significantly higher gross returns (Rs 1,30,795 ha-1), net returns (Rs 87,892 ha-1) and benefit cost ratio (3.05) as compared to all the other treatments.

Keywords: *Rapeseed-mustard, biomass, mono-culture*

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Performance of mustard under customized fertilization practices

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Dihydrate Polyhalite (Poly 4) is a multi-nutrient fertilizer containing Ca, Mg, K and S. Polyhalite ($K_2Ca_2Mg(SO_4)_4 \cdot 2(H_2O)$) is the natural mineral which occurs in sedimentary marine evaporates, consisting of a hydrated sulfate of K, calcium (Ca) and magnesium (Mg). The deposits of this mineral, typically consist of K_2O: 14%, S: 19%, MgO: 6%, CaO: 17%. As a fertilizer providing four key plant nutrients *viz.* S, K, Mg, and Ca - polyhalite may offer attractive solutions to crop nutrition. In this context, a field experiment was conducted during *rabi* 2023-24 and *rabi* 2024-25 at Rajasthan Agricultural Research Institute,

Durgapura, Jaipur to study the effect of Dihydrate Polyhalite fertilizer on growth, productivity and quality of mustard. The crop was nourished with two doses of NP with or without Dihydrate Polyhalite. The experiment was conducted in Randomized Block Design with 07 treatments consisted of different doses of Dihydrate Polyhalite with recommended dose of fertilizers (RDF) and farmer practise (FP). Each treatment was replicated thrice. The results revealed that customized fertilization with dehydrate polyhalite significantly influenced the yield attributes and yield of mustard during both the years. Maximum siliqua plant^{-1} and seed yield were recorded with application of 160 kg Poly 4 ha-1 along with recommended dose of N & P. Application of 160 kg Poly 4 ha-1 along with recommended dose of N & P recorded 24.0% and 8.6% more seed yield than recommended dose of NP and NPS, respectively. Similarly, Application of 160 kg Poly 4 ha-1 along with farmer practice recorded 20.3% more seed yield in comparison to farmer practice. Significantly more seed yield was also recorded with application of 120 kg Poly 4 ha-1 along with RD of NP and FP than the yields recorded in RDF & FP only. Seed yields recorded with 120 kg Poly 4 ha-1 along with FP was statistically at par with seed yield recorded with 160 kg Poly 4 ha-1 + FP. Based on the results it may be concluded that application of Poly 4 in mustard crop may be an efficient method for maximizing yield under semi-arid conditions of Rajasthan. Application of 160 or 120 kg Poly 4 ha-1 along with recommended doses of N & P or FP may provide an effective solution to enhance crop growth and productivity of mustard crop.

Keywords: *Seed yiled, RFD, yield*

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Response of macro and micro nutrient bio-fertilizers of liquid consortia for enhancing mustard productivity and profitability

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The extensive and indiscriminate use of chemical fertilizers and other agro-chemicals in intensive farming have deteriorated soil health, soil macro and microflora, quality of water, food and fodder and have adversely affected the human and animal health due to their entry in food chain. The combined use of inorganic sources of plant nutrient and microbial consortia not only pushes the production and profitability of crops, but also it helps in maintaining the fertility status of the soil. A field experiment was conducted at Agricultural Research Station, Kota during the *rabi* season of 2024-25 to study the effect of macro and micro nutrient bio-fertilizers of liquid consortia in enhancing mustard productivity and profitability in irrigated area of south-east Rajasthan. The experiment comprised of three fertility levels *viz*., F_1: 100% RDF (100: 50: 30 kg/ha NPK), F_2: 75% RDF, F_3: Control and six microbial consortia treatment *viz*., M_1: Azotobactor, M_2: Phosphate Solubilising Microorganism (PSMO), M_3: Potassium Mobilizing Biofertilizer (KMB), M_4: Zinc Solubilizing Biofertilizer (ZSB), M_5: NPK consortia + ZSB and M_6: Control (No biofertilizer) were laid out in split- plot design with three replications. Among the different fertility and microbial consortia, significantly maximum seed yield (2263 kg/ha) was recorded under nutrient management level of 100% RDF (100:50:30 kg/ha $NP_2O_5K_2O$) in conjunction with seed treatment by NPK consortia of bio-fertilizers + ZSB (50 ml/kg seed each).

Keywords: *Chemical fertilizers, micro nutrient, bio-fertilizers*

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Response of mustard (*Brassica juncea* L.) genotype to macro- and micro nutrient bio-fertilizers in the acidic and lateritic soils of Jharkhand

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Mustard is one of the most important edible oilseed crops that contribute more in Indian economy. The low yield of mustard in Jharkhand is the result of several interconnected challenges such as unpredictable weather, including irregular rainfall and lack of proper crop management practices, particularly those linked to the poor soil fertility as soils of Jharkhand are acidic in nature. Farmers apply blanket dose of fertilizers, leading to low productivity. The lack of awareness of optimal and balanced nutrition through integrated use of inorganic fertilizers along with macro and micro nutrient biofertilizers for enhancing yield and to make nutrient management, climate-resilient. Hence, evaluating the impact of different macro and micro nutrient biofertilizers is critical for enhancing both yield and economically viable, socially acceptable. A field experiment was conducted during Rabi 2023-24 and 2024-25 on sandy loam soil at Agronomy Research Farm of the Birsa Agricultural University, Kanke, Ranchi, Jharkhand to investigate the response of macro and micro nutrient bio-fertilizers in enhancing mustard productivity and soil health. The experiment was laid out in split plot design, replicated thrice with three levels of fertilizer as inorganic source i.e., 100% RDF,75% RDF and control, in main plot and six microbial biofertilizer levels i.e. Azotobactor, Phosphate Solubilizing Micro Organism (PSMO), Potassium Mobilizing Biofertilizer (KMB) Zinc Solubilizing Biofertilizer (ZSB), NPK consortia + ZSB and Control (No biofertilizer) in sub plot and their interaction. Mustard var. BBM-1 was given RDF of 80 kg N ha^{-1}, 40 kg P_2O_5 ha^{-1}, 20 kgK_2O ha^{-1} and 20 kg S ha^{-1} and maintained spacing 30 cm x 10cm. The results revealed that among fertility levels maximum plant height, a greater number of primary and secondary branches per plant, and siliqua per plant of mustard were recorded with 100% of RDF i.e.1.75cm,4.41 4.71 and 188, respectively. and was comparable with 75% RDF. Among different biofertilizers and their combinations taller plant(161cm) was recorded with biofertilizer NPK consortia in combination with zinc solubilizing bacteria. Similarly greater number of primary branches per plant (3.91) as well as secondary branches (3.82) and (174) siliqua per plant were registered with biofertilizer NPK consortia in combination with zinc solubilizing bacteria. The interaction effect on plant height, branches and number of siliquae per plant not found significant. Result also exhibited that maximum seed yield (1358 kg ha^{-1}) and monetary net return (46464 ¹ ha^{-1}) were recorded with 100% RDF and was found to be comparable with 75% RDF. Treatment receiving biofertilizer NPK consortia + zinc solubilizing bacteria recorded maximum seed yield (1285 kg ha^{-1}) and net return (43287 ¹ ha^{-1}). The interaction effect did not reach the level of significance. However, the treatment combination 100% RDF along with application of NPK consortia+ zinc solubilizing bacteria was found better for increasing the yield and yield attributes viz., plant height, branches and number of siliquae per plant. The increase in yield might be due to macro- and micronutrient bio-fertilizers enhance nutrient availability, root growth, flowering, pod formation, oil synthesis, and soil microbial activity, leading to better growth, higher yield attributes, and yield for sustainable productivity.

Keywords: *mustard, growth, profitability, macro and micro biofertilizers, NPK consortia, ZSB, PSMO, KMB, Azotobactor*

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Integrated use of microbial consortia and fertilizers for sustainable soybean production

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Soybean [*Glycine max* (L.) Merrill) is referred to as a miracle crop due to its wide use as food, feed, and an important commercial commodity. It is highly adaptable to diverse agro-climatic conditions and valued for its high-quality protein, edible oil, and micronutrient content. As a legume, soybean enriches soil fertility through biological nitrogen fixation, making it suitable for crop rotation and intercropping systems. Although India's soybean area (12.69 million hectares) and production (12.82 million tonnes) have increased (SPOA, 2024), productivity remains lower (932 kg/ha) than the global average (3.01 tonnes/ha), indicating a need for improved crop management and balanced nutrition. Soybean require both macro and micronutrients for optimal growth and development; however, conventional fertilizer use often leads to nutrient losses and deficiencies. Therefore, the field experiments were conducted during the Kharif seasons of 2021–2023 at the Agharkar Research Institute, Pune, Maharashtra, India. The soil of the experimental plot was a well-drained, vertisol with a slightly alkaline pH (7.0–7.4), and the site's climate is subtropical. The experiment was laid out in a randomized complete block design (RCBD) with three replications and seven nutrient management strategies (NMS), NMS 1: Control (without nutrient), NMS 2: 100% RDF, NMS 3: 75% RDF only, NMS 4: 75% RDF + Bio Zn, NMS 5: 75% RDF + Bio NPK, NMS 6: 75% RDF + Bio Zn + Bio NPK and NMS 7: 75% RDF + Rhizobium + MDSR 14 +12c (12c: Burkholderia arboris- High P solubilizing bacteria). Soybean variety 'DSb 21' was sown during the fourth week of June at a seed rate of 62.5 kg ha{ ¹. Results revealed that the integrated application of microbial consortia with fertilizers significantly improved soybean growth, root nodulation, yield, and its attributes, nutrient uptake, and economic returns. The NMS comprising 75% RDF, Rhizobium, MDSR-14, and 12c (NMS 4) recorded higher dry matter accumulation, root nodulation and their dry weight at R5 stage, number of pods per plant, and the seed yield (3104 kg ha{ ¹), comparable to NMS 2-100% RDF (3004 kg ha{ ¹), and was superior over the NMS 1- control (2259 kg ha{ ¹). Seed yield increased by 37.41% over the control (NMS 1), without yield loss. Enhanced nodulation and increased nutrient availability resulting from microbial inoculation contributed to improved N, P, and K uptake, leading to a better nutrient balance. Economically, NMS 7 resulted in the highest net returns (¹ 80,346 ha{ ¹) and benefit–cost ratio (2.99) by saving 25% of the recommended fertilizer dose without compromising yield. Overall, integrated nutrient management using microbial consortia proved effective in improving productivity, profitability, and soil fertility in soybean cultivation.

Keywords: *Microbial consortia, nutrient management, soybean, yield enhancement*

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Crop diversification with soybean in scarce rainfall zone of Andhra Pradesh

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Oilseeds account for 14.3% of the yearly gross cropped area. India ranks first in the production of castor, safflower, sesame and niger; second in groundnut; third in rapeseed-mustard; fourth in linseed; and fifth in soybean. Soybean is ideally suited for vegetarian dominated Indian society. It is also called poor man's meat. It fits efficiently in cropping pattern replacing some efficient *kharif* crops. Crop

diversification also acts as a powerful tool in minimization of risk in farming. Soybean is undoubtedly a wonder crop. Its productivity level is not keeping a pace with time. Because of both biotic and abiotic stresses, its cultivation is becoming less remunerative in Andhra Pradesh and is less popularized. This needs a fill up for its possible adoption and spread. Rainfed agriculture in India forms the backbone of rural livelihoods, particularly for small and marginal farmers. The increasing unpredictability of monsoons due to climate change has intensified the frequency of droughts and crop failures. Andhra Pradesh comprises approximately 4.0 million hectares of rainfed land, with nearly 45% (1.6 million ha) located in the scarce rainfall zone that includes Kurnool, Nandyal, Anantapuramu, and Sri Sathyasai districts with annual average rainfall of 627 , 747,525 and 596 mm respectively. Five demonstrations were conducted with Soybean variety DSB-35 and 25 demonstrations with KDS 726 in black soils of Nandyal and Kurnool district respectively in Scarce rainfall zone of Andhra Pradesh during *Kharif* 2025. Demonstrations (25 Nos) was also conducted in Kurnool district with Soybean + Bajra (4:1) intercropping system. In Kurnool district an amount of 670 mm was received in 34 rainy days. Average yield of Soybean KDS 726 recorded 1525 kgha^{-1} with net returns of Rs.43025 ha^{-1} compared to farmers' practice of sole Redgram with net returns of Rs. 38,050 ha^{-1}. In Nandyal district an amount of 716 mm was received in 43 rainy days. Average yield of Soybean DSB-35 recorded 2420 kg ha^{-1} with net returns of Rs. 74,525 ha^{-1} compared to farmers practice of Maize with net returns of Rs. 55,760 ha^{-1}.In Kurnool district soybean (KDS 726) recorded 1220 kg ha^{-1} of seed yield and Bajra (ABV-04) recorded 1530 kgha^{-1} of seed yield. Intercropping of Soybean + Bajra (4 :1) recorded net returns of Rs.59440kg ha^{-1} compared to net returns of Rs.38200 ha^{-1} with sole crop of Bajra. These results indicates that crop diversification with improved varieties of Soybean i.e KDS726 and DSB 35 with higher yields and increased net incomes compared to tradition practice of Redgram and maize crops. Intercropping of Soybean + Bajra (4 :1) is climate resilient with 56 percent higher net returns compared to sole crop of Bajra. In recent years the area under soybean is increasing due to short duration, less cost of cultivation with higher net returns compared to traditional crops.

Keywords: *Crop diversification, Rainfed farming, Andhra Pradesh*

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Influence of nitrogen and phosphorus fertilization on growth and productivity of soybean (*Glycine max* L.)

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A field experiment was conducted during *Kharif* 2024 at the Instructional Farm, College of Agriculture, Ummedganj–Kota, to study the effect of nitrogen and phosphorus levels on growth and productivity of soybean (*Glycine max* L.). Experiment was laid out in Factorial Randomized Block Design (FRBD) with three replication and twelve treatment combinations, among which application of N*f* • P† • kg ha{ ¹ recorded the best performance. This treatment significantly improved plant height, dry matter accumulation, number of branches, chlorophyll content, root nodulation and crop growth rate. Yield attributes such as number of pods plant{ ¹ and seeds pod{ ¹ were also maximized. Consequently, the highest seed yield, straw yield and biological yield were obtained under N*f* • P† • . The study suggests that 30 kg N and 60 kg P, O… ha{ ¹ is an optimum nutrient level for enhancing soybean productivity under the conditions of Kota, Rajasthan.

Keywords: *Nitrogen, phosphorus, growth, productivity, yield.*

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Isolation and characterization of *Bacillus haynesii*: A sustainable bioinoculant for agrochemical remediation

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India is divided into 15 agro-climatic zones, with diverse soil microbiome .The soil microbiome includes bacteria, fungi, algae, protozoa, archaea, and viruses, that plays an important role in promoting sustainable agriculture and boosting crop productivity. Microbial bio-diversity of soil from various regions of India has been subjected to several studies for its biochemical properties and use as bio-inoculant. However, extensive agrochemical use has degraded soil fertility, posing health and environmental risks, while conventional disease control methods also harm sustainability in agriculture. The current study addresses these challenges by isolating heat-resistant, spore-forming Bacillus strains from diverse agro-climatic zones, characterizing their plant growth-promoting rhizobacteria (PGPR) traits, pesticide compatibility, and heavy metal tolerance. Selected isolates underwent detailed phenotypic, biochemical, microbiological characterization, and molecular analysis with sequencing at MTCC, Pune. One of the isolates, *Bacillus haynesii* shows degradation of a commonly used pesticide Malathion. Quantitative GC-MS analysis also confirmed its malathion degradation capacity. These findings highlight the potential of native Bacillus haynesii as a sustainable bioinoculant for enhancing crop yield, and agrochemical bioremediation across India's varied agro-climatic conditions.

Keywords: *Bio-inoculants, heavy metal resistance, plant growth-promoting, pesticide resistance, Rhizobacteria mineral solubilisation, sustainable agriculture,*

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An integrated AI-based decision support system for soybean disease and insect forecasting

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Soybean is a major oilseed crop in India; however, its productivity is significantly affected by weather variability, disease incidence, and insect pest infestation. Existing advisory systems often lack early warning capability, varietal specificity, and effective last-mile delivery to farmers. To address these limitations, the present study develops a climate-smart, AI-based decision support system for soybean that integrates disease prediction, insect pest forecasting, weather-driven advisories, and farmer-friendly support services. The system is developed using historical soybean disease and insect pest incidence data collected during 2018-2024 from All India Coordinated Research Project (AICRP) trials, integrated with key agro-meteorological parameters such as maximum and minimum temperature, rainfall, number of rainy days, and relative humidity. Weather data and short-term forecasts are sourced from reliable platforms including the India Meteorological Department (IMD), NASA POWER, and Open-Meteo. Machine learning and deep learning models are employed to predict the early-stage occurrence of nine major soybean diseases, namely Anthracnose, Bacterial Pustule, Charcoal Rot, Collar Rot, Frog Eye Leaf Spot, Myrothecium

Leaf Spot, Rhizoctonia Aerial Blight, Yellow Mosaic Disease, and Rust, along with seven major insect pests, viz. Whitefly, Pod Borer, Girdle Beetle, Semilooper, Tobacco Caterpillar, Stem Fly, and Bihar Hairy Caterpillar. In addition to weather and varietal susceptibility, crop age and growth stage have been incorporated into the modeling framework, as several diseases and insect pests are known to occur at specific crop growth periods. The system dynamically calculates crop age based on sowing date and integrates it with prediction outputs to improve temporal accuracy. Along with predicting occurrence, the model estimates the severity level of the identified disease or insect infestation and suggests preventive and management measures recommended by agricultural scientists, considering crop stage and severity. To ensure practical applicability at the field level, a dedicated weather-based web application has been developed to provide real-time agro-meteorological information, short-term forecasts, and advisories tailored to soybean cultivation. A bilingual advisory interface has been integrated to improve accessibility and usability for farmers. The integrated platform supports precision advisory delivery, reduces dependence on indiscriminate pesticide use, and enhances farmer preparedness against climate-induced crop risks. This work demonstrates the potential of artificial intelligence and digital technologies in strengthening government-led agricultural extension services and promoting sustainable and climate-resilient soybean production in India.

Keywords: *Artificial intelligence, forecasting, soybean, yield*

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Residue-incorporated permanent broad bed furrow enhances soil microbial dynamics, carbon cycling (*cbbL* gene abundance), and sustains soybean productivity in long term cropping systems

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Permanent broad bed furrow (PBBF) serves as an effective soil conservation agriculture practice that enhances soil quality and sustains crop productivity compared with conventional tillage systems. This long-term study evaluated the effects of residue-incorporated PBBF on soil rhizomicrobial diversity, enzyme activities, soil microbial biomass carbon (SMBC), substrate induced respiration (SIR) and total phospholipid fatty acid (TPLFA), *cbbL* gene abundance, and soybean yield in soybean-based cropping systems. The experiment included four land configurations (LC): PBBF without residue (PBBF+WR), PBBF with residue (PBBF+R), conventional tillage farmer's practices with residue (CTFP+R), and without residue (CTFP+WR), along with three cropping system (CS): soybean-maize (S-M), soybean-wheat (S-W) and soybean-chickpea (S-C) with residue retention of 2.5, 1.5 and 1Mg ha^{-1}, respectively. Results revealed that PBBF+R and PBBF+WR significantly improved soil microbial diversity, enzyme activities, microbial biomass carbon (SMBC), substrate-induced respiration (SIR), total PLFA (TPLFA), glomalin content, spore density, and *cbbL* gene abundance compared with conventional tillage practices. Dehydrogenase and â-glucosidase activities increased by 22.5% and 23.0% under PBBF+R, and by 30.0% and 21.0% under PBBF+WR respectively. SMBC and SIR increased by more than 41% under both PBBF treatments. Similarly, PBBF+R and PBBF+WR significantly enhanced the glomalin content (28.40 and 31.57 %) and spore density (35.13 and 38.05 %), TPLFA (35.81 and 35.52 %) and *cbbl* gene abundance (47.50 and 16.84 %) compared to CTFP+R and CTFP+WR, respectively. Among the three crop rotations, S-M retaining the 2.5Mg ha^{-1}crop residue showed the highest values of enzyme activities, SMBC, SIR, glomalin, spore density, TPLFA and abundance of cbbl gene. In the case of yield, highest soybean yield was observed in PBBF+R (2473 kg ha^{-1}) and S-M (2155 kg ha^{-1}) against LC and CS,

respectively. Principal component analysis (PCA) revealed that PLFA microbial communities explained 88.5 % and 8.9 % of total variance in land configuration biplots, and 83.8 % and 16.2% in cropping system biplots for PC1 and PC2 respectively. Overall, residue retained PBBF under suitable crop rotation significantly improved the soil biological health and soybean productivity and can be recommended as a sustainable soil management practice.

Keywords: *Permanent broad bed furrow; Conservation agriculture; Soil microbial diversity; PLFA; cbbL gene; Soybean yield; Crop residue retention*

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Harnessing microbial symbionts to enhance soybean productivity and soil carbon sequestration

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Soybean (*Glycine max* L.) productivity in Indian agro-ecosystems remains constrained by recurrent moisture stress, declining soil fertility, and depletion of soil organic carbon (SOC). Developing climate-resilient and resource-efficient production systems is therefore imperative. Beneficial microbial symbionts, particularly moisture-stress tolerant soybean rhizobia and arbuscular mycorrhizal fungi (AMF), offer an ecologically sound strategy to simultaneously enhance crop productivity, nutrient-use efficiency, and soil carbon sequestration. Moisture-stress tolerant rhizobial strains were isolated from nodules of drought-tolerant soybean genotypes characterized by high trehalose accumulation. The isolates were identified using Fatty Acid Methyl Ester (FAME) profiling and 16S rRNA gene sequencing, and evaluated for osmotic stress tolerance under polyethylene glycol (PEG-6000)-induced conditions, along with key plant growth-promoting traits. Field experiments were conducted using single and consortium inoculations of *Bradyrhizobium* spp. and AMF at 75% of the recommended dose of fertilizers (RDF), in comparison with farmer practice (100% RDF). Parallel studies evaluated AMF biomass and soil carbon dynamics across contrasting soil management systems, including zero tillage, minimum tillage, conventional tillage, and raised-bed systems. AMF biomass was quantified using microscopic methods and the PLFA C16:1ù5 biomarker, while glomalin-related soil protein (GRSP), microbial biomass carbon (MBC), enzyme activities, and SOC stocks were measured to assess soil carbon sequestration potential.

Results includes a novel soybean rhizobial strain which was identified as *Bradyrhizobium daqingense*, reported for the first time from Indian soils. Along with *B. liaoningense*, this strain tolerated osmotic stress equivalent to 20% PEG-6000 and exhibited high expression of stress-alleviating traits such as ACC deaminase activity, indole-3-acetic acid (IAA) production, and osmolyte accumulation. Under controlled conditions, *B. daqingense* recorded significantly higher nodulation (20-30% increase), leghaemoglobin content (25-40% increase), and nitrogenase activity compared to native and commercial rhizobial strains. Under field conditions, inoculation with moisture-stress tolerant rhizobia and AMF at 75% RDF enhanced nodule biomass and leghaemoglobin content by 18-35% over un-inoculated controls and produced soybean grain yields statistically non-significant or 8-12% higher than farmer practice (100% RDF), indicating a fertilizer saving of approximately 25% without yield penalty. AMF-based studies further revealed that zero-tillage and raised-bed systems supported 1.4 to 1.8-fold higher AMF biomass (PLFA C16:1ù5), 30-60% greater GRSP pools, and 20-45% higher SOC stocks compared to conventional tillage systems. Strong positive relationships were observed between AMF biomass, GRSP, and SOC stocks ($r = 0.68$ to 0.94), establishing these AMF-derived parameters as reliable indicators of soil carbon sequestration potential.

Overall, the integration of moisture-stress tolerant soybean rhizobia and AMF represents a scalable, climate-smart approach to enhance soybean productivity while reducing chemical fertilizer inputs. Beyond

yield benefits, AMF-mediated glomalin production and enhanced microbial activity contribute substantially to soil carbon sequestration and long-term soil health, supporting the development of resilient soybean-based agro-ecosystems under changing climatic conditions. It is concluded that the integration of moisture-stress tolerant soybean rhizobia and AMF offers a scalable, climate-smart approach to improve soybean productivity while reducing chemical fertilizer inputs. Beyond yield benefits, AMF-mediated glomalin production and enhanced microbial activity contribute substantially to soil carbon sequestration and long-term soil health. Harnessing these microbial symbioses can play a key role in developing resilient soybean-based agro-ecosystems under changing climatic conditions.

Keywords: *Soybean, moisture stress, Bradyrhizobium daqingense, arbuscular mycorrhizal fungi, glomalin-related soil protein, soil organic carbon, climate-smart agriculture*

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Yield and economics of different soybean [*Glycine max* (L.) Merrill] varieties under different phosphorus levels along with inoculation of PSB

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A field experiment was conducted during the summer season of 2024 at Dusty Acre Farm, JNKVV, Jabalpur (M.P.) to evaluate the yield performance and economic feasibility of different soybean cultivars under varying phosphorus levels integrated with phosphate-solubilizing bacteria (PSB). The experiment was laid out in a Factorial Randomized Block Design with three varieties (JS 20-34, JS 20-98, JS 20-116) and six phosphorus–PSB management treatments, P1- 100% Recommended dose of N, P2- 100% of N and K + 75% P, P3- 100% Recommended Dose of N & K + 75% P + seed Treatment with PSB @ 10 g kg^{-1} seed, P4- 100% Recommended Dose of N & K + 75% P + seed Treatment with PSB @10 g kg^{-1} seed + soil application of PSB @ 5 kg ha^{-1}, P5- 100% Recommended Dose of N, P & K + seed Treatment with PSB @ 10 g kg^{-1} seed, P6- 100% Recommended Dose of N, P & K + seed Treatment with PSB + soil application of PSB @ 5 kg ha^{-1}, replicated four times. Results revealed significant variation in biomass yield due to variety and phosphorus management. Among cultivars, JS 20-116 recorded the highest biomass yield (3406 kg ha{ ¹), followed by JS 20-98 and JS 20-34, demonstrating its superior genetic potential and nutrient uptake efficiency. Phosphorus levels combined with PSB inoculation positively influenced biomass accumulation, with the highest biomass observed under P6 (100% NPK + PSB seed and soil application), indicating synergistic benefits of integrated nutrient management. Economic analysis showed that treatment V3×P6 achieved the maximum gross (Rs. 80669 ha{ ¹) and net returns (Rs. 47328 ha{ ¹), along with the highest B:C ratio (2.42), establishing it as the most profitable combination. Correlation studies revealed strong positive relationships between grain yield and plant height, branches per plant, LAI, nodulation, pods per plant, and seed index, highlighting the contribution of physiological and reproductive traits to productivity under improved phosphorus availability. Overall, the study concludes that JS 20-116 combined with full NPK and PSB application (P6) optimises growth, yield, and profitability in soybean cultivation.

Keywords: *Randomized Block Design, integrated nutrient management, yield*

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Effect of herbicides on growth, yield attributes and yeld of soybean [*Glycine max* (L.) Merrill]

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A field experiment was conducted at Agricultural Research Station, Ummedganj, Kota during Kharif 2023 to study the Effect of herbicides on growth, yield attributes and yield of soybean (*Glycine max* L.). The experiment was comprising five treatments viz T_1: Diclosulam @ 26 g/ha as pre emergence T_2: Diclosulam @ 26 g/ha as pre emergence + One hand weeding at 40 DAS), T_3: Propaquizafop 2.5% + Imazethapyr 3.75% at 2.0 l/ha at 15-20 DAS, T_4: Weedy check , T_5: Weed-free check (2 hand weeding at 20 and 40 DAS) with four replications. The soil of the experimental field was clay loam, alkaline in reaction (pH 7.7), medium in organic carbon (0.55 %), medium in potassium (312 kg/ha) and low in available phosphorus (22.2 kg/ha) and sulphur (15.5 kg/ha). Results revealed that Diclosulam @ 26 g/ha as pre-emergence + One hand weeding at 40 DAS), significantly reduced weed population and dry weight at 30 and 60 DAS, respectively. Diclosulam @ 26 g/ha as pre-emergence + One hand weeding at 40 DAS), increased significantly number of pods/plant (51.11), seeds weight (9.88g), seed yield (2556 kg/ha), straw yield (3877 kg/ha) and net return (Rs84767/ha) over, propaquizafop 2.5% + Imazethapyr 3.75% @ 2.0 l/ha at 15-20 DAS, Diclosulam @ 26 g/ha as pre-emergence**,** weedy check, respectively but at par with weed-free check (2 hand weeding at 20 and 40 DAS)

Keywords: *Soybean, Diclosulam, herbicide, weeds and yield*

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Exploration of agronomic traits and genetic factors influencing soybean suitability for mechanized harvesting

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Soybean (*Glycine max* [L.] Merr.) is a globally important crop used for food, feed, and industrial purposes, contributing about 25% of the world's edible oil. Globally, it is cultivated on approximately 135 million hectares, with a production of 420.77 million tons and a productivity of 3.1 tons per hectare; Brazil, USA, Argentina, China, and India are the major producers. In India, soybean occupy about 11.2 million hectares, producing 12.1 million metric tons with an average productivity of 925 kg/ha, which is below the global average. Despite wide adaptability and high yield potential, productivity remains low due to poor crop management, imbalanced nutrition, pest and disease pressure, and inefficient harvesting. Manual harvesting is labour-intensive and prone to loss, while mechanization is limited by low pod height and lodging. Hence, developing soybean genotypes with improved plant architecture, higher first pod height, lodging resistance, and suitability for mechanical harvesting is essential. This study aims to screen soybean genotypes and agronomic traits for efficient mechanized harvesting and enhanced productivity. A field experiment was conducted at the experimental farm of MACS Agharkar Research Institute, Pune (MS), during *Kharif* 2025. A set of 255 soybean genotypes, including released varieties, breeding lines, exotic, and indigenous lines, based on preliminary screening for yield and first pod height, was sown in a one-meter row length in an augmented RBD along with four check entries. The crop was raised following the standard cultivation practices. The genotypes under study were assessed for phenological traits observed at various stages of

growth and development for further analysis. Results showed that, among the growth attributes, the hypocotyl length from the ground surface ranged from 1.7 to 4.8 cm, with an average of 2.9 cm, at the seedling stage. The average plant height recorded at 30, 45, 60 days after sowing (DAS) and at harvest was 26.8 cm, 43 cm, 59.2 cm, and 56.23 cm, respectively. Variation in plant height among genotypes might be due to differences in the genotypic makeup of the accessions under study. The range for the number of branches per plant was observed to be from 1 to 8, pods per plant from 15 to 88, and clusters per plant from 6 to 52. First pod height (FPH) is a crucial trait that determines the suitability of soybean genotypes for mechanized harvesting and helps to reduce harvest losses. The first pod height was measured at full maturity and ranged from 3.46 to 22.04 cm, with an average of 9.51 cm. The first pod height above 12 cm is considered suitable for mechanical harvesting, resulting in minimal yield losses. In the present study, 40 soybean genotypes recorded more than 12 cm FPH. Similarly, the stem's strength is another important trait that determines the soybean plant's suitability for cutting above ground, as it prevents lodging and makes it easier for the harvester's cutter bar to catch the plant. The stem girth was measured using a vernier caliper, ranging from 3.2 to 8.26 mm. The ratio of FPH to plant height, assessed at maturity, was observed to be high in 40 soybean genotypes, ranging from 0.15 to 0.38, suggesting suitability for mechanical harvesting as the pods are less likely to be left unharvested near the ground. Soybean genotypes assessed based on the lodging angle at the R8 stage using the lodging score method given by researchers showed that 170 genotypes had a score of 0, 21 genotypes had a score of 1, 51 genotypes had a score of 2, and 15 genotypes had a score of 4. Genotypes with higher lodging scores are more likely to lodge and are not suitable for mechanical harvesting. Among the genotypes, the seed yield ranged from 153 to 4813 kg/ha with an average of 2129 kg/ha. An association study showed that plant height, lodging angle, branches, and pods per plant were positively associated, whereas FPH and the FPH-to-height ratio were negatively associated with yield. Suggested that FPH should be higher for reducing harvest losses and for suitability to mechanized harvesting, but the lowest FPH/PH ratio should be kept to a minimum. Further study is ongoing to identify and obtain detailed genetic information on mechanically harvestable soybean genotypes.

Keywords: *Soybean genotype, agronomic traits, RBD*

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Quality and yield of soybean (*Glycine max* L. Merrill) as influenced by various level of phosphorus, sulphur and iron

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A field experiment was conducted during the *kharif* season of 2024 at SKUAT- Kashmir, Wadura, to evaluate the quality and yield of soybean (var. Shalimar Soybean-2) as influenced by various level of phosphorus, sulphur and iron. The study used RCBD having thirteen treatments replicated thrice. Treatments included $T_1(P_{40}S_{10}Fe_{0.25})$, $T_2(P_{40}S_{10}Fe_{0.5})$, $T_3(P_{40}S_{20}Fe_{0.25})$, $T_4(P_{40}S_{20}Fe_{0.5})$, T_5:$P_{40}S_{30}Fe_{0.25}$, $T_6(P_{40}S_{30}Fe_{0.5})$, $T_7(P_{60}S_{10}Fe_{0.25})$, $T_8(P_{60}S_{10}Fe_{0.5})$, $T_9(P_{60}S_{20}Fe_{0.25})$, $T_{10}(P_{60}S_{20}Fe_{0.5})$, $T_{11}(P_{60}S_{30}Fe_{0.25})$, $T_{12}(P_{60}S_{30}Fe_{0.5})$, T_{13}(Control). Results revealed that T_{11} (60 kg P_2O_5 + 30 kg S + 0.25% Fe) performed consistently well with respect to growth parameters (Plant height, dry matter and LAI) and yield attributes. In terms of productivity, the combined application of 60 kg P, O… + 30 kg S + 0.25% Fe (T11) proved superior among the various nutrient treatments, recording the highest grain yield (2.41 t ha{ ¹), stover yield (4.50 t ha{ ¹) and total biological yield (6.91 t ha{ ¹). This treatment was statistically at par with T12 (60 kg P, O… + 30 kg S + 0.5% Fe). Furthermore, application of T_{11} resulted in the highest protein (39.17%) and oil content (21.97%) compared to all other treatments. This treatment also maximized the content and total uptake of nitrogen, phosphorus, sulphur, and iron, though results remained statistically similar to T_{12}. The study of nutrient use efficiencies showed that phosphorus use efficiency was highest in T_5, while

sulphur efficiency peaked in T_7. T_{11} also recorded the highest agronomic efficiency for iron. Economically, T_{11} was the most viable, providing the highest net returns (76,510 ha^{-1}) and a B:C ratio of 1.66. The study recommends the application of 60 kg P_2O_5 + 30 kg S + 0.25% foliar Fe for sustainable and profitable soybean cultivation in temperate conditions.

Keywords: *quality and yield of soybean, level of phosphorus, sulphur and iron*

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Herbicidal weed control and its effect on oil out-turn in groundnut cultivation (*Arachis hypogaea* L.)

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A field experiment was conducted at Instructional Farm, Dr. B.R. Choudhary ARS, Mandor, Jodhpur (Rajasthan) during *kharif* season of 2024 to study the Herbicidal Weed Control and its Effect on Oil out-turn in Groundnut Cultivation (*Arachis hypogaea* L.). The Field experiment was laid out in randomized block design (RBD) with ten treatments replicated thrice. The treatments comprised of T_1- Diclosulam 25 g/ha (PE)+ Fenoxapeop-p-ethyl 78 g/ha, T_2- Fomesafen 11.1%+Fluzifop-p-butyl 11.1% EC @ 230g/ha,T_3- Propaquizafop 2.5 %+Imazethapyr 3.75 % w/w @ 125 g/ha, T_4- Aciflourfen sodium 16.5%+Clodinofop-propargyl 8% EC @ 180g/ha, T_5- Fomesafen 12%+Quizalofop ethyl 3% SC @ 150g/ha, T_6- Imazethapyr 35% + Imazamox 35 % WG @ 50 g/ha, T_7- Topramezone 33.6% SC 20.6 g/ha, T_8- Pendimethalin 30%+Imazethapyr 2% EC @ 750 g/ha pre-emergence, T_9- Weed free, T_{10}- Weedy check. Results indicated that post-emergence application of fomesafen 11.1%+fluzifop-p-butyl 11.1% EC @ 230g/ha followed by propaquizafop 2.5 % + imazethapyr 3.75 % w/w @ 125 g/ha, fomesafen 12% + quizalofop ethyl 3% SC @ 150g/ha and aciflourfen sodium 16.5% + clodinofop-propargyl 8% EC @ 180g/ha significantly reduced total weed density and total dry weight of weed. Results in achieving higher weed control efficiency at all growth stages of crop that improved weed index and also lesser nutrient removals (N, P, K) recorded at 60DAS. Similarly, significantly number of kernel/pod (2.0/pod) and seed index (54.6 g) were recorded under post-emergence application of fomesafen 11.1%+ fluazifop-p-butyl 11.1 % @ 230g/ha followed by propaquizafop 2.5 % + imazethapyr 3.75 % w/w @ 125 g/ha, fomesafen 12% + quizalofop ethyl 3% SC @150g/ha and aciflourfen sodium 16.5% + clodinofop-propargyl 8% EC @ 180g/ha resulted in production of higher kernel yield. Higher the kernel yield will be ultimately showing the higher oil out-turn (kg/hac) under the above mention treatments. Improvement in pod yield that resulted in higher monetary advantages in terms of gross returns, net returns and B:C by application of most effective treatment fomsafen 11.1%+fluzifop-p-butyl 11.1% EC @ 230g/ha, propaquizafop 2.5%+imazethapyr 3.75% w/w@125 g/ha, fomesafen 12%+quizalofop ethyl 3% SC @150g/ha and aciflourfen sodium 16.5%+clodinofop-propargy l8% EC @180g/ha, as compared to weedy check. However, among all the treatments weed free recorded significantly highest growth and yield attributing characters and yield over rest of the treatments tested during field trial.

Keywords: *Groundnut, herbicide, nutrient, oil, weed control,*

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Effect of foliar application of nitrogen through nano urea and urea phosphate on growth, yield and economics of summer groundnut (*Arachis hypogaea* L.)

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A field experiment was conducted during *summer* season 2023,2024 and 2025 under Mahatma Phule Krishi Vidyapeeth, Rahuri (M.S.) at research farm of Oilseeds Research Station, Jalgaon (Maharashtra), India to study the "Effect of foliar application of Nitrogen through Nano Urea and Urea Phosphate on growth, yield and economics Summer Groundnut (*Arachis hypogaea* L.)". The experiment was laid out under Randomized Block Design with three replications with ten treatments. The three treatment consisting

of 100, 75, 50 % RDF, three treatments consisting of 100, 75 and 50 % RDF with combination of 0.2 and 1 % nano urea and urea phosphate spray at flowering stage, three treatments consisting of 100, 75 and 50 % RDF with combination of 0.2 and 1% spray of nano urea and urea phosphate at flowering and peg formation stage, respectively and one treatment consisting of 100 % RDF + 2% urea spray at 30 and 60 DAS, respectively were applied to the groundnut var. JL-776 (Phule Bharati) with uniform application of 10 ton of FYM to all the treatments as per recommendation. The results showed that, application of 100% RDNPK + (0.2% Nano urea + 1 % Urea phosphate) at flowering stage & peg formation stage (T_7) to groundnut produced significantly highest groundnut dry pod yield (2933 kg/ha), haulm yield (5381 kg/ha), gross returns (Rs.1,81,376/ha), net returns (Rs.1,17,470/ha) and B:C ratio 2.84 over Control. Treatment T_7 was found at par with T_1 + foliar application of urea @ 2% at 30 & 60 DAS (T_{10}) and T_2 + application of (0.2% Nano urea + 1 % Urea phosphate) at flowering stage & peg formation stage (T_8).

Keywords: *Nano urea, urea phosphate, yield, economics, summer groundnut, foliar application*

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Saturation vapor pressure and mean temperature as eco-climatic factors affecting groundnut productivity in India

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Groundnut is an important oilseed crop being cultivated primarily rainy season under rainfed situations. Gujarat state is leading interms of area and production whereas Pondichery and Tamil Nadu are leading interms of per hectare productivity. District wise crop profile for groundnut indicates that districts such as Ariyalur, Cuddalore, Theni of Tamil Nadu; and Gandhinagar, Mahesana, Surendranagar of Gujarat record very high per hectare productivity and classified as "High-productivity Districts (HPD)" whereas districts such as Anantapur, Kadapa, Kurnool belonging to Andhra Pradesh and Belgaum, Bellary, and Chitradurga districts belonging to Karnataka record very low productivity and classified as "Low-productivity Districts (LPD)". Environment plays a major role and significantly influences the productivity of these regions. But the environmental context is poorly characterised in multi-environment datasets to link crop growth conditions to ecophysiological processes. Hence, Objective of this study was to study environmental differences between HPD and LPD to understand environmental factors responsible for high productivity. For each location/ season, data on 19 environmental covariables (EC) were collected on a daily basis from "NASA's Prediction of Worldwide Energy Resources" (NASA POWER, https://power.larc.nasa.gov/) using the R package EnvRtype. These weather data were collected for the period 2013-14 to 2022 – 2023. Similarly district wise groundnut productivity for HPD and LPD were collected from UPAg (https://upag.gov.in/dash-reports/statewiseapy?rtab=Area%2C+Production+%26+Yield&rtype=reports) website. Analysis of environmental data and district wise productivity data were abalysed using packages *Envrtype* and *mdatool*. Productivity of HPD districts ranged from 2540 – 3253 kg/ha whereas that of LPD districts ranged from 479 – 1161 kg/ha. 19 environmental covariables (EC) of HPD and LPD were compared on every 15 days which resulted in 190 Eco-climatic factors (EFs) which were used for running Partial linear square (PLS) regression model with productivity of those districts over the period of 10 years. Clustering based on Envirotyping results clearly differentiated HPD and LPD districts into distinct clusters and environmental variables such as Number of sunshine hours, temperature and saturation vapor pressure being the major differentiating factors between the two groups. PLS regression models of these EFs indicated that EFs "July 1st half saturation vapor pressure (july1hSPV)", September 2nd half mean temperature (sep2hT2M), "September 2nd half saturation vapor pressure (sep2hSPV)", "July 1st half mean temperature (july1hT2M)" and July 2nd half saturation vapor pressure (july2hSPV)" are the main Eco-climatic factors differentiating HPD and LPD regions. Designing management practices to overcome these EFs may help improve productivity of LPD regions and inturn improve groundnut production and productivity of the country.

Keywords: *Eco-climatic factors, groundnut, vapor pressure, productivity, temperature*

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Evaluating triple super phosphate as an alternative phosphorus source for improving phosphorus use efficiency in groundnut-mustard cropping system

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Phosphorus use efficiency (PUE) in Indian cropping systems remains low due to strong soil fixation, poor recovery of applied phosphorus and reliance on conventional fertilizer sources with limited synchronization between nutrient supply and crop demand. Enhancing PUE is therefore essential for improving crop productivity, reducing fertilizer input costs and ensuring sustainable nutrient management. A field experiment was conducted during 2024–25 to evaluate the effect of different phosphorus sources and integrated nutrient management strategies on PUE in a groundnut–mustard cropping system grown under medium phosphorus status soils. The study emphasized the comparative performance of Triple Super Phosphate (TSP) and Diammonium Phosphate (DAP), along with their integration with sulphur, phosphorus solubilising bacteria (PSB), and foliar phosphorus nutrition. Phosphorus use efficiency was evaluated using standard indices such as Agronomic Phosphorus Use Efficiency (APUE), Apparent Phosphorus Recovery Efficiency (APRE), Phosphorus Utilization Efficiency (PUtE), Partial Factor Productivity of Phosphorus (PFP-P), nutrient uptake, Nutrient Harvest Index (NHI), and post-harvest soil available phosphorus. Application of recommended phosphorus significantly improved all PUE parameters compared to farmers' practice and phosphorus-deficient control. In groundnut, phosphorus uptake increased from 14.7 kg ha^{-1} under control to 17.2-23.4 kg ha^{-1} under recommended P treatments, while mustard recorded an increase from 16.36 kg ha^{-1} to 20.72-37.21 kg ha^{-1}, indicating enhanced phosphorus absorption and utilization under recommended application of P. Among the major phosphorus sources, DAP and TSP performed statistically at par across all PUE indicators which shows equivalent plant availability and internal utilization of phosphorus from both fertilizers. For instance, APUE was 7.71 with DAP and 7.65 with TSP in groundnut while 5.18 with DAP and 5.25 with TSP in mustard, confirming comparable efficiency of TSP with the conventional DAP source. TSP-based treatments integrated with PSB, FYM and foliar nutrition with MAP improved APRE at least by 38.7% in groundnut and PUtE at least by 78.5% in mustard over sole TSP or DAP application, primarily due to improved P solubilization and reduced soil fixation. In the overall groundnut-mustard cropping system, the TSP + FYM treatment recorded the highest PFP-P of 43.00 kg kg^{-1}, closely followed by TSP + PSB (42.65 kg kg^{-1}) and TSP + MAP (41.64 kg kg^{-1}), demonstrating greater yield output per unit of phosphorus applied under integrated treatments. These treatments also recorded higher nutrient harvest index values, indicating more efficient translocation of absorbed phosphorus to economic yield. Post-harvest soil analysis after groundnut revealed that integrated TSP treatments maintained slightly higher available soil phosphorus compared to conventional P sources which resulted in a positive residual effect on the succeeding mustard crop. This also contributed to higher P uptake and recovery efficiency in mustard and showed improved system-level PUE across the cropping sequence. One-year results establish TSP as an equally efficient alternative to DAP in terms of phosphorus use efficiency. Also, its integration with biofertilizers, FYM and foliar phosphorus nutrition substantially enhances PUEs. Adoption of TSP-based integrated phosphorus management can therefore serve as a sustainable strategy for improving PUE, optimizing fertilizer use and enhancing long-term soil fertility and system productivity in groundnut-mustard cropping systems.

Keywords: *Cropping system, groundnut, mustard, phosphorus, triple super phosphate*

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Metal organic framework fertilizers: The future of micronutrient management in oilseed crops

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Metal-organic frameworks (MOFs) are highly porous, crystalline materials made up of metal ions coupled with organic ligands. Their extraordinarily large surface area, adjustable pore size, and ability to regulate nutrient release make them ideal carriers for tailored fertilizer and micronutrient delivery with low losses. Oilseed crops require precise micronutrient supply at key growth phases, however standard fertilizers frequently fail owing to fixation, leaching, or insufficient synchronization with crop demand. In this context, MOF-based nutrient delivery systems represent a novel way to enhancing efficiency and sustainability in oilseed feeding. Micronutrients have a significant impact on oilseed crop yield and quality, particularly during flowering and seed-filling. Photosynthesis, reproductive development, oil biosynthesis, and antioxidant defense all require nutrients including Zn, Fe, and B. Traditional micronutrient fertilizers usually exhibit low use efficiency, resulting in poor crop response and environmental degradation. MOFs solve these restrictions by providing for controlled, stage-specific nutrient availability as well as the simultaneous delivery of numerous micronutrients. Their potential to act as both nutrient carriers and nutrient sources emphasizes their significance as next-generation fertilizers for oilseed-based agricultural systems. Studies have successfully built MOFs with important micronutrient metals such as iron, zinc, and copper, allowing them to function as both transporters and nutrient providers. Iron-based MOFs have been shown to enhance chlorophyll content, photosynthetic efficiency, and plant growth more effectively than conventional iron salts. Controlled-release studies show that MOF fertilizers can keep nutrients available for 30-60 days, considerably increasing nutrient absorption efficiency while reducing leaching and soil fixation losses. MOF systems also provide multi-micronutrient loading, allowing for the simultaneous treatment of numerous deficits. However, large-scale field validation and cost-effective production remain significant research difficulties. MOF-based fertilizers have significant promise for use in precision and climate-smart farming systems. MOFs can improve fertilizer efficiency, production stability, and oil content and quality in oilseed crops by coordinating micronutrient release with crop physiological demands. Their use may reduce fertilizer inputs and environmental contamination while promoting sustainable development of oilseed production. MOF fertilizers are expected to play a key role in future crop nutrient management methods as manufacturing and field-level validation improve.

Keywords: *Fertilizers, metal organic framework, micronutrient management, oilseed crops*

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Enhancing system productivity and phosphorus use efficiency in a groundnut-wheat cropping sequence through phosphorus management and biological mobilization

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Phosphorus (P) is an essential macronutrient involved in energy transfer, nucleic acid synthesis, and membrane formation. In alkaline soils of southern Saurashtra, applied P is rapidly immobilized as calcium phosphates, resulting in low recovery efficiency (15–20%) during the season of application. The groundnut–wheat cropping system is predominant in the Saurashtra region of Gujarat; however, system productivity is constrained by low phosphorus (P) availability due to chemical fixation in alkaline soils. A field study was conducted during *Kharif* 2024 and *Rabi–Summer* 2024–25 at ICAR–IIGR, Junagadh, to enhance

phosphorus use efficiency (PUE) through integrated P management. Twelve treatments, ranging from P omission to 100% of the recommended dose of fertilizer (RDF), with and without phosphorus-solubilizing bacteria (PSB), were evaluated. The highest system productivity (4128 kg ha^{-1} groundnut pod equivalent yield) was recorded with 100% P application to both crops. However, integration of 50% P with PSB significantly improved PUE (33.9%) compared to sole 100% P application (21.4%). PSB inoculation enhanced phosphatase activity and labile soil P pools, enabling reduced fertilizer P input without yield penalty. The study highlights microbial P mobilization as a sustainable strategy to improve P efficiency, soil biological health, and economic returns in the groundnut–wheat system.

Keywords: *Groundnut, Cropping system, wheat, P fractions, alkaline phosphatase, P use efficiency (PUE)*

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Sustainable groundnut production through crop diversification and tillage systems in central plateaus

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The rapidly growing global population coupled with climate change has necessitated sustainable transformation of agricultural productions to ensure food security. An Experiment conducted at College of Agriculture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, Sandy loam soil under AICRP-Groundnut during *kharif* 2021, 2022, 2023 and 2024 explores crop diversification and tillage systems as a sustainable strategy in Groundnut production**.** Different tillage practices significantly influenced growth and yield of groundnut crop. During 2021, 2022, 2023 and 2024, tillage practices influenced significantly the Dry pod yield and Groundnut equivalent grain yield while other parameters were not differed significantly. The higher values of shelling out tern, 100-seed weight (g), SMK (%), dry pod yield (kg/ha), dry haulm yield (kg/ha), groundnut equivalent yield (kg/ha) were found higher under minimum tillage. Tillage management also had a significant influence on values of net returns as well as BC ratio of groundnut crop. Result revealed that on the Basis of pooled analysis, the treatments showed a significant difference with respect to growth and yield attributes. The significantly higher pod yield (1389.04 kg/ha) and dry haulm yield (5054.83 kg/ha) yield of groundnut under minimum tillage were 6.10% and 12.82% higher over that obtained under conventional tillage (1309.13 and 4480.47 kg/ha), respectively. The higher groundnut equivalent yield was found higher under minimum tillage, which was differed significantly with the groundnut equivalent yield (1601.0 kg/ha) recorded under conventional tillage. However, the net return (97972 Rs/ha) and B: C ratio (2.904) was higher in case of minimum tillage. In case of cropping system, the higher values of 100-seed weight, SMK (%) and shelling out-turn were found under Groundnut-wheat. The pod yield of 1705.56 kg/ha and dry haulm yield of 6204.95 kg was also found higher under Groundnut-wheat. The highest values of groundnut equivalent yield (1840.8 kg/ha) were obtained under Groundnut-wheat followed by Groundnut-mustard and Groundnut + Pigeonpea-wheat. The net return as well as the B: C ratio was recorded significantly higher under Groundnut-wheat followed by Groundnut-mustard, Groundnut + Pigeonpea-wheat and Groundnut + Bajra-wheat respectively. Concluded that as per experimentation minimum tillage with Groundnut-wheat based cropping system are profitable and sustainable as compared to conventional and other groundnut based cropping system.

Keywords: *Climate change, crop diversification, groundnut equivalent yield, minimum and conventional tillage.*

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Microbial culture-mediated enhancement of phosphorus utilization and yield in summer groundnut (*Arachis hypogaea* L.)

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A series of field experiments were conducted to enhance phosphorus utilization efficiency in summer groundnut (*Arachis hypogaea* L.) through microbial culture application during the summer seasons of 2019, 2020, and 2021 at the Main Oilseeds Research Station, Junagadh Agricultural University, Junagadh, Gujarat, India. The experimental soil was medium black in texture, slightly alkaline (pH 7.65), low in available nitrogen (215 kg ha^{-1}), medium in available phosphorus (29.60 kg ha^{-1}), and high in available potassium (289 kg ha^{-1}). The experiment was laid out in a randomized block design (RBD) with three replications, comprising twelve treatment combinations involving seed treatment with DGRC culture inoculants @ 10 g kg^{-1} seed or PSB culture inoculants @ 15 g kg^{-1} seed, in combination with different phosphorus levels (20, 40, and 60 kg P, O ha^{-1}), along with FYM-based treatments. Groundnut variety GJG-31 was used for the study. Recommended doses of nitrogen, potassium, farmyard manure, seed rate and standard agronomic practices were uniformly followed across all treatments. Pooled analysis of three years revealed that application of 40 kg P, O… ha^{-1} along with PSB culture (15 ml kg^{-1} seed) or DGRC (15 g kg^{-1} seed) culture significantly improved growth and yield attributes of groundnut. This treatment recorded the highest number of branches per plant (4.04), number of pods per plant (14.52) and pod yield (2590 kg ha^{-1}), outperforming higher phosphorus doses applied without microbial inoculation. Importantly, the integration of microbial culture with phosphorus application saved 20 kg P, O ha^{-1} without compromising yield, indicating enhanced phosphorus use efficiency. The same treatment also resulted in maximum gross returns (1,33,559 ha^{-1}), net returns (94,829 ha^{-1}), and benefit–cost ratio (3.45), thereby proving its economic superiority. Nutrient uptake studies indicated significantly higher uptake of phosphorus (10.76 kg ha^{-1}) and potassium (40.23 kg ha^{-1}) under microbial inoculated treatments, whereas nitrogen uptake did not differ significantly among treatments. Quality parameters of groundnut were also favourably influenced by the combined application of phosphorus and microbial cultures. The results clearly demonstrate that integration of microbial cultures, particularly PSB or DGRC, with moderate phosphorus fertilization enhances phosphorus availability, nutrient uptake, yield, and profitability of summer groundnut. Based on pooled results, it is concluded that application of 40 kg P, O ha^{-1} along with PSB or DGRC seed inoculation is an efficient, economical and sustainable nutrient management strategy for summer groundnut cultivation under the agro-climatic conditions of South Saurashtra, Gujarat.

Keywords: *Groundnut, phosphorus utilization efficiency, microbial culture, nutrient uptake, yield, economics*

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Response of groundnut to spacing and fertilizer levels

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Among oilseed crops, Groundnut is one of the major oilseed crop cultivated in India. Being a predominate crop, in the present scenario, changing in the weather conditions throughout India is a challenge task for crop cultivation. This uncertain and abnormal weather resulting in difficult to obtain higher yield . Under these conditions there is a urgent need for reconsideration of crop production aspects like time of sowing , method of sowing, spacing, fertilizer recommendation, irrigation and choice of latest crop varieties. Hence, a present study was conducted on groundnut crop under different levels of fertilizer application and spacing with latest

developed high yielding Girnar 4 groundnut variety (V_1). A field experiment was conducted during *Kharif*, 2025 at RARS, Palem, with a experimental design comprised of seven treatments with three replications. The treatments are T_1 : V_1 + 30 x 10 cm spacing + 75% RDF, T_2 : V_1 + 30 x 10 cm spacing + 100% RDF, T_3 : V_1 + 30 x 10 cm spacing + 125% RDF, T_4 : V_1 + 45 x 10 cm spacing + 75% RDF, T_5 : V_1 + 45 x 10 cm spacing + 100% RDF, T_6 : V_1 + 45 x 10 cm spacing + 125% RDF, T_7 : Popular variety of the location (Visishta) + 30 x 10 cm spacing + 100% RDF (Check Treatment). The recommended dose of fertilizer for groundnut crop was 40-40-50 NPK Kg ha^{-1}. The observations with respect to growth and yield components were recorded and compared with the check treatment. Highest yield was obtained in T_3 : V_1 + 30 x 10 cm spacing + 125% RDF (2571.67 kg ha^{-1}) when compared with other treatments.

Keywords: *Crop production, fertilizer, girnar 4, spacing and weather*

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Integrating deep learning and remote sensing for monitoring growth and yield of oilseed crops: A modern approach for enhancing India's edible oil security

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India faces a major challenge in edible oil security with 57% import dependency despite being a major oilseed producer. Climate variability further causes yield variability in oilseed crops including groundnut, soybean, and rapeseed-mustard, making accurate prediction essential for sustainable production. Recent advances in artificial intelligence (AI) and remote sensing offer transformative potential for monitoring crop growth and predicting yields with reasonable accuracy. This review synthesizes successful methodologies from recent research for application in Indian oilseed production systems. A systematic review was conducted of three key studies representing different oilseed crops and methodological approaches: (1) For groundnut, Shahi et al., (2023) cooperative machine learning framework using UAV multispectral imagery with simulated annealing optimization was analyzed; (2) For soybean, Teodoro et al., (2021) comparative study of deep learning versus traditional machine learning models using spectral bands and vegetation indices was evaluated; (3) For rapeseed-mustard, Ajith et al., (2023) weather indices-based approach with stepwise regression and ANN/SVR models was examined. Methodologies were evaluated based on data acquisition protocols, model architectures, optimization techniques, and validation approaches. Performance metrics including R^2, RMSE, MAE, and correlation coefficients were extracted and compared across studies to identify best practices for different crop monitoring objectives. The synthesis revealed distinct methodological strengths: Groundnut monitoring achieved highest accuracy (R^2=0.86, RMSE=0.56 t/ha) through cooperative ensemble of Random Forest, SVM, and XGBoost models. Soybean growth stage prediction showed deep learning superiority for days to maturity (r=0.66) using only spectral bands, while Random Forest performed best with vegetation indices (r=0.79). Rapeseed-mustard yield prediction demonstrated ANN's effectiveness (R^2 up to 0.91) with weather indices and tanh activation function. Key findings include: (a) maturity stages consistently show strongest spectral correlations across crops; (b) ensemble approaches reduce prediction errors by 15-25% compared to single models; (c) input data type (spectral bands vs. vegetation indices vs. weather indices) significantly influences model selection; (d) hyperparameter optimization (simulated annealing, grid search) improves accuracy by 8-12%. The integrated framework derived from this synthesis provides a strong, evidence-based approach for implementing AI-driven monitoring systems for Indian oilseed crops. By adapting tested techniques from international research, a comprehensive system can be developed addressing growth stage monitoring, yield prediction, and stress detection specific to diverse agro-climate regions of India. Future implementation should prioritize multi-year data collection, region-specific calibration, and farmer-accessible interfaces to enhance oilseed productivity and contribute to India's edible oil security.

Keywords: *growth, edible oil security, integrating deep learning, monitoring, oilseed crops, remote sensing, yield*

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Strain-specific effects of Rhizobia symbiosis on productivity and economic returns of groundnut (*Arachis hypogaea* L.), under semi-arid eastern plain of Rajasthan

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Groundnut (*Arachis hypogaea* L.), is an important crop in India's agricultural landscape that supports millions of farmer's livelihoods as well as the nation's economy. Groundnut cultivation promoting sustainable farming practices through its symbiotic relationship with nitrogen-fixing bacteria. The use of synthetic nitrogenous fertilizers has become a ubiquitous practice in modern agriculture. A field experiment was conducted under All India Coordinated Research Project on Groundnut during *Kharif* 2022 to 2024 at Research Farm, Rajasthan Agricultural Research Institute, Durgapura, Jaipur, Rajasthan to investigate the efficacy of different competitive strains of rhizobia towards improvement in the productivity and profitability of groundnut. The experimental setup followed a randomized block design with eight treatments; each replicated three times. The experiment comprised a set of treatments involving diverse, competitively effective strains of rhizobia that was $Rhizo_1$ (DGR 23), $Rhizo_2$ (DGR 24), $Rhizo_3$ (DGR 25), $Rhizo_4$ (DGR 26), $Rhizo_5$ (DGR 35) $Rhizo_6$ (TAL 1000), $Rhizo_7$ (IGR 6), including a non-inoculated control treatment where no rhizobia seed inoculation was applied. The experiment results of the three years study revealed that the seed the inoculation with strain $Rhizo_7$ (IGR 6) has gave the highest number of pods per plant (23.00), hundred kernel weight (70.09 g), sound mature kernels (91.93 %), pod yield (4426 kg/ha), haulm yield (5629 kg/ha), biomass yield (10,060 kg/ha), kernel yield (3194 kg/ha), gross return of 260594 ha^{-1}, net return of 207803 ha^{-1}, and a B:C ratio of 3.94. The findings of this study indicated that the seed inoculation with strain $Rhizo_7$ (IGR 6) show great promise as peanut seed inoculants, exhibiting comparable impacts on groundnut productivity and profitability as other available strains.

Keywords: *Groundnut, rhizobia, productivity, profitability*

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Climate change and groundnut (*Arachis hypogaea* L.) production: Impacts and adaptation-mitigation strategies

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Climate change has emerged as a critical constraint to sustainable agricultural production, particularly for climate-sensitive crops such as groundnut (*Arachis hypogaea* L.). Rising temperatures, erratic rainfall patterns, frequent droughts, and elevated atmospheric carbon dioxide (CO_2) concentrations are increasingly influencing groundnut growth, productivity, and quality, especially in semi-arid and rainfed regions where the crop is predominantly cultivated. Given groundnut's importance as a major oilseed-legume crop contributing to food security, nutritional quality, soil fertility enhancement through biological nitrogen fixation, as well as supporting rural livelihoods, understanding the impacts of climate change and identifying effective adaptation and mitigation strategies is essential for enhancing resource utilization and sustaining production. To address these challenges, a combination of adaptation and mitigation strategies focused on efficient

resource utilization is required. Precision farming technologies have emerged as critical tools for improving resource utilization and enhancing productivity in climate-stressed groundnut systems. Remote sensing and Geographic Information Systems (GIS) enable real-time monitoring of crop health, soil conditions, and climatic variables. Satellite imagery and drone-based sensing have proven effective in detecting early symptoms of water stress, nutrient deficiencies, and pest infestations, allowing timely interventions. GIS-based spatial analysis facilitates site-specific input management, optimizing fertiliser and water application while reducing environmental footprints. Studies from India have demonstrated a 15-20% increase in groundnut yield through GIS-guided input optimization based on spatial variability. In groundnut cultivation, variable rate application has been shown to significantly reduce input costs and environmental impacts by avoiding over-application in low-demand zones. Conservation-oriented agronomic practices further strengthen climate resilience. Conservation tillage, involving minimal soil disturbance, has been reported to increase soil organic carbon by 12-15%, improve soil moisture retention by 8-10%, and reduce soil erosion by up to 40%, particularly in semi-arid regions. These practices enhance soil health, water-use efficiency, and long-term sustainability of groundnut-based production systems. These technologies not only enhance productivity under variable climatic conditions but also contribute to mitigation through reduced input wastage and improved carbon efficiency. Overall, addressing these challenges requires an integrated approach that combines climate-smart and precision agriculture with supportive policies and capacity building to enhance resilience, promote sustainable intensification, and maintain resource-use efficiency under changing climatic conditions.

Keywords: *Adaptation, climate change, groundnut, mitigation strategies, production*

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Yield optimization of *Rabi* groundnut through nano DAP application

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A field experiment was conducted under AICRP on Groundnut at Horticulture Research Station, OUAT, Bhubaneswar to assess the effect of Nano-DAP on growth, yield, and economics of groundnut during the *rabi* season of 2024-25. The experiment was laid out in a Randomized Block Design with seven treatments and three replications using the groundnut variety 'Dharani' (TCGS 1043). The treatments consisted of T_1: RDF 100% NPK, T_2: 100% NK +50% P + One foliar spray of Nano-DAP at 25 DAS @500 ml ha^{-1}, T_3:100% NK + 50% P +Two foliar sprays of Nano-DAP at 25 DAS and 50 DAS @ 500 ml ha^{-1}, T_4: 100% NK + 75% P + One foliar spray of Nano-DAP at 25 DAS @ 500 ml ha^{-1}, T_5: 100% NK + 75% P + Two foliar sprays of Nano-DAP at 25 DAS and 50 DAS @ 500 ml ha^{-1}, T_6: 100% NK + 100% P + One foliar spray of Nano-DAP at 25 DAS @500 ml ha^{-1} and T_7: 100% NK + 100% P + Two foliar sprays of Nano-DAP at 25 DAS and 50 DAS @ 500 ml ha^{-1}. The soil of the experimental site was sandy loam in texture with a neutral reaction, medium organic carbon content (0.48%), low available nitrogen (125.40 kg ha^{-1}), high available phosphorus (35.10 kg 20-40-40 N, P_2O_5, K_2O kg ha^{-1}), and medium available potassium (212.50 kg ha^{-1}). Recommended dose of fertilizer was 20-40-40 kg N, P_2O_5, K_2O ha{ [1]. All plots received the full recommended dose of nitrogen and potassium as a basal application. The result of the experiment revealed maximum plant height (52.3 cm), maximum branches per plant (6.1cm), maximum dry matter accumulation (38 g) and number of pods per plant (14.4) with the application of T7 to the crop. Similarly, application of T7 also resulted in maximum pod yield (3038 kg ha{ [1]), kernel yield 2114 kg ha^{-1}, haulm yield (5763 kg ha^{-1}), oil yield (1067.86 kg ha^{-1}) and protein yield (791.16 kg ha^{-1}), which was also statistically at par with T_6 and T_5. The economic analysis revealed that application of 100% NPK + Two foliar sprays of Nano-DAP at 25 DAS and 50 DAS @ 500 ml (T_7) recorded the

highest gross return (Rs.218736 ha^{-1}), net return (Rs.123602 ha^{-1}) and B;C of 2.37.Hence, the application of 100% recommended dose fertilizer (20-40-40 kg N, $P2O_5$, K_2O ha{ ¹) as basal applications along with 2 foliar spray of nano DAP (@500 ml ha^{-1}) at 25 and 50 days after sowing was considered a better nutrient management practice for growing groundnut during *rabi* season.

Keywords: *groundnut, rabi, nano DAP, yield*

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GPBD 4: A proven high-volume groundnut variety sustaining India's seed supply chain

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GPBD 4 is one of the most widely adopted groundnut variety in India, owing to its stable performance, farmer acceptability, and consistent demand across diverse agro-ecological regions. The present summarizes long-term seed production trends of GPBD 4 using multi-year data encompassing breeder, foundation, certified, and truthfully labeled seed production. The objective of this assessment was to evaluate the contribution of GPBD 4 to the formal seed system and its role in strengthening groundnut cultivation through sustained seed availability. Analysis of production data revealed that GPBD 4 recorded substantial and consistent breeder seed production of 20 years, cumulatively exceeding 34,000 quintals, indicating its continued importance in the varietal replacement and seed multiplication programme. Regular breeder seed output facilitated downstream multiplication, as reflected by a cumulative foundation seed production of over 25,000 quintals. This strong linkage between breeder and foundation seed stages ensured uninterrupted supply to the certified seed system. Certified seed production of GPBD 4 showed remarkable growth and stability, with a cumulative production of more than 17,000 quintals, highlighting large-scale farmer demand and wide adoption. The presence of over 16,400 quintals of truthfully labeled seed further demonstrates the variety's penetration into both formal and semi-formal seed channels, ensuring accessibility even in regions where certified seed availability is limited. Year-to-year increases in certified and truthfully labeled seed production clearly reflect the confidence of seed producers and farmers in the varietal performance of GPBD 4. The data also indicate that GPBD 4 remained a priority variety in seed production planning over a long period, which can be attributed to its agronomic superiority, adaptability, and consistent yield performance under varying climatic conditions. Sustained seed multiplication efforts suggest its relevance not only for productivity enhancement but also for varietal stability in groundnut-based cropping systems. In conclusion, GPBD 4 has played a pivotal role in strengthening the groundnut seed supply chain through high breeder seed output, efficient seed multiplication, and large-scale certified seed availability. The sustained and diversified seed production pattern confirms GPBD 4 as a cornerstone variety in India's groundnut cultivation, contributing significantly to yield stability, farmer income, and national oilseed production.

Keywords: *Climatic conditions, groundnut, production, seed supply chain*

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Dh 256: An emerging groundnut variety with gradual integration into the seed production system

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Dh 256 is a relatively recent addition to the groundnut varietal portfolio, developed to address region-specific requirements of productivity and adaptability. The present study analyzes the seed production trends of Dh 256 across different seed classes, namely breeder, foundation, certified, and truthfully labelled seed, using cumulative five years production data. The objective was to assess the pace of varietal integration into the formal seed production system and to evaluate its emerging role in groundnut cultivation. The seed production data indicate that Dh 256 had a modest initial phase, with breeder seed production increasing gradually over the years. The cumulative breeder seed production was approximately 11,000 quintals, reflecting a targeted and cautious multiplication strategy rather than rapid large-scale deployment. Such a pattern is characteristic of varieties under phased adoption, where breeder seed production is aligned with initial demand assessment and multi-location performance validation. Foundation seed production of Dh 256 reached nearly 10,500 quintals, indicating effective conversion of breeder seed into the subsequent multiplication stage. This level of foundation seed production demonstrates growing institutional confidence in the varietal performance and its suitability for further scaling. Certified seed production remained comparatively lower, with a cumulative output of about 7,950 quintals, suggesting limited but gradually increasing farmer-level adoption, primarily in specific agro-climatic regions. In addition, truthfully labelled seed production amounted to approximately 5,600 quintals, reflecting the early inclusion of Dh 256 in alternative seed dissemination channels. Overall, the seed production pattern of Dh 256 suggests that the variety is currently in the expansion phase, with greater emphasis on strengthening breeder and foundation seed availability before large-scale certified seed multiplication. This phased approach is essential to ensure genetic purity, consistency in varietal performance, and adequate evaluation under farmers' field conditions prior to widespread commercialization. In conclusion, Dh 256 represents an emerging groundnut variety undergoing systematic integration into the seed production system. Although current seed volumes are moderate compared to long-established varieties, the steady progression across seed classes highlights its potential for future expansion. Strategic seed planning, targeted dissemination, and performance-based promotion can further enhance the adoption of Dh 256 and contribute to diversification and productivity improvement in groundnut cultivation.

Keywords: *Agro-climatic regions, certified seed, groundnut, variety, seed production system*

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Effect of tillage and residue management practices on performance of groundnut based cropping systems in western Rajasthan

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Groundnut (*Arachis hypogaea* L.) is one of the most important oilseed crop in India with a total annual production of 10.2 million tonnes from 4.7 M ha area. It is a major oilseed crop accounting for ~18% of the area and ~30% of the production of oilseeds in the country. However, the current average yield level of groundnut in the country is very low as compared to USA and China. Excessive tillage not only exacerbates oxidation of soil organic matter but also increases the cost of production. The experiment

has been conducted during 2022-23 to 2024-25 at ICAR-IIGR, RRS, Bikaner to assess the impact of tillage and residue management practices on yield and economics of groundnut-based cropping systems. The treatments were: five tillage and residue management practices *viz.* farmers' practice [FP; conventional tillage (*kharif*) - conventional tillage (*rabi*)], conventional tillage + residue incorporation (*kharif*) - conventional tillage (*rabi*) [CT-CT (+R)], conventional tillage + residue incorporation (*kharif*) - zero tillage (*rabi*) [CT-ZT (+R)], zero tillage + residue retention (*kharif)* - conventional tillage (*rabi*) [ZT-CT (+R)], and zero tillage + residue retention (*kharif*) - zero tillage (*rabi*) [ZT-ZT (+R)] in vertical strip plots; and three cropping systems *viz.* groundnut-mustard (CS1), groundnut-chickpea (CS2) and groundnut-wheat (CS3) in horizontal strip plots. Results showed that, significantly higher pod yield and haulm yield of groundnut was under conventional tillage+residue incorporation (*kharif*)-zero tillage (*rabi*) and it was at par with conventional tillage + residue incorporation (*kharif*) - conventional tillage (*rabi*), and conventional tillage (*kharif*) - conventional tillage (*rabi*). Ground pod equivalent yield (GPEY) was also found significantly higher with conventional tillage + residue incorporation (*kharif*) - zero tillage (*rabi*) being at par with conventional tillage + residue incorporation (*kharif*) - conventional tillage (*rabi*). Among cropping systems, higher pod yield and haulm yield of groundnut, and GPEY were found under groundnut-chickpea system, but differences were non-significant. Further results showed that seed yield and stalk yield of mustard, and seed yield and straw yield of chickpea were higher under conventional tillage + residue incorporation (*kharif*) - zero tillage (*rabi*) being at par with all other treatments except conventional tillage (*kharif*) - conventional tillage (*rabi*). Higher grain yield and straw yield of wheat were under conventional tillage + residue incorporation (*kharif*) - conventional tillage (*rabi*), and conventional tillage + residue incorporation (*kharif*) - zero tillage (*rabi*), respectively being at par with all other treatments except conventional tillage (*kharif*) - conventional tillage (*rabi*). Moreover, highest net returns (184772) were obtained under conventional tillage + residue incorporation (*kharif*)-zero tillage (*rabi*) and it increased by 21294 than conventional tillage (*kharif*)-conventional tillage (*rabi*). Among cropping systems, groundnut-chickpea cropping system gave highest net returns (176225) and it increased by 14598 over groundnut-wheat cropping system. The study revealed that the adoption of conventional tillage during *kharif* with residue incorporation followed by zero tillage during *rabi* proved to be the most efficient practice which gave higher system yield and net returns. The study concludes that adopting conservation tillage along with crop residue management in groundnut-based cropping systems is a sustainable approach for improving productivity and profitability, thereby ensuring long-term agricultural sustainability in western Rajasthan under prevailing climatic conditions.

Keywords: *Groundnut, cropping systems, residue management, tillage*

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Impact of nano urea and urea phosphate on productivity and profitability of groundnut (*Arachis hypogea*)

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Groundnut (*Arachis hypogea*) is third most important oilseed crop of India, grown on an area of 5.76 m ha giving 11.94 m tonnes at average of 2073 kg/ha. The productivity of groundnut in India is quite low when compared to other major producers of world like USA (4400 kg/ha) and China (3710 kg/ha). The main forces behind low productivity in India are its cultivation on marginal lands, lack of improved cultivation practices. Nitrogen and phosphorus are essential macro nutrients required in large quantities. Although being a leguminous crop N requirement of groundnut is low in comparison to cereals. Yet foliar application of nitrogen as well as phosphorus particularly at later stages i.e. flowering onwards may enhance groundnut production. The present study was conducted at CCSHAU Regional Research Station, Bawal during *kharif* 2022 to 2024. The treatments included 100% RDNPK (Control), 75 % RDNPK,

50% RDNPK, and one spray of 0.2% Nano urea + 1% Urea phosphate at flowering over these treatments; and two sprays of 0.2% Nano urea + 1% Urea phosphate at flowering and peg formation; and RDNPK + Foliar application of urea @ 2% at 30 & 60 DAS; RDNPK + application of (0.2% Nano urea) at flowering & peg formation; RDNPK + application of (1 % Urea phosphate) at flowering & peg formation; and RDNPK + application of (1 % Urea phosphate) at flowering & peg formation stage. The results of study indicated that foliar application of liquid fertilizers had significant impact over yield attributes (kernels/pod) as well as pod yield of ground nut. Treatment T_7 (RDNPK + 0.2% Nano urea + 1% Urea phosphate both at flowering and peg formation stage) recorded the highest pod yield (31.74 q/ha) followed by T_{10} (RDNPK + foliar application of urea @ 2% at 30 & 60 DAS). The pod yield under these treatments was 10.7 and 5.9% higher than T_1 (100% RDNPK: 28.66 q/ha). With regard to economic studies, T_7 was most profitable with the highest net returns (Rs. 124830/ha, 15.8% higher than RDNPK) and B: C (2.75). Hence it is recommended that foliar supplementation of 0.2% Nano urea + 1% Urea phosphate both at flowering and peg formation stages coupled with RD-NPK may be done for higher production and net profit in *kharif* groundnut.

Keywords: *Groundnut, nano urea, urea phosphate, productivity, profitability*

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Screening of groundnut genotypes for identification of resistance sources to leafhopper and thrips

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Groundnut is one of the most important oilseed crops cultivated in the semi-arid tropics. It is mainly cultivated for its high quality edible oil, digestible protein and vitamins. Among the insects recorded on groundnut, leafhopper,(*Empoasca kerri* Pruthi) and thrips, *Scirtothrips dorsalis* (Hood.), *Thrips tabaci* (Lindman) are major sucking pests causing severe yield losses. Among various alternatives for reducing pesticide usage, development and growing of insect resistant varieties has assumed importance in the recent years due to most economical and eco-friendly way of reducing insect pest losses. Therefore, some new genotypes of groundnut were screened against major sucking insect pest leafhopper to check the resistance levels. Field trials were conducted at research farm, Regional Research Station, Vridhachalam during *Kharif*, 2023 and *Kharif*, 2024 with 78 groundnut entries received from IIGR, Junagadh to evaluate against sucking pests. The genotypes were sown as each entry in 5 m row length flanked with susceptible check VRI 2 for every four rows of genotypes for screening against leafhoppers and thrips to find out the resistant sources. Observations on population of leafhopper and thrips were recorded as number in top three leaves/10 plants and damage intensity for leafhoppers by yellowing on apical end of leaflets and for thrips by browning of foliage on lower surface of leaves were recorded in vegetative to pod formation stages viz., 15, 30, 45 and 60 days after germination of the crop, as the damage caused by sucking pests at these stages will affect the potential yield of the crop. Among the entries screened against leafhopper and thrips damage, none of groundnut genotypes was found completely free from attack of these pests. In 18 entries, leafhopper population ranged from 0.6 to 1.4 Nos./plant and the damage by sucking pests was very low (0-4.83%) with injury grade of 1-2 during vegetative stage (15-30 days after germination). At 45-60 days after germination, leafhopper population ranged from 1.1 to 2.5 Nos./plant and the damage was 6.33-9.87 % during vegetative to pod formation stages in entries AVTSB-1-2023-7, AVTSB-1-2023-10, AVTSB-1-2023-13, AVT-VG-2023-4, AVT-VG-2023-6, AVT-SB-2023-1, AVT-SB-2023-3,AHOVTSB-2023-4, AHOVTSB-2023-7, ALSVT-2023-1, ALSVT-2023-5, AVTSB-1-2024-4,AVTSB-1-2024-7,AVTSB-1-2024-12 AVT-VG-I-2024-3, AVT-VG-I-2024-4, AVTSB-1I -2024-7 and AVTSB-1I -2024-15 when compared to injury grade of 6 -7 with damage of 42.57-51.43 % in susceptible check,VRI 2.

These 18 groundnut entries performed better with less foliar damage for sucking pests were promising entries showed resistance sources to leafhopper and thrips.

Keywords: *Groundnut, genotypes, leafhopper, resistance, thrips*

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Impact of technological change on groundnut production in major groundnut-growing states of India: A temporal and regional analysis

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The present study examines the impact of technological change on Groundnut Production in Major Groundnut-Growing States of India, using regression analysis. Production was regressed on area under cultivation and time, with time serving as a proxy for technological change. The analysis was carried out for major groundnut-growing states; Gujarat, Unified Andhra Pradesh, Karnataka, Rajasthan, Tamil Nadu, Maharashtra, Madhya Pradesh and at the all-India level over three distinct periods: Period I (Pre–Technology Mission on Oilseeds period, 1966–67 to 1985–86), Period II (TMO implementation to liberalization period, 1986–87 to 1999–2000), and Period III (Post-liberalization period, 2000–01 to 2018–19). The results indicate that area expansion was a consistent and significant contributor to production growth in almost all states and periods. Technological change showed a differential impact across regions and time. Significant positive effects of technological change on groundnut production were observed during Period III and the overall period in Gujarat; Period I and the overall period in Karnataka; Period I, Period III, and the overall period in Rajasthan; the overall period in Tamil Nadu; Period I, Period II, and the overall period in Maharashtra; Period III and the overall period in Madhya Pradesh; and Period I, Period III, and the overall period at the national level. In contrast, Unified Andhra Pradesh exhibited no significant technological contribution, with production growth largely driven by area expansion. Overall, the study highlights that while expansion of cultivated area remains a dominant factor in groundnut production growth; technological change has played a significant and growing role in several states and at the national level, particularly in later periods.

Keywords: *Area under cultivation, Groundnut, oilseeds, production, regression analysis, technological change*

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Performance of irrigated groundnut under nano urea and urea phosphate foliar spray in Puducherry

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Groundnut is important oil, food and forage crop of the country. India is the second largest producer of groundnut in the world. The rapid increase in population growth rate necessitates phenomenal increase in crop productivity. Groundnut requires high nutrients during flowering, pegging and pod filling stages when soil nutrient uptake may be insufficient. Foliar applications directly supply nutrients at these stages, reducing deficiencies and improving nutrient balance inside the plant. In order to, Response of Groundnut to foliar nutrition of Nano Urea and Urea Phosphate in Groundnut at Puducherry Region under irrigated condition,

three field experiments were conducted during *Rabi Summer 2022*-23, 2023-24 & 2024-25 at Perunthalaivar Kamaraj Krishi Vigyan Kendra (PKKVK), Puducherry State experimental farm in a Randomized Block Design with three replications. The treatments were consisted T1- 100% RDNPK(Control), T2- 75 % RDNPK, T3- 50% RDNPK, T4- T1 + Application of 0.2% Nano urea + 1 % Urea phosphate) at flowering stage , T5- T2 + Application of (0.2% urea + 1 % Urea phosphate) at flowering stage, T6- T3 + Application of (0.2% Nano urea + 1 % Urea phosphate) at flowering stage & peg formation stage , T7- T1 + Application of (0.2% Nano urea + 1% Urea phosphate) at flowering stage & peg formation stage, T8- T2 + Application of (0.2% Nano urea + 1 % Urea phosphate) at flowering stage & peg formation stage, T9- T3 +Application of (0.2% Nano urea + 1 % Urea phosphate) at flowering stage & peg formation stage condition and T10- T1 + Foliar application of urea @ 2% at 30 & 60 DAS of groundnut cropping that were tested. The findings of three seasons pooled data, the application of 75 % RDNPK (T2)+Foliar application of (0.2% Nano urea + 1 % Urea phosphate) at flowering stage & peg formation stage(T8) recorded significantly the highest pod yield (3983 kg/ha) as compared to over control (3388 kg/ha) but, it was remained at par with application of 100 % RDNPK (T1) + Foliar application of (0.2% Nano urea + 1% Urea phosphate) at flowering stage & peg formation stage(T7) (3893 kg/ha). In economics, among the treatments application of 75 % RDNPK (T2) + Foliar application of (0.2% Nano urea + 1 % Urea phosphate) at flowering stage & peg formation stage (T8) recorded the higher net return (Rs. 100690/ha) and B:C ratio (2.43).

Keywords: *Groundnut, foliar nutrition, yield, economics*

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Effect of different tillage practices and groundnut based intercropping systems in castor under rainfed conditions

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Field experiments were conducted during *kharif* 2021-22 to 2024-25 at the Tapioca and Castor Research Station, Tamil Nadu Agricultural University, Yethapur, to evaluate the effect of tillage practices and legume-based intercropping systems on growth, yield, and profitability of castor under rainfed conditions. The experiment was laid out in a split plot design with three replications, consisting of two tillage practices (conventional tillage and minimum tillage) as main plots and four intercropping systems as subplots, namely sole castor, castor + greengram (1:3), castor + cowpea (1:3), and castor + groundnut (1:3). Pooled analysis of four years revealed that tillage practices did not exert a significant influence on growth parameters, yield attributes, seed yield, or biomass yield of castor and intercrops. However, numerically higher values were consistently recorded under conventional tillage compared to minimum tillage. The highest seed yield of the base crop (1152 kg ha^{-1}) and intercrop (481 kg ha^{-1}) was obtained under conventional tillage. Among intercropping systems, castor + groundnut (1:3) recorded the highest castor seed yield (1058 kg ha^{-1}), which was on par with sole castor (1020 kg ha^{-1}) and castor + greengram (907 kg ha^{-1}). Sole castor recorded significantly higher seed and biomass yields, followed by castor + groundnut and castor + greengram intercropping systems, owing to reduced inter-row competition and better utilization of growth resources such as moisture, nutrients, space, and solar radiation. The castor + cowpea intercropping system recorded the lowest castor seed yield (837 kg ha^{-1}), attributed to severe competition for space and nutrients, resulting in reduced plant height and fewer productive branches. Biomass production was maximum in castor + groundnut intercropping (8083 kg ha^{-1}), followed by sole castor (7742 kg ha^{-1}), while the lowest biomass was recorded in castor + greengram intercropping (6350 kg ha^{-1}). Although intercropping resulted in a marginal reduction in the seed yield of the base crop, higher overall productivity was achieved through increased castor equivalent yield (CEY). Castor + groundnut (1:3) and castor + greengram (1:3) systems recorded significantly higher CEY compared to sole castor, owing to the additional yield from intercrops and relatively smaller reduction in castor yield. These systems also exhibited better resource use efficiency and higher total biomass production. Economically, castor + groundnut (1:3) intercropping recorded the highest benefit–cost ratio, indicating superior profitability over sole castor and other intercropping systems. Therefore, under rainfed conditions, conventional tillage combined with castor + groundnut (1:3) intercropping emerged as the most productive and profitable system, followed by castor + greengram (1:3), for sustainable castor-based cropping systems.

Keywords: *Castor, Conventional tillage, Castor equivalent yield, Intercropping, Legume, Minimum tillage, Rainfed agriculture*

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Nature of gene action and epistasis for seed yield traits in castor (*Ricinus communis* L.)

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The efficiency of genetic improvement for seed yield in castor (*Ricinus communis* L.) largely depends on a clear understanding of the nature of gene action governing yield and its component traits. The present study was undertaken to estimate additive, dominance, and epistatic gene effects for seed yield per plant and its contributing characters in four crosses of castor through generation mean analysis. Six generations (P, P, F, F, BC and BC) derived from each cross were evaluated under field conditions, and the data were subjected to analysis of variance, scaling tests (A, B, C, and D), and joint scaling test to assess the adequacy of the additive–dominance model and to quantify gene effects. The analysis of variance revealed highly significant differences among crosses and among generations within each cross for all the characters studied, indicating the presence of substantial genetic variability. Scaling tests indicated significant deviations from the additive–dominance model for most traits across the crosses, thereby confirming the involvement of non-allelic interactions. However, for number of nodes up to primary raceme in the cross SKP 84 × SKI 215, all scaling tests were non-significant, suggesting that the additive–dominance model was adequate and that this trait was primarily governed by additive and dominance gene effects. Estimates of gene effects revealed that seed yield per plant and most of its component traits were controlled by a combination of additive (d), dominance (h), and epistatic gene effects. The magnitude of dominance effects was generally higher than additive effects for seed yield and several yield-related traits, indicating the predominance of non-additive gene action. Significant dominance × dominance (l) interactions were observed for many characters, while additive × additive (i) and additive × dominance (j) effects were significant for some traits in specific crosses, suggesting cross-specific genetic control. Fixable gene effects (additive and additive × additive interactions) were prominent for certain traits in selected crosses, indicating good prospects for improvement through pedigree selection. In contrast, traits governed predominantly by dominance and dominance × dominance interactions are likely to respond poorly to direct selection in early generations. For such traits, breeding strategies involving biparental mating or intermating among selected segregants in early segregating generations, followed by one or two cycles of selfing, would be effective in breaking undesirable linkages and enhancing the frequency of favorable alleles. Epistatic interactions played a crucial role in the inheritance of most traits, with duplicate type epistasis being more prevalent than complementary epistasis across characters and crosses. The predominance of duplicate epistasis suggests potential buffering of genetic effects and reduced efficiency of simple selection methods. These findings highlight the complexity of the genetic architecture underlying seed yield in castor and underscore the need for trait- and cross-specific breeding approaches. Overall, the study demonstrates that both additive and non-additive gene actions, along with epistatic interactions, significantly influence seed yield and its component traits in castor. The results provide valuable genetic insights for optimizing breeding strategies aimed at developing high-yielding and stable castor genotypes.

Keywords: *Gene action, Epistasis, Seed yield traits, Castor*

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Integrated climate-resilient crop and nutrient management for sustainable productivity and profitability of rice–linseed cropping system

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Rice is the staple food of more than half of the global population. Hence, exploring ways to increase rice production with less resource are essential for increasing food security. Climate change can reduce agricultural income by 15-25 per cent; it is high time that rationale of climate-resilient agriculture is valued and implemented more rigorously. It is therefore, necessary to develop climate resilient package and practices for increasing productivity and profitability of rice based cropping system. The result of the studies on crop establishment method and weed management in direct seeded rice revealed that the maximum net monetary return and B:C ratio were computed in the conventional tillage-vattar-DSR through multi-crop planter fitted with inclined plate seed metering mechanism method, among the establishment methods. Whereas, the pre *fb* post emergence application of oxadiargyl 80 WP @ 80 g ha^{-1} PE *fb* bispyribac-sodium @ 25 g ha^{-1} at 20 DAS among the weed management practices. The rice-linseed cropping system analyzed on the basis of interaction effects and revealed that the rice may be grown under conventional tillage direct seeding with 100: 60:40 kg NPK ha^{-1} + 2 t FYM and following linseed through zero tillage + residue (Happy seeder) or conventional tillage. The linseed may fertilized either with 100 % RDF (60:30:30 kg NPK ha^{-1}) or 100 % RDF + 2 t FYM. These treatment combinations are suitable to obtain higher seed yield, nutrient uptake, net return, B:C ratio and energy input and output and increase organic carbon, available nitrogen, phosphorus potassium in the soil. Various activities have been carried out for promotion of linseed at farmer's level through FLDs and up to 50% yield increment was observed over farmer's practices. Farmers and entrepreneur was also linked with value addition programme under ICAR, NAHEP-W2W project, under the project various activities has been carried out like purchase of linseed stem, prepared linseed fibre and linseed yarn was used for making high valued clothes by rural women of the tribal dominated state of India.

Keywords: *Climate resilient practices, Nutrient management, Rice-linseed cropping system, Yield*

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Response of different fertility level for different AVT genotype in niger crop [*Guizotia abyssinica* (L.f.) Cass.]

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Niger [*Guizotia abyssinica* (L.f.) Cass.] is an important minor oilseed crop grown in tropical and subtropical countries like India, Ethiopia, East Africa, West Indies and Zimbabwe. It is the lifeline of tribal agriculture and economy in India. It is grown by tribal's on marginal and sub marginal lands with negligible input leading to very low productivity. A field experiment was carried out during *kharif* 2024 at JNKVV, Zonal Agricultural Research Station, Chhindwara, Madhya Pradesh. The soil of the experimental field was sandy loam in texture and neutral (PH 7.1) in reaction. A total number of eight genotypes were undertaken for the study, *viz*., JNS 22-7, IGPN 2004-1, NRS-2302, JNS-9, ONS-187, JNS 2017-2, JNS 2016-1115, and JNS 28 were oriented in main plots, where's, three fertility levels *viz*., F_1-75% RDF, F_2-100%, F_3-125% RDF were oriented in sub plots. The maximum plant height (cm) found in genotype ONS-187

(139.6cm) and minimum in IGPN 2004-1 (125.1cm), whereas, maximum number of branches per plant found for JNS 28 (10.5) and minimum in IGPN 2004-1 (9.4). Similarly, the maximum number of capitula per plant found for JNS 22-7 (39.9) and minimum for NRS-2302 (30). The thousand grain weight (g) highest for JNS 22-7 (4.3) and lowest for JNS 28 (3.9). The maximum seed yield of 391 kg/ha was recorded in G_1 (JNS 22-7) followed by 377 kg/ha in G_6 (JNS 2017-2) and 366 kg/ha in G_4 (JNS-9). Whereas the minimum seed yield 178 kg/ha was recorded in G_5 (ONS-187). The maximum NMR of Rs 27909/ha and B:C ratio 2.47 were recorded in G_1 (JNS 22-7) followed by Rs. 26239/ha and 2.38, respectively in G_6 (JNS 2017-2). Whereas, minimum NMR and B:C ratio were recorded Rs. 2352/ha and 1.12, respectively in G_5 (ONS-187). In all the fertility levels tested the seed yield of 299 kg/ha was obtained in F_3 (125% RDF) which was significantly higher in comparison to 266 kg/ha in F_1 (75% RDF) but at par to 293 kg/ha in F_2 (100% RDF). Similarly, the maximum NMR of Rs 16211/ha and B:C ratio 1.82 were noted in F_3.

Keywords: *Fertility levels, Genotypes, Niger, Nutrient Management, Yield*

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Agronomic performance of niger (*Guizotia abyssinica* L.) in association with foxtail millet in the North Eastern Zone of Tamil Nadu

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Niger (*Guizotia abyssinica* L.) is an important oilseed crop cultivated mainly under rainfed conditions in the marginal and sub-marginal lands of Tamil Nadu. The crop is valued for its adaptability to poor soils and low input requirements, making it suitable for dryland farming systems. However, niger productivity in the region remains low due to erratic rainfall, declining soil fertility, and limited adoption of improved cropping systems. Intercropping with short-duration millets has emerged as a viable agronomic option to improve resource use efficiency, stabilize yields, and enhance system productivity under rainfed conditions. Foxtail millet, being a low-input and short-duration crop, is well suited for intercropping with niger, offering better utilization of light, moisture, and nutrients. A field experiment was conducted during the *kharif* season at the Centre of Excellence in Millets, Athiyandal, located in the North Eastern Zone of Tamil Nadu. The soil of the experimental site was sandy clay loam. The experiment was laid out in a Randomized Block Design with four replications, consisting of treatment with different intercropping row proportion treatments involving niger and foxtail millet. The study was conducted entirely under rainfed conditions by following the recommended package of agronomic practices for both crops. Niger grown in association with foxtail millet under different row ratios was compared with sole cropping of niger. Observations were recorded on growth parameters such as plant height, number of branches, leaf area index, and dry matter production, along with yield attributes including number of capitula per plant and seed yield. The results revealed that intercropping systems significantly influenced the growth and yield performance of niger. Among the different treatments, the foxtail millet + niger intercropping system in a 4:1 row ratio recorded superior growth and yield attributes. In this treatment, niger plants attained a height of 82.4 cm, produced 8.6 branches per plant, and recorded the highest number of capitula per plant (192), resulting in a seed yield of 210 kg/ha. In contrast, the 6:1 row ratio resulted in slightly shorter plants (81.0 cm) with a higher number of branches (18.2 per plant). Niger grown in association with foxtail millet exhibited growth and yield attributes comparable to sole niger while improving land use efficiency through better spatial and temporal utilization of resources. Foxtail millet complemented niger without exerting significant competitive stress, resulting in higher system productivity. Therefore, niger intercropping with foxtail millet, particularly in a 4:1 row ratio, can be recommended as a sustainable agronomic practice for enhancing productivity and resilience under rainfed conditions in the North Eastern Zone of Tamil Nadu.

Keywords: *Foxtail Millet, Intercropping, Niger, North Eastern Zone of Tamil Nadu, Rainfed Agriculture*

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Quantifying economic gains from aphid resistance in safflower under differential insecticidal spray schedules

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Aphid (*Uroleucon compositae*) is the most economically important insect pest of safflower, causing significant yield losses and farmers mostly to rely on insecticidal sprays for its management. Frequent chemical use not only increases the cost of crop protection but also causes adverse effects on the environment. Therefore, using a aphid tolerant variety may reduce the input costs and increase the net additional income to the farmer. However, economic gains obtained by employing a resistant/tolerant variety is never been worked out. The present study was undertaken to quantify the economic gains of using aphid-resistant safflower varieties under different insecticidal spray regimes. The experiment involved two cultivars, a tolerant variety (A1) and a susceptible variety (ISF-764) and were evaluated under three spray treatments: no spray, one spray, and two sprays, in a factorial randomized block design. Observations on aphid population were recorded at regular interval and seed yield at harvest. Cost–benefit analyses were performed. The tolerant variety consistently harboured lower aphid populations in all treatments compared with the susceptible variety. Seed yields of tolerant and susceptible varieties were comparable when two sprays were applied, indicating effective aphid control in both. However, with only one spray, the resistant variety recorded a yield advantage of 1.86 q/ha and a net economic gain of ¹ 8100/ha over the susceptible variety. Economic comparison between resistant (one spray) and susceptible (two sprays) treatments revealed a saving of one spray (800/ha) and a comparable yield, giving a modest net benefit of 450/ha. In contrast, growing a susceptible variety with a single spray led to a loss of 8550/ha, indicating its dependence on frequent spraying. The study concludes that the use of aphid-tolerant safflower varieties can effectively reduce insecticidal sprays without compromising seed yield, resulting in lower production costs and reduced environmental impact. Integrating host plant resistance into pest management thus offers a sustainable and eco-friendly approach for aphid management in safflower.

Keywords: *Aphid, Crop resistance, Economics, Insecticidal spray schedules, Management, Safflower, Yield*

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Calibration and validation of the DSSAT simulation model for safflower (*Carthamus tinctorius* L.) for the Indian conditions

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Safflower (*Carthamus tinctorius* L.) is an important *rabi* oilseed crop cultivated mainly under rainfed and residual moisture conditions in semi-arid regions of India. Its productivity is highly influenced by rainfall variability, soil depth and management practices. Reliable simulation models are therefore required to assess crop response to environmental stresses and to develop location-specific management strategies. The present study aimed to calibrate and validate the DSSAT crop simulation model for safflower under Indian agro-climatic conditions. The simulation was model was evaluated with the data of field experiment conducted for three years varying rainfall patterns and soil depths with 8 spiny and non-spiny cultivars of safflower. The standard statistical indices (MBE, MAE, RMSE and d-index) were used to test the performance of the model. Under normal rainfall years, the model showed good agreement between observed and simulated yields, particularly in shallow and deep soils, with high d-index values (0.91–

0.93). Although a moderate underestimation was observed in deep (MBE = –21) and medium-deep soils (MBE = –4.25), shallow soils showed slight overestimation (MBE = 36.5). RMSE values ranged from 63.4 to 86.3. During excess rainfall years, the model performance remained satisfactory, with d-index values between 0.87 and 0.93. The model tended to underestimate yields in deep and medium-deep soils (MBE = –42.5 to –9.75), while shallow soils showed minimal bias. RMSE ranged from 62.1 to 86.1. In drought years, model accuracy declined, particularly in shallow soils, where higher bias (MBE = 47.3) and RMSE (53.3) were recorded. The d-index values were comparatively lower (0.62–0.72), indicating reduced model reliability under moisture stress conditions. However, MAE and RMSE were lower in deep and medium-deep soils, suggesting relatively better performance under drought in deeper soil profiles. Overall, DSSAT simulated safflower yields with acceptable accuracy under normal and excess rainfall conditions, while performance under drought years was moderate and more sensitive to soil depth, highlighting the need for further refinement for stress environments.

Keywords: *Crop response to environmental stresses, DSSAT simulation model, Management. Safflower*

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Economic analysis of rainfed sesame under different organic nutrient sources

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Sesame (*Sesamum indicum* L.), widely referred to as the "queen of oilseeds," is among the oldest cultivated oilseed crops. It is valued for its superior-quality edible oil, rich in unsaturated fatty acids (about 85%) and natural antioxidants. Owing to these attributes, sesame holds significant importance in human nutrition, health care and the cosmetic industry. During the late *kharif* season of 2019, a field study was undertaken at the College Farm, Agricultural College, Polasa, Jagtial, PJTAU, Telangana, to evaluate the impact of organic nutrient management practices on yield attributes and economic returns of sesame (*Sesamum indicum* L.). The experiment was laid out in a factorial randomized block design with three replications, consisting of main treatments of organic nutrient sources such as FYM, vermicompost, enriched vermicompost, neem cake, humic acid, and microbial consortia, and sub-treatments comprising foliar organic applications including Panchagavya, NSKE, vermiwash and humic acid. Among the main treatments, T„ (75% N through FYM + 25% N through enriched vermicompost + microbial consortia @ 2 kg ha^{-1}) recorded the highest seed yield (478 kg ha^{-1}) and stalk yield (827 kg ha^{-1}) followed by T, . Though foliar sprays did not show significant differences, numerically higher seed yield (449.7 kg ha^{-1}) and stalk yield (773.8 kg ha^{-1}) were recorded with *Panchagavya* @ 3%, followed by humic acid, NSKE, and vermiwash. The results of the economic assessment indicated that T„ was the most profitable treatment, recording the highest gross income (73,023 ha^{-1}), net income (41,642 ha^{-1}), and benefit–cost ratio (2.33) followed by T, . With respect to foliar organic applications, S•(Panchagavya @ 3%) outperformed the others by registering the maximum net returns (37,108 ha^{-1}) and B:C ratio (2.14). The combined application of T with S yielded the highest economic advantage, achieving a B:C ratio of 2.44. Hence, the integrated use of FYM, enriched vermicompost, and microbial consortia together with Panchagavya foliar spray can be recommended for improving nutrient uptake and profitability of sesame under rainfed organic farming systems.

Keywords: *Economics, organic nutrient management, sesame, yield*

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Chemical weed management and its impact on weed biomass and productivity of sesame in Western Rajasthan

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The sesame is grown in in diverse climatic and edaphic conditions, extending from semi-arid tropics and subtropics to temperate regions making it a resilient agricultural commodity Weed management studies were conducted to find out economically viable and cost-effective application of herbicides on productivity of sesame during *kharif* season of 2022 on sandy loam soils of Rajasthan. The eight treatments with three replications were tested in randomized block design. The maximum number of capsules plant^{-1} (43.0) were recorded with post emergence application of clethodim 50 ml/ha followed by quizalofop-ethyl 40 g/ha at 20 DAS (41.0) as against the weedy check (37.0). The rest of treatments were at par to each other but significantly superior to weedy check. The clethodim 50 ml/ha at 20 DAS recorded the maximum seed yield of 4.25 q ha^{-1} followed by pendimethalin 1000ml/ha PE (4.2 q/ha) and were at par with rest of treatments except weedy check. A significant increase in crop growth, yield attributes and yield was also recorded with these treatments. Although, weed free treatment recorded higher seed yield. Hence, application of herbicides in sesame holds a great promise for timely, cost effective and economic weed management.

Keywords: *Herbicides, weed biomass, weed management, yield, sesame*

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Performance of nano urea integrated with neem-coated urea on productivity and profitability of sesame (*Sesamum indicum* L.) in Western Rajasthan

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Sesame (*Sesamum indicum* L.) is a vital oilseed crop of arid and semi-arid regions, particularly Western Rajasthan, where productivity remains low due to poor soil fertility and in-efficient nitrogen management under rainfed conditions. Nitrogen plays a critical role in growth and yield of sesame; however, conventional soil application of prilled urea is often associated with low nitrogen use efficiency owing to volatilization and leaching losses in sandy soils. Nano urea, an emerging nano-fertilizer, offers a promising approach to enhance nitrogen use efficiency through efficient foliar absorption and targeted nutrient delivery. Integrating nano urea with reduced doses of conventional nitrogen fertilizers may improve productivity and profitability while lowering nitrogen input. A field experiment was conducted during *kharif*, 2022, 2023 and 2024 at the research farm of Dr. B R Choudhary Agricultural Research Station, Mandor, Jodhpur (26Ú21‘9" N latitude, 73Ú2‘41" E longitude and 231 m altitude). The soil of the experimental site was sandy and its moderately calcareous and alkaline in reaction. This is poor in organic matters (0.15%), nitrogen (173 kg ha^{-1}), Iron (3.4 mg kg^{-1}) and medium in phosphorus (21.2 kg P_2O_5 ha^{-1}) and zinc (1 mg kg^{-1}) while, rich in potassium (321 kg K_2O ha^{-1}). The experiment was conducted laid out in a randomized block design (RBD) with three replications and ten nitrogen management treatments involving different combinations of neem-coated urea and nano urea. Nitrogen was applied according to the respective treatments, while phosphorus was applied as a basal dose at the time of sowing as per the recommended dose of fertilizer (RDF: 40 kg N and 25 kg P ha^{-1}). Seeds of sesame variety RT 351, line sowing was done after field

preparation using seed rate of 2.5 kg^{-1}. Crop geometry was 30 ´10 cm. Standard agronomic practices were followed throughout the crop growth period. Seed yield and profitability of sesame varied significantly under different integrated nitrogen management strategies. The highest seed yield (552 kg ha{ ^{1}), net return (28,808 ha^{-1}), and benefit–cost (B:C) ratio (2.55) were recorded with the application of 100% recommended nitrogen through neem-coated prilled urea applied in three splits (50% as basal + 25% at 20 DAS + 25% at early flowering). This treatment was statistically superior to most treatments but remained statistically at par with the 50% N through neem-coated urea as basal + nano urea spray @ 4 ml L^{-1} at 30 and 45 DAS, 75% recommended N integrated with nano-urea spray at 45 DAS and 75% recommended N combined with 2% urea spray at 45 DAS. Among nano-urea–based treatments, 50% recommended N through neem coated prilled urea as basal + 4 ml L^{-1} nano urea spray at 30 DAS and 4 ml/l spray at 45 DAS and 75 % recommended N through neem coated prilled urea (50% N as basal + 50% N at 30 DAS + 4 ml L^{-1} nano urea spray at 45 DAS) performed comparatively better, producing seed yields of 543 and 527 kg ha^{-1} with B:C ratios of 2.37 and 2.35, respectively. In contrast, the lowest yield and economic returns were recorded under the no-fertilizer treatment. Overall, while split application of the application of 100% recommended nitrogen through neem-coated prilled urea applied in three splits (50% as basal + 25% at 20 DAS + 25% at early flowering) was the most effective practice for maximizing sesame productivity and profitability, partial substitution of chemical nitrogen using nano urea particularly the application of 50% N through neem-coated urea as basal + nano urea spray @ 4 ml L^{-1} at 30 and 45 DAS proved to be a viable and resource-efficient alternative without compromising yield under Western Rajasthan conditions.

Keywords: *Nano urea, neem-coated urea, nutrient management, yield, sesame*

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Response to different levels of potassium and sulphur on yield and economics of summer sesame

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A field experiment was conducted in a factorial randomized complete block design during the summer seasons of 2019–20, 2020–21 and 2022–23 at the Agricultural Research Station, Junagadh Agricultural University, Amreli, Gujarat to evaluate the effect of potassium (0, 20, and 40 kg K, O ha^{-1}) and sulphur (0, 10, and 20 kg S ha^{-1}) on seed yield and economics of summer sesame (*Sesamum indicum* L.). The results revealed that application of 40 kg K, O ha^{-1} produced significantly the highest seed yield of 751, 1751 and 1442 kg ha^{-1} during summer 2020, 2021 and 2022, respectively, with a pooled mean yield of 1315 kg ha^{-1}. This treatment was statistically at par with application of 20 kg K, O ha^{-1} during summer 2021 (1635 kg ha^{-1}). Among sulphur levels, application of 20 kg S ha^{-1} recorded significantly higher seed yields of 744, 1728, and 1418 kg ha^{-1} during summer 2020, 2021 and 2022, respectively, with a pooled mean of 1297 kg ha^{-1}; however, it remained statistically at par with 10 kg S ha^{-1} across individual years. Economic analysis indicated that potassium application at 40 kg K, O ha^{-1} resulted in the highest net return (49,953 ha^{-1}) and benefit–cost ratio (2.17), followed by 20 kg K, O ha^{-1} (43,950 ha^{-1} and 2.06). Similarly, sulphur application at 20 kg S ha^{-1} yielded the highest net return (46,994 ha^{-1}) and benefit–cost ratio (2.06) followed by 10 kg S ha^{-1} (44,174 ha^{-1} and 2.04). Overall, balanced application of potassium and sulphur significantly improved productivity and profitability of summer sesame.

Keywords: *Economics, potassium, sesame, sulphur, yield*

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Evaluation of sesame genotypes for variability in yield

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Sesame, the queen of oilseeds, is one of the nine major oilseed crops in our country. Our country is not self-sufficient in oilseed production due to huge demand-supply gap. As an oilseed crop sesame can play an important role to solve the problems of shortage of edible oilseeds in our country. There is urgent need to enhance production of sesame which is possible either by area expansion or by increasing productivity. Area expansion is not possible due to other competitive crops. Therefore, only available opportunity is to enhance productivity through developing high yielding varieties. In order to develop high yielding varieties a total of 13 cultures were evaluated along with 3 checks (two national i.e. GT-10 and TKG-22, and one local/Zonal i.e Nirmala) in RBD with three replications during *kharif* 2025 under station yield trial at AICRP on Sesame, RRTTS, Dhenkanal, Odisha. Among them, eleven cultures viz., OSC-19-12-3 (1047.22/ha), OSC-18-12-1 (1005.55/ha), OSC-18-13-2 (1001.38kg/ha), OSC-18-6-2 (947.22kg/ha), OSC-19-13-2 (918.05kg/ha), OSC-19-10-1(915.27 kg/ha), OSC-19-13-3(884.72 kg/ha), OSC-18-5-2 (845.83 kg/ha), OSC-20-17-1(738.88 kg/ha), OSC-18-6-1(730.55 kg/ha) and OSC-18-3-1(722.22 kg/ha) recorded a mean seed yield of more than 720 kg/ha which is significantly superior than the best check variety Nirmala (701.38kg/ha). These eleven cultures will be evaluated under the All India Coordinated Research Project (Sesame & Niger) for agronomic and yield-related traits.

Keywords: *Genotypes, sesame, sariability, yield*

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Performance of sesame to organic management modules in a soybean-sesame cropping systems in the summer season

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Globally sesame (*Sesamum indicum* L.) is an important oilseed crop is exported in the form of seed. Organic sesame seeds are small flat creamy white seeds in appearance, containing oil-soluble and water-soluble antioxidants such as sesamin, sesaminol, sesamolin, and sesaminol glucosides. There is great demand for Indian organic sesame in European countries. Field experiments consecutively for five years since 2018 were conducted in deep Vertisols at IIOR-ICRISAT farm in a fixed plot with eight nutrient management modules with complete organic package of practices to study the response of sesame in a soybean-sesame cropping system. The nutrient management modules comprised of 100% RDF (FYM + Rock phosphate) + PSB; 100% RDF (Green leaf manure *Glyricidia* sp. + RP) + PSB; 100% RDF (Castor oilcake + RP) + PSB; 100% RDF (Neem oilcake + RP) + PSB ; 100% RDF (FYM + vermicompost + Goat manure) + RP) + PSB; 50% inorganic + 50% organic (through FYM + Rock phosphate); 100% RDF through Urea, SSP, MOP alongwith an absolute control in a randomised block design replicated thrice. Nutrient management was on equal nitrogen basis and the balance of phosphorus through RP. Potassium was not applied separately. Recommended fertiliser dose of 30:30:20 kg NPK/ha and 20:60:20 kg NPK/ha for sesame and soybean was followed. Fresh *Glyricidia* loppings were collected every season from ICRISAT, Hyderabad farm were applied as per the recommended blanket fertiliser dose in the specified treatment. A spacing of 45 x 15 cm and 45 x 5 cm was followed for sesame and soybean

respectively. A plot size of 45 m^2 was maintained for each experimental unit. Seed treatment with *Trichoderma viride* 4g/kg, cultivation of sorghum and daincha along the border, prophylactic spray with neem oil at fortnightly interval, installing "T" perch, 3% Panchagavya spray and bio fertilizers *viz*., PSB, KSB, Rhizobium for both the crops wherever applicable. On an average over five years (2019-23), organic sesame in the soybean-sesame cropping system responded well to organic modules with temporal variations. Average of 5 years' data indicated that application of 100% RDF (FYM + vermicompost + Goat manure) + Rock phosphate) + PSB yielded 826 kg/ha while inorganic management yielded 889 kg/ha of sesame. Substitution of sesame nutrient requirement through one third each of FYM, vermicompost and goat manure produced comparable yield to that of nutrient management through inorganic means. There were a lot of variations in soil nutrient content probably due to their decomposition pattern and composition.

Keywords: *Organic nutrient management module, sesame, soybean-sesame cropping system, yield*

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Lignin-based seed pelleting for small-seeded crops: Importance, functional advantages, and multi-input delivery using IIOR biopolymer matrices

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Seed pelleting plays a vital role in improving crop establishment and productivity in small-seeded crops such as sesame (*Sesamum indicum* L.) and mustard (*Brassica* spp.), where traditional sowing practices often result in poor plant stand, excessive seed rate, and inefficient use of agricultural inputs. Due to their small seed size and irregular shape, sesame and mustard are commonly sown by broadcasting or shallow line sowing, leading to uneven seed distribution, variable sowing depth, and increased susceptibility to soil-borne pathogens and abiotic stresses. Seed pelleting overcomes these limitations by increasing seed size and uniformity, enabling precision sowing, improving seed placement, and ensuring optimal plant population under field conditions. The choice of filler material is a critical component of an effective seed pelleting system. Conventional pelleting formulations frequently rely on inorganic fillers such as talc, bentonite, kaolin, or calcium carbonate, which are largely inert and offer limited functional benefits beyond increasing pellet mass. In contrast, lignin, a renewable organic biopolymer derived from agricultural residues and biomass processing streams, offers multiple advantages when used as a filler in seed pelleting. Rich in polyphenolic compounds, lignin exhibits inherent antimicrobial and antioxidant properties that contribute to reduced seed- and soil-borne disease incidence during early stages of germination and seedling establishment. Its organic nature also improves biological compatibility with seeds and soil microflora compared to mineral fillers. In lignin-based pelleting systems, lignosulphonate serves as an effective filler due to its water dispersibility, good flow properties, and compatibility with biodegradable binders. Unlike inorganic fillers, lignosulphonate contributes to improved pellet integrity, reduced dusting, and enhanced moisture buffering around the seed, creating a favorable microenvironment for germination. The gradual biodegradation of lignin in soil ensures that pellet disintegration is synchronized with radicle emergence, avoiding mechanical resistance to seedling growth while providing early protection against pathogens and storage pests. The adhesive component of the pelleting formulation is equally important and, in this context, IIOR-developed biopolymer matrices, particularly cellulose-based systems, play a multifunctional role. These biopolymers act not only as binders that impart mechanical strength to the pellet but also as delivery carriers for multiple crop inputs. The IIOR biopolymer matrices enable uniform entrapment and controlled release of beneficial microbes, nutrients, pesticides, and other agrochemicals directly at the seed–soil interface. This targeted delivery enhances input use efficiency, reduces chemical losses, and lowers overall application rates, contributing to environmentally sustainable crop management. The integration of lignin-based fillers with IIOR biopolymer adhesives thus enables the development of advanced

seed pelleting systems tailored for low-volume seed crops like sesame and mustard. Such systems support precision sowing, reduce seed rate, improve germination and field establishment, and facilitate multi-input delivery to address biotic and abiotic stresses. Overall, lignin-based seed pelleting represents a sustainable and scalable approach for enhancing productivity and resilience in small-seeded crops while promoting the valorization of agricultural biomass.

Keywords: *Biopolymer matrices, Functional advantages, Lignin, Seed pelleting, Small-seeded crops*

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Effect of herbicidal weed management on growth and yield performance of sesame (*Sesamum indicum* L.)

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A field experiment was conducted during *Kharif* season of 2025-26 in sandy loam soil at the Research Farm, Project Coordinating Unit (Sesame and Niger), JNKVV, Jabalpur to study the effect of herbicidal weed management on growth and yield performance of sesame. The experiment was laid out in a randomized block design having three replications with twelve treatments. The treatments were T1: weedy check, T2: Two hand weedings at 20 & 40 DAS, T3: Pendimethalin @ 750 g a.i/ha as PE,T4: Metolachlor @ 750 g a.i/ha as PE, T5: Pendimethalin @ 750 g a.i/ha as PE fb Quizalofop-p-ethyl 50 g a.i/ha at 25-30 DAS as PoE, T6: Pendimethalin @ 750 g a.i /ha as PE fb Propaquizafop @ 100 g a.i/ha at 25-30 DAS as PoE, T7: Metolachlor @ 750 g a.i./ha as PE fb Quizalofop-p-ethyl 50 g a.i/ha at 25-30 DAS as PoE, T8: Metolachlor @ 750 g ai./ha as PE fb Propaquizafop @ 100 g a.i/ha at 25-30DAS as PoE, T9: Pretilachlor @ 600 g a.i/ha as PE, T10: Pyrazosulfuron @ 10 ga.i./ha + Pretilachlor @ 400 g a.i/ha as PE ,T_{11}: Metolachlor @ 750 g ai/ha + Imazethapyr @ 50 g a.i/ha as PE, T12: Pendimethalin @ 750 g a.i/ha + Imazethapyr @ 50 g a.i/ha as PE. Sesame variety RT-372 was sown in the experimental field with recommended package of practice at a spacing of 40cm row to row and 10cm plant to plant during the 3rd week of July. The predominant weeds associated with sesame in the experimental field were *Cyperus rotundus, Digitaria sanguinalis, Dactyloctenium aegyptium, Celosia argentea*.Weed index was the lowest in T_{11} (16.01%)which was followed by T_7 (35.21%). The results showed that among herbicidal weed management treatments the highest weed control efficiency was observed with (T8) Metolachlor @ 750 g ai./ha as PE fb Propaquizafop @ 100 g a.i/ha at 25-30 DAS as PoE. Significant effect of weed management practices on growth and yield attributes of sesame as compared to weedy check was recorded under all the treatments. The treatment T_{11} recorded maximum plant height (85.30), number of branches at 60 DAS (2.11). The treatment T_2 recorded the highest number of capsule per plant (37.83) and T8 recorded the highest number of seeds per capsule (52.89). The treatment T2 recorded highest seed yield (662.22 kg ha^{-1}) which was significantly superior over all the treatments. Among herbicidal weed management treatments T_{11} (556.14 kg ha^{-1}) recorded maximum seed yield. Hence the study concluded that either two hand weedings at 20 and 40 DAS or pre-emergence application of metolachlor@ 750 g ai./ha fb post emergence application of Propaquizafop @ 100 g a.i/ha at 25-30DAS can be adopted for weed management in sesame.

Keywords: *Herbicides, sesame, weed management, weed index*

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Study on integrated application of fertilizers and nano fertilizers on growth and yield of sesame (*Sesamum indicum* L.)

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A field experiment was conducted on sesame during *kharif* season of 2025-26 in sandy loam soil at the Research Farm, Project Coordinating Unit (Sesame and Niger), JNKVV, Jabalpur to study the effect of integrated application of fertilizers and nano fertilizers on growth and yield of sesame. Sesame variety RT- 372 was sown in the experimental field with recommended package of practices at a spacing of 40 × 10 cm row to row and plant to plant during the third week of July. The experiment was laid out in a randomized block design having three replications with fourteen treatments. The treatments were T1: RDF (60:40:20) 50% N as basal and remaining N in 2 equal splits at 30 & 50 DAS, T2: 100 % P_2O_5 & K_2O as basal & 75% RDN (50% basal & 50% at 30 DAS), T3: 100 % P_2O_5 and K_2O as basal & 75 % RDN (top dressing in 3 equal splits at 15, 30, & 50 DAS), T4: 100 % P_2O_5 and K_2O & 50 % RDN as basal, T5: 50 % RDN , 50 % P_2O_5 and 100 % K_2O as basal, T6: 50 % RDF (30 : 20 : 10) 50 % N as basal & 50 % at 30 DAS, T7: T4 + Nano Urea (4 ml / liter water) spray at 30 and 50 DAS @ 300 & 400 L / ha, T8: T5 + Nano DAP (4 ml / liter water) spray at 30 and 50 DAS @ 300 & 400 L / ha, T9: T6 + Nano DAP (4 ml / liter water) + K (1 % KCL) spray at 30 and 50 DAS @ 300 & 400 L/ ha, T10: T6 + Nano Urea at 30 & Nano DAP at 50 DAS (4 ml / liter water) + K (1 % KCL) @ 300 & 400 L / ha, T11: T6 + spray of water at 30 and 50 DAS @ 300 & 400 L/ha, T12: RDF (60 : 40: 20) N in 3 equal splits at 15 , 30 & 50 DAS, T13: 125 % (75 : 50: 50) 50% N as basal and remaining N in 2 equal splits at 30 & 50 DAS, T14: No fertilizer. The results showed significantly higher values of growth parameters *viz*., plant height (126 cm), number of branches per plant (2.67) and yield attributes *viz*., number of capsules / plant (64.33), number of seeds / capsule (68.89), test weight (3.63 gm) and seed yield (756.54 kg/ha) were recorded under treatment T13 followed by treatment T12 (RDF (60: 40: 20) N in 3 equal splits at 15, 30 & 50 DAS). Among integrated nutrient management treatments, treatment T9 and T10 were found superior with seed yield of 590.77 kg/ha and 589.88 kg/ha respectively. However, these treatments could not attain the level of significance. Significantly lowest values of growth parameters *viz*., plant height (92.44 cm), number of branches per plant (1.33) and yield attributes *viz*., number of capsules / plant (24.67), number of seeds/capsule (55.44), Test weight (3.20 gm) and seed yield (267.85 kg/ha) were recorded under absolute control (T14).

Keywords: *Foliar application, nutrient management, nano fertilizers, nesame, yield*

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Accessing the variability for key agro-morphological traits and oil content in diverse *sesame* (*Sesamum indicum* L.) germplasm

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Sesame (*Sesamum indicum* L.), a member of the family Pedaliaceae, is popularly referred to as the "Queen of Oilseeds." It is a diploid crop with a chromosome number of 2n = 26 and is among the oldest oilseed crops cultivated by humans. Sesame is primarily grown for its edible oil which is valued for its

quality. The oil has good amounts of natural antioxidants such as sesamin, sesamolin, and sesamol, and is predominantly composed of polyunsaturated fatty acids (PUFAs). Additionally, its seeds are also good source of protein, vitamins and minerals. Sesame seeds contain a high protein content (18–25%) and have ample quantities of essential amino acids, (methionine and cysteine). Despite its advantages, the crop has received limited attention from breeders due to its low productivity. Therefore, assessing genetic variability within sesame germplasm is essential for identifying superior genotypes with high yield potential and oil content, thereby improving overall productivity and broadening its acceptance among farmers.The present experiment was conducted during the kharif 2025 at two locations (Ludhiana and Bathinda) in Punjab. The study used an augmented block design 100 diverse sesame accessions along with two checks (RT 346 and Till No. 2) to assess variability in yield-related traits and oil content among the germplasm lines. Five plants per sesame accession were randomly selected and tagged for evaluation of agronomical traits. Key morphological traits were measured such as, seed yield (g), number of capsules per plant, capsule length (cm), 1000-seed weight (g), plant height at maturity (cm), days to 50% flowering, days to final maturity, along with total seed oil content.Oil content in the intact seeds was estimated by Nuclear Magnetic Resonance (NMR) (MQC23, Oxford Instruments, UK).The sesame genotypes exhibited a wide range of diversity in their morphological traits with notable variations observed in plant height (69.4-142.8 cm), number of capsules per plant (24-96), capsule length (1.76-3.66), number of branches per plant (2-9), seed yield per plant (2.80-10.20 g). Oil content ranged from 31.26% (EC-346131) to 48.01% (IC 129819). More than 45% oil content was recorded in >20 genotypes making them promising genotypes for further use in sesame breeding programs. The findings highlighted the value of using agro-morphological data to identify potential genotypes for use in hybridization programs.

Keywords: *Morphological traits, NMR, oil content, Sesame germplasm, yield*

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Enhancing the effectiveness of source-sink partitioning to increase sesame (*Sesamum indicum* L.) productivity

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The global demand for vegetable oil consumption has increased and there is an urgency to improve the oilseed crop yield. Among the oilseed crops, sesame (*Sesamum indicum* L.) is called as nutritive gold mine due to its encapsulation of several vitamins, minerals, antioxidants and beneficial fatty acids; the oil is safe for consumption. It is extensively grown throughout the world's tropical and subtropical regions. However, several constraints hamper successful cultivation of sesame, particularly due to poor source-sink partitioning the yield of sesame is low. In this view, research attempts were made to regulate the crop growth by enhancing the source-sink partitioning efficiency with the objective to increase the productivity of sesame. Field experiments were conducted at Regional Research Station, TNAU, Vridhachalam during *kharif* 2022 and *kharif* 2023 to regulate the crop growth for enhancing the effectiveness of source – sink partitioning in sesame. The experiment was laid out in randomised block design with eight treatments involving terminal clipping and foliar spray of plant growth regulators which were replicated thrice. The pooled mean results of the experiments revealed that terminal clipping of sesame at 30 DAS registered higher specific leaf weight (11.4 mg cm^{-2}), higher SPAD value (49.2), number of branches/plant (8.2), number of capsules/plant (120), number of seeds/capsule (51) and higher seed yield (996 kg/ha). Among the growth retardants, foliar spray of Mepiquat chloride @ 200 ppm at 30 DAS showed its superiority in recording higher seed yield (909 kg/ha).

Keywords: *Plant growth regulators, Productivity, Sesame, Source-sink partitioning, Terminal clipping*

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Combined application of conventional urea fertilizer and nano urea foliar nutrition on productivity and profitability of irrigated sunflower

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To evaluate the response of irrigated sunflower to the combined application of conventional urea fertilizer and nano urea foliar nutrition, consecutive field experiments were conducted at Department of Oilseeds, Tamil Nadu Agricultural University, Coimbatore, during *Kharif* season of year 2022 and 2023 by implementing the following treatment details *viz*., T_1 - 50% Recommended Dose of Nitrogen (RDN - 30kg N ha^{-1}) through urea as basal + nano-urea foliar nutrition @ 1ml $litre^{-1}$ at 45 DAS, T_2 - 50% RDN through urea as basal + nano-urea foliar nutrition @ 2ml $litre^{-1}$ at 45 DAS, T_3 - 50% RDN through urea as basal + nano-urea foliar nutrition @ 3ml $litre^{-1}$ at 45 DAS, T_4 - 50% RDN through urea as basal + nano-urea foliar nutrition @ 4ml $litre^{-1}$ at 45 DAS, T_5 - 50% RDN through urea as basal + normal urea foliar nutrition @ 2% at 45 DAS, T_6 – 100% RDN through urea (50 % as basal + 50 % as 45 DAS), T_7 - Nano urea foliar nutrition @ 2ml $litre^{-1}$ at 15, 30 and 45 DAS, T_8 - Nitrogen free control and replicated thrice. Foliar nutrition of nano-urea with diverse concentration *viz*., 2ml $litre^{-1}$, 3ml $litre^{-1}$ and 4ml $litre^{-1}$ combined with 50% RDN as basal fertilizers demonstrated significant effects on yield traits, seed yield and economics of irrigated sunflower. Among the levels of RDN application as well as nano-urea foliar nutrition investigated, basal application of 50% RDN through urea + foliar nutrition of nano urea 4ml lit^{-1} at 45 DAS (T_4), significantly recorded higher values of head diameter (19.3 cm), grain $capitulum^{-1}$ (986 Nos.,) seed yield (2317 kg ha^{-1}), gross return (125118 ha^{-1}), net return (63478 ha^{-1}) and benefit-cost ratio of 2.03. However, it was on par with application of 100% RDN through urea @ 50% RDN as basal and @ 50% RDN as top dressing at 45 DAS (T_6), which registered head diameter of 19.8 cm, grain capitulum of 992 Nos., seed yield of 2367 kg ha^{-1}, stalk yield of gross return of 127818 ha^{-1}, net return of 66364 ha^{-1} and benefit-cost ratio of 2.08. Whereas, the lowest values of yield attributes *viz*., head diameter (12.4 cm), grain $capitulum^{-1}$ (644 Nos.), seed yield (1641 kg ha^{-1}), gross return (88614 ha^{-1}), net return (32169 ha^{-1}) and higher benefit-cost ratio (1.57) were observed under nitrogen free absolute control (T_8). From the experiment result, it concluded that combined application of 50% RDN through urea as basal + foliar nutrition of nano urea @ 4ml lit^{-1} at 45 DAS significantly recorded higher productivity and profitability, which are at par with application of 100% RDN as basal (50% RDN) and top dressing (50% RDN) at 45 DAS.

Keywords: *Foliar nutrition, irrigated sunflower, nano urea, productivity, profitability, sunflower*

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Sustainable technologies to enhance nutrient use efficiency in sunflower

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Urea is one of the most important and widely used nitrogenous fertilizers in agriculture due to its high nitrogen content, cost-effectiveness, and versatility. Among the various nitrogenous fertilizers, urea is the dominant source, accounting for approximately 73.4% of the total nitrogen (N) fertilizer demand worldwide. Despite its widespread use, urea is highly susceptible to nitrogen losses through volatilization, leaching, and denitrification, which significantly reduce its effectiveness. Consequently, only 30-60% of the applied nitrogen is actually utilized by crops, largely due to the poor nitrogen use efficiency (NUE) of conventional urea fertilizers. Sunflower is an important and third-largest oilseed crop after soybean and rapeseed

grown throughout the subtropical and temperate regions of the world. Sunflower plants need nitrogen consistently and in higher amount for optimum growth and development. Globally, sunflower productivity has shown a decreasing trend during the past decade, mainly because of lower resource use efficiency, reduced NUE. To address these challenges, there is a growing need to develop slow-release urea fertilizers that minimize nitrogen losses and enhance NUE, thereby contributing to sustainable agricultural production while mitigating climate change impacts. Although polymer-coated slow-release urea fertilizers are currently available, the synthetic polymers used as coating materials and sealants often result in the accumulation of microplastic pollution, increasing the environmental footprint of these products. To overcome this limitation, research efforts are increasingly focused on the use of biopolymeric coatings derived from natural, biodegradable materials. These polysaccharide-based biopolymers, offer an eco-friendly alternative to synthetic polymers and have shown significant potential in improving NUE, reducing nitrogen losses, and promoting sustainable fertilizer management practices. The present study was conducted at the ICAR–Indian Institute of Oilseeds Research (ICAR-IIOR), Rajendranagar, Hyderabad. Various polysaccharide-based biopolymers were used for coating urea granules. The biopolymer-coated urea formulations were prepared in a coating pan. The dissolution behaviour of the coated urea granules was evaluated under controlled conditions. Neem-coated urea was included as a check for comparison with the biopolymer-coated urea formulations. The biopolymer-coated urea formulations significantly increased the dissolution time to 40–50 minutes, whereas neem-coated urea dissolved within less than 60 seconds under 100% saturated conditions. The coating of urea with biopolymeric materials imparted hydrophobic characteristics to the formulation, and the incorporation of polysaccharide-based biopolymer further facilitated a controlled and slow release of urea.

Keywords: *Nutrient use efficiency, polysaccharide-based biopolymers, slow-release urea fertilizers, sunflower*

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Unlocking immobilized phosphorus through functionalization strategies in sunflower

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Sunflower (*Helianthus annuus* L.) is an important oilseed crop valued for its high oil content (48–53%), protein (14–19%) and crude fibre (16–27%). phosphorus (P) and sulphur (S) play a crucial role in ensuring optimal growth, seed development and oil productivity of sunflower. Phosphorus, the second most important macronutrient after nitrogen, is essential for profitable crop production and is absorbed by plants primarily in the forms of H, PO and HPO². Adequate P nutrition promotes root development, improved grain quality and increased resistance to diseases. Crop P requirements are mainly met through fertilizers such as diammonium phosphate (DAP), single superphosphate (SSP) and triple superphosphate (TSP), with DAP being the most widely used source due to its high nutrient content (46% P, O and 18% N). However, phosphorus availability in soils is often limited due to fixation by iron and aluminium in acidic soils and by calcium and magnesium in alkaline soils, resulting in less than 20% utilization of applied P fertilizers by plants. Improving phosphorus use efficiency is therefore essential and several approaches such as band placement, intercropping, microbial inoculation and fertilizer coating have been adopted. Among these, fertilizer coating is considered a promising strategy as it reduces nutrient losses by regulating nutrient release. Coating materials include biodegradable organics, polymers, elemental sulphur, nano sulphur, starch and waxes. The application of elemental and nano sulphur-based DAP composites represents an emerging class of advanced functionalized fertilizers with potential to enhance phosphorus availability, nutrient use efficiency and overall sunflower productivity. The experiment was carried out at the ICAR-Indian Institute of Oilseeds Research (IIOR), Hyderabad. We tested five coating compositions and evaluated their suitability based on dissolution studies. The best-performing composition have been selected

for further experimentation. Using the selected coating material, diammonium phosphate (DAP) fertilizer will be coated with both elemental sulphur (ES) and nano sulphur (NS) at different coating levels, namely ES1, ES2, ES3 and NS1, NS2, NS3.These treatments were used to evaluate the performance of sulphur-based functionalized DAP formulations. For coating, DAP was first placed in a coating pan, the selected composition was sprayed onto the granules, and ES or NS was evenly distributed over the granules, followed by drying and storage. Among the five coating formulations evaluated, the optimized coating formulation was identified based on dissolution behaviour and was used for subsequent coating studies. Its suitability was attributed to favourable adhesive properties and film-forming ability, which facilitated effective binding of sulphur onto fertilizer granules. Diammonium phosphate (DAP) was coated with elemental sulphur and nano sulphur using a coating pan, and the treatments were designated as ES1, ES2 and ES3 for elemental sulphur and NS1, NS2 and NS3 for nano sulphur. Image-based evaluation indicated that coatings corresponding to ES3 and NS3 exhibited relatively uniform surface coverage compared to ES1, ES2, NS1 and NS2. At the intermediate level, NS2 showed relatively improved coating characteristics compared to ES2, which were attributed to differences in particle size and surface activity.

Keywords: *Fertilizer coating, Nutrient release, Nutrient use efficiency, Sunflower*

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Influence of crop geometry on morphophysiological traits and yield of sesame (*Sesamum indicum* L.)

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Sesame (*Sesamum indicum* L.), belonging to the family Pedaliaceae , an important oilseed crop valued for its high-quality oil, nutritional significance, and adaptability to diverse agro-ecological conditions. The field experiment was conducted during the kharif season of 2025 at the Research Farm, All India Coordinating Research Project Unit (Sesame and Niger), Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.). The experiment was laid out in a Randomized Block Design with three replications and 12 crop geometry treatments involving different row and plant spacings. The sesame variety RT-372 was sown following the recommended package of practices. The results indicated that crop geometry significantly regulates plant population, light interception, and resource-use efficiency, thereby influencing growth behaviour and yield in sesame. Optimized spacing enhanced physiological efficiency and overall productivity under field conditions. Plant population varied widely among treatments due to differences in spacing, ranging from 9.67 to 21.33 plants m². Wider and skip-row geometries recorded lower plant population but exhibited superior per-plant performance in terms of yield attributes. The number of capsules per plant ranged from 52.11 to 68.44, while seeds per capsule varied from 54.00 to 61.11. Test weight (3.6–3.7g) remained statistically uniform across treatments, indicating that spacing had negligible influence on seed size. Maximum seed yield was recorded under 30x10cm spacing (767.59 kg/ha) which at par with T2 (690.77kg/ha) & T10 (681.25 kg/ha). In conclusion, crop geometry plays a crucial role in regulating plant population, yield attributes, and seed yield of sesame. Among the treatments, closer spacing of 30 × 10 cm (T) proved to be the most productive under the agro-climatic conditions of Jabalpur and can be recommended for achieving higher sesame seed yield.

Keywords: *Crop geometry, plant spacing, yield attributes, productivity*

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Impact on productivity and economics of technological interventions under CFLD on niger (*Guizotia abyssinica* L.) in Madhya pradesh

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A Study was conducted on scientific production techniques on Impact on productivity and economics of Technological Interventions under CFLD on Niger (*Guizotia abyssinica* L.) in Madhya Pradesh by KVK Chhindwara - II of Madhya Pradesh under ICAR-ATARI, Zone IX, Jabalpur during 2023-24 covering 125 farmers and 50 ha area to evaluate. The technological interventions were improved cultivars JNS 28 with improved cultivation practices viz. line sowing, treatment of seed with fungicide, balanced nutrition and insect-pest management and weed management. The Niger seed yield under CFLD and Farmer's Practice (FP) was recorded as 5.50 q ha^{-1} and 3.16 q/ha, respectively. The per cent increase in yield with Improved Practices (IP) over FP was found to be 59.83. The extension gap and technological index were 2.07 q/ha and 74.05 per cent. The observed technology gap 2.34 q/ha reflected the farmer's cooperation in carrying out demonstrations. The higher average net-return and average cost-benefit ratio was recorded under demonstration plot (Rs. 6600 per ha and 1.71 respectively) as compared to Farmers Practices (Rs. per ha. and 1.88 respectively). Therefore, the results clearly indicate that the use of improved practices with scientific intervention contributed to increase the productivity and profitability of niger crop with scientific approach.

Keywords: *Clusters frontline demonstrations, extension gap, niger yield, technology transfer, technology index*

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Impact of technological interventions of CFLD on soybean (*Glycin max* L.) Merrill productivity and profitability in Madhya Pradesh

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Demonstration was conducted on scientific production techniques on Soybean (*Glycin max* L.) was evaluated through cluster frontline demonstrations (CFLDs) at KVK Chhindwara – II of Madhya Pradesh under ICAR-ATARI, Zone IX, Jabalpur during the year 2020 to 2024 whereas demonstration was conducted at 125 farmers field with 50 ha each year. The technological interventions were improved cultivars with full package and practices viz. line sowing, treatment of seed with fungicide, balanced nutrition and insect-pest management and weed management. The soybean seed yield under CFLD and Farmer's Practice (FP) was recorded as 17.94 q ha^{-1} and 13.29 q ha^{-1}, respectively. The per cent increase in yield with Improved Practices (IP) over FP was found to be 34.94 per cent. The extension gap and technological index were 13.94 q/ha and 33.79 per cent, respectively. The observed technology gap 6.06 q/ha reflected the farmer's cooperation in carrying out demonstrations. The higher average net-return and average cost-benefit ratio was recorded under demonstration plot (Rs.70745 per ha and 4.04, respectively) as compared to Farmers Practices (Rs. 66463 per ha and 2.81 respectively). Therefore, the results clearly indicate that the use of improved variety with full package and production intervention

contributed to increase the productivity and profit of Soybean crop with scientific approach.

Keywords: *Cluster frontline demonstrations, cost of cultivation, economics analysis, extension gap, soybean, technology transfer, technology index*

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Compositional diversity and multivariate identification of nutritionally superior oil palm germplasm from West and Central Africa grown under Indian conditions

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Oil palm (*Elaeis guineensis* Jacq.) is the world's most important source of edible vegetable oil; however, its nutritional profile, particularly saturated fatty acid content, remains a key concern. The present study comprehensively evaluated experimental data generated from 102 oil palm germplasms originating from Tanzania and Zambia to dissect variability in fatty acid composition, lipid fractions, nutritional quality indices, carotene content, free fatty acids, and fresh fruit bunch (FFB) yield using an integrated univariate and multivariate analytical framework. Experimental measurements revealed wide variation in major fatty acids, with palmitic acid ranging from 26.33 to 56.84% and oleic acid from approximately 31 to 49%. Subsequent clustering of germplasm based on standardized experimental traits resulted in four distinct clusters, whose mean values highlighted pronounced nutritional differentiation. Cluster-wise palmitic acid content varied from 40.38 ± 0.57% to 56.84 ± 0.78%, oleic acid from 36.29 ± 1.14% to 44.89 ± 0.56%, and linoleic acid from 3.40 ± 0.49% to 9.57 ± 0.22%. Nutritional quality indices derived from experimental fatty acid profiles showed marked differences, with PUFA/SFA ratios ranging from 0.06 ± 0.01 to 0.21 ± 0.01, iodine value from 37.08 ± 0.76 to 55.18 ± 0.54 g I, /100 g, atherogenic index from 0.81 ± 0.02 to 1.61 ± 0.07, and health-promoting index from 0.64 ± 0.03 to 1.26 ± 0.04. Experimentally quantified carotene content ranged from 51.89 to 1359.24 mg kg^{-1} across germplasm, while cluster means varied significantly from 538.83 ± 39.89 to 740.77 ± 71.40 mg kg^{-1}. FFB yield, measured under field conditions, ranged from 23 to 187 kg $palm^{-1}$ $year^{-1}$ at the experimental level, with cluster means spanning 100.78 ± 8.29 to 118.00 ± 6.38 kg $palm^{-1}$ $year^{-1}$, indicating no yield penalty in nutritionally superior clusters. Correlation analysis of experimental traits revealed strong negative associations between palmitic and oleic acid (r = –0.85), SFA and UFA (r = –0.98), and atherogenic index with iodine value (r = –0.95), confirming the antagonistic relationship between saturated and unsaturated lipid fractions. Principal component analysis explained 59.14% and 18.44% of total variance in the first two components, while canonical discriminant analysis clearly separated the four clusters in multivariate space. Two-way MANOVA demonstrated a highly significant effect of cluster membership (Wilks' ë = 0.0507, p < 0.001), along with significant effects of origin (p H" 0.047) and cluster × origin interaction (p < 0.01). Trait importance ranking based on composite scores identified oleic acid (0.67), palmitic acid (0.47), MUFA (0.47), and SFA (0.43) as the primary drivers of germplasm differentiation. Overall, the study identifies experimentally validated oil palm germplasm combining improved fatty acid composition, favorable nutritional quality indices, high carotene content, and stable yield, providing a strong foundation for health-oriented oil palm breeding and selection programs.

Keywords: *Oil palm, diversity, germplasm, yield*

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Response of Groundnut to the foliar application of nano urea and urea phosphate

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An agronomic investigations to study yield response of groundnut to foliar application of nano urea and urea phosphate was carried out at Main Agricultural Research Station, Dharwad *Kharif* 2022, 2023 and 2024**.** In order to accomplish the objectives set out for the experiment, a total of 10 treatments were laid using RCBD design. The results of three year data revealed that the application of 0**.**2**%** Nano urea **+** 1 **%** Urea phosphate at flowering stage & peg formation stage along with recommended NPK had resulted in realizing significantly higher dry pod yield **(**275 kg ha^{-1}**)**, haulm yield**(**2948 kg ha^{-1}**)** and kernel yield**(**1849 kg ha^{-1}**)** over other foliar nutrient applied plots**.** It was at par with 75**%** recommended NPK with 0**.**2**%** nano urea**+**1**%** urea phosphate at flowering stage & peg formation stage and 100**%** NPK **+** 2**%** urea spray at 30 and 60 DAS**(**Check treatment**).** Further, application of 0**.**2**%** Nano urea **+** 1 **%** Urea phosphate at flowering stage & peg formation stage along with recommended NPK and FYM registered significantly higher gross returns **(**Rs**.** 153522 ha^{-1}**)**, net returns **(**Rs**.** 87432 ha^{-1}**)**, and BCR **(**2**.**32**)** over other treatments**.** Thus, it can be concluded that the application of 0**.**2**%** Nano urea **+** 1 **%** Urea phosphate at flowering stage & peg formation stage along with recommended NPK had resulted in realizing significantly higher dry pod yield**(**275 kg ha^{-1}**)**

Keywords: *Nano Urea, Urea Phosphate and Dry pod yield*

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Innovations in Weed Control through Biodegradable Mulches in Oilseed Production Systems

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Weed infestation continues to be one of the most enduring biophysical challenges that restrict productivity, resource-use efficiency and profitability of oilseed crops in various agro-ecological regions. Traditional weed management methods in oilseeds, which rely on manual weeding, mechanical interventions and extensive herbicide application, are increasingly confronted with rising labor costs, herbicide resistance, environmental pollution and negative effects on soil health. While plastic mulching is effective for weed suppression and soil moisture conservation, it raises significant concerns regarding non-biodegradable waste accumulation, microplastic contamination, soil degradation and disposal expenses. In this scenario, biodegradable mulches have surfaced as a promising eco-friendly alternative that supports sustainable and climate-resilient agricultural production systems.

Biodegradable mulches (BDMs) derived from natural biopolymers and its derivatives have designed to deliver the agronomic benefits of plastic mulches while overcoming their environmental drawbacks by limiting light penetration, changing soil temperature patterns and adjusting moisture dynamics. These mulches effectively prevent weed seed germination and the establishment of early seedlings. In oilseed crops like groundnut, mustard, sunflower, sesame and soybean, biodegradable mulches have shown notable

decreases in weed density, weed biomass and weed competition indices, especially during the crucial crop–weed competition phase. These reductions lead to improved crop vigour, enhanced nutrient absorption and greater yield stability.

Building on these recent insights into biodegradable mulches and their multifunctional role in weed management, a comprehensive experimental study was initiated at the ICAR–Indian Institute of Oilseeds Research (ICAR-IIOR), Rajendranagar, Hyderabad. A bench scale protocol for development of biodegradable mulch formulations were developed using natural biopolymers and their derivatives. These optimized formulations were systematically evaluated for their effect on seedling emergence and weed suppression under controlled experimental conditions. The developed mulch film compositions were further characterized for their physico-chemical and functional attributes, including dissolution behaviour, FTIR analysis and viscosity measurements, to assess their structural stability and performance characteristics. To enable comparative assessment, commercially available plastic mulch and no mulch were incorporated as standard controls in all experiments to evaluate the performance of the newly developed formulations. The findings showed that seed germination with biodegradable mulch treatments were similar to the control, achieving 100% germination and a higher germination rate index. This response can be attributed to the mulch layer's ability to conserve soil moisture and minimize evaporative losses, thereby maintaining continuous water availability for germinating seeds during the critical early stages of seedling establishment. Additionally, notable weed suppression was noted, with weed counts restricted to merely 1–5% of prevalent weed species like *Cyperus spp*., at 30 days after experiment, unlike the control treatment, which recorded 10–15% weed occurrence of *Cyperus spp., Portulaca spp., Digitaria spp.* This clearly demonstrates that the developed biodegradable mulches effectively reduced weed proliferation while maintaining normal seedling emergence and successful crop establishment.

Biodegradable mulches provide a cost-effective and sustainable weed management alternative in oilseed crops by reducing weed infestation, labour requirements, and dependence on herbicides. Along with conserving soil moisture and ensuring uniform crop establishment, their eco-friendly nature and elimination of disposal costs enhance overall farm profitability and economic sustainability.

Keywords*: Oilseeds, biodegradable, mulches, biomass*

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Role of artificial intelligence in oilseed development in India

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Artificial intelligence (AI) has emerged as a powerful enabler of modern agriculture, offering significant potential to enhance oilseed crop development, productivity and sustainability in the context of rising food and energy demands, climate variability and resource constraints. Oilseed crops such as soybean, groundnut, rapeseed–mustard, sunflower and sesame are highly sensitive to environmental stresses, pest pressure and nutrient imbalances, making them suitable candidates for AI-driven, precision-based management. The integration of AI technologies, including machine learning, deep learning, computer vision, and decision-support systems, enables efficient analysis of large datasets generated from remote sensing, unmanned aerial vehicles (UAVs), Internet of Things (IoT) sensors and historical agronomic and climatic records. In oilseed production systems, AI-based models support precision agronomy by optimizing sowing time, plant population, nutrient management and irrigation scheduling according to site-specific soil and weather conditions. Machine learning algorithms facilitate early detection and diagnosis of major oilseed pests, diseases and nutrient deficiencies through image-based analysis, allowing timely and targeted interventions that reduce yield losses and minimize excessive use of agrochemicals. AI-enabled yield prediction and crop growth modeling assist farmers, researchers and policymakers in forecasting production, managing

market risks and ensuring supply chain stability. AI also plays a critical role in breeding and genetic improvement of oilseed crops. Advanced data analytics and AI-driven phenotyping platforms accelerate the identification of high-yielding, stress-tolerant and oil-rich genotypes by integrating genomic, phenomic, and environmental data. This shortens breeding cycles and enhances the efficiency of varietal development programs. Furthermore, AI-assisted climate risk assessment tools help in developing climate-resilient oilseed production strategies by predicting the impacts of drought, heat stress and erratic rainfall patterns. Post-harvest management and value addition in oilseed systems are increasingly supported by AI applications. Computer vision and sensor-based technologies enable rapid assessment of seed quality, oil content and contamination, while AI-driven supply chain management improves storage, processing efficiency, traceability and market intelligence. Despite these advantages, challenges such as limited data availability, high initial investment costs, digital infrastructure gaps and inadequate technical capacity restrict widespread adoption, particularly among smallholder oilseed farmers. Overall, AI represents a transformative approach for oilseed development by enhancing productivity, resource-use efficiency, and resilience while reducing environmental footprints. Strategic integration of AI with agronomic research, extension services and supportive policy frameworks will be essential to realize its full potential in achieving sustainable and competitive oilseed production systems.

Keywords*: Artificial, oilseed, precision, site-specific, IoT*

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Sustainable development of oilseed crops through organic package of practices

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Organic farming has emerged as a pivotal approach for sustainable development of oilseed crops by enhancing soil health, nutrient cycling and ecological resilience while reducing reliance on synthetic agrochemicals. Recent research highlights the capacity of organic systems to maintain competitive yields in crops such as sunflower, soybean and mustard through optimized crop rotations, green manures, and organic nutrient inputs. Studies demonstrate that incorporation of legume-based cover crops (e.g., cowpea and mungbean) in rotation with oilseeds significantly increases soil nitrogen availability via biological nitrogen fixation, resulting in improved yield and oil quality. Organic nutrient components such as organic amendments and vermicompost has been shown to enhance soil organic carbon, improve water retention and facilitate slow-release nutrient supply, thereby fostering robust root development and higher nutrient uptake in oilseed crops. Advances in biofertilizer technologies, including inoculation of plant growth–promoting rhizobacteria (PGPR) such as *Azospirillum* and *Bacillus* spp., have been reported to augment phosphorus solubilization and phytohormone production, further improving oilseed productivity. Recent field trials indicate that integration of microbial consortia with organic amendments can significantly enhance groundnut, sunflower and rapeseed yields by improving nutrient use efficiency and suppressing soilborne pathogens. Research on organic pest and disease management has highlighted the effectiveness of botanicals (e.g., neem and garlic extracts) and biological control agents (e.g., *Trichoderma* spp.) in reducing incidence of major insect pests and fungal diseases without adverse environmental effects. Furthermore, studies on soil–plant–microbe interactions reveal that organic systems promote greater microbial diversity and beneficial symbiotic associations, contributing to long-term soil fertility and crop resilience under abiotic stress. Despite generally lower initial yields compared to conventional systems, organic oilseed production has been associated with improved oil quality attributes, such as higher levels of beneficial fatty acids and antioxidants. Collectively, recent research affirms that organic farming offers a viable and ecologically sound framework for oilseed development by enhancing system sustainability, soil biological function, and crop health.

Keywords: *Organic farming, nutrient, mungbean, cowpea , phytohormone*

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Enhancing the growth and productivity of *gobhi sarson* with different rice residue management methods and nitrogen levels under rice-*gobhi sarson* (*Oryza sativa* L.- *Brassica napus* L.) rotation

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Rapeseed-mustard is the world's third most important edible oilseed crop. Despite increasing area and production, its productivity in India remains low due to inadequate nutrition, moisture stress, delayed sowing and poor crop establishment. Mulches can mitigate the critical constraints of moisture and nutrient stress by conserving soil moisture and enhancing nutrient availability. In northwestern India, *gobhi sarson* (*Brassica napus* L.) is sown after rice, where heavy paddy residue from combine harvesting poses major management challenges. Although advanced rice residue management techniques are well studied in rice-wheat system, their evaluation for the rice-*gobhi sarson* rotation remain limited. Therefore, optimizing nitrogen levels under residue management is crucial to improve its growth and productivity. The field experiment was conducted during winter seasons of 2023-24 and 2024-25 at Punjab Agricultural University, Ludhiana. The soil was sandy loam in texture, medium in organic carbon (0.44%) and available nitrogen (304 kg/ha) with near-neutral pH (7.36) and normal EC (0.20 dS/m). A split-plot design with three replications was used for the experiment. Main plots included three rice residue management methods: Happy seeder, Surface seeding-cum-mulching and Conventional method. Sub-plots comprised three nitrogen levels: 75% of the recommended dose of nitrogen (RDN) (75 kg N/ha), 100% RDN (100 kg N/ha) and 125% RDN (125 kg N/ha). In Happy seeder treatment, the crop was directly sown into standing and loose rice residues using the PAU Happy Seeder machine after uniform straw distribution. Under surface seeding-cum-mulching, crop seed was broadcasted after combine harvesting, followed by uniform straw spreading using a straw cutter-cum-spreader and a light irrigation was applied immediately after sowing. In conventional method, residues were completely removed and sowing was done with a tractor-drawn dual seed drill. Variety GSC 7 was used for the study. Growth parameters, yield attributes, and seed and stover yield were recorded at harvest, and data were analyzed using a split-plot design with treatment means compared using the critical difference at the 5% level of significance. Among rice residue management methods, sowing with Happy seeder resulted in greater plant height, dry matter accumulation, primary and secondary branches per plant and yield attributes at harvest during both the years. The seed yield increased by 10.7% and stover yield by 8.3% over conventional method, and by 23.9% and 18.9% over surface seeding-cum-mulching (two-year average) likely due to better seed-soil contact, enhanced root growth, and efficient uptake of moisture and nutrients. Under nitrogen levels, application of 125% RDN significantly enhanced growth and yield parameters of *gobhi sarson* over 75% RDN, though it remained statistically comparable with 100% RDN. Moreover, application of 125% RDN increased seed yield by 19.3%, and 100% RDN by 15.6%, over 75% RDN across two years. This might be due to nitrogen role in enhancing cell division, chlorophyll synthesis and photosynthetic efficiency. Overall, combining happy seeder sowing with 100% RDN enhanced growth and productivity of *gobhi sarson* and efficiently managed rice residue, offering a sustainable approach for rice-*gobhi sarson* rotation.

Keywords: *Rapeseed, gobhi sarson, happy seeder, stress*

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THEME - IV

KNOWLEDGE CENTRIC TECHNOLOGY TRANSFER AND DIGITAL OUTREACH

Impact of integrated crop management technologies on productivity and energy budgeting of mustard under cluster frontline demonstrations in Sawai Madhopur District, Rajasthan

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In India, oil seed production is given significant importance due to the enormous disparity between supply and demand, which led to the purchase of vegetable oil worth millions of rupees yearly. The present investigation evaluated the performance of CFLDs conducted by Krishi Vigyan Kendra (KVK), Sawai Madhopur, during the period 2022–23 to 2024–25 to assess the impact of integrated crop management (ICM) practices in mustard, as recommended in the package of practices of Agriculture University, Kota. The study adopted a combination of experimental and before–after research designs, and a total of 492 beneficiary farmers were included under the CFLD programme. Performance of improved mustard varieties Radhika and RH-725 under CFLD plots was compared with farmers' prevailing practices (local check). The results revealed that the demonstrated plots consistently produced significantly higher seed yield than the local check across all three years of study. On pooled basis, the mean extension gap and technology gap were observed to be 4.36 q ha^{-1} and 3.51 q ha^{-1}, respectively, indicating substantial scope for enhancing mustard productivity through improved technological interventions. Furthermore, the demonstrated plots recorded higher net returns and benefit–cost ratios compared to farmers' practices during all seasons, highlighting the economic superiority of ICM technologies. Energy analysis further substantiated the effectiveness of CFLDs, as higher energy use efficiency and energy productivity (kg MJ^{-1}) were recorded under the demonstration plots in comparison to farmers' plots, reflecting improved resource-use efficiency under integrated crop management practices.

Keywords: *CFLD, economics, ICM, Indian mustard, profitability*

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Unlocking mustard yield potential through frontline demonstrations and yield gap analysis in rice fallow areas of Eastern Vidarbha, Maharashtra

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In Eastern Vidarbha of Maharashtra, over 8 lakh ha is under paddy during kharif, but 70% of land remains fallow after harvest due to lack of irrigation and stray animal damage. Mustard, with low water needs and minimal damage from animals, is suitable for rice fallow lands. Around 4–5 lakh ha can be converted to mustard, covering ~5% of India's mustard area. Mustard area in the region has increased from 1511 ha (2021–22) to 5252 ha (2024–25), but productivity remains low compared to the national average, mainly due to late sowing, unused crop production technologies and use of local varieties. The project hence, was proposed to raise awareness among the farmers through varietal replacement along with use of critical inputs, frontline demonstrations, and training to boost yield and farmer income. The Project was conducted by the AICRP on mustard, College of Agriculture, Nagpur, at Farmers farm during the Rabi season of 2021-22, 2022-23, 2023-24 and 2024-25. The farmers of one or two villages of each block were selected. The project was run in four districts (Bhandara, Gondia, Chandrapur and Gadchiroli) from Eastern Vidarbha. For the experiment, the mustard cultivar TAM-108-1and PDKV Kartik, which are suited for timely sown and late sown conditions respectively, was used along with

critical inputs. A list of appropriate places at the respective villages was prepared before the On Farm Trail (OFT) by holding group meetings and site visits. An area of 0.40 ha was determined for each farmer from block. Both the local check and the technology that was exhibited were conducted according to custom. The output data were gathered from the demonstrated and control plots and then the extension gap, technology gap, and technology index were calculated, along with the benefit-cost ratio. Based on four years of data, the average yield from FLD plots was 725 kg/ha, significantly higher than the control plots (407 kg/ha), showing an additional yield of 318 kg/ha and a 79.56% increase in productivity. The technology index was 39.61%, and the technology gap was 475 kg/ha. The extension gap ranged from 163 to 463 kg/ha. These results highlight the impact of FLDs in enhancing mustard productivity in Eastern Vidarbha. The study also focused on farmer education and promoting the adoption of improved technologies to bridge the extension gap.

Keywords: *FLD, rapeseed-mustard, rice fallow area, yield gap analysis*

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Transforming mustard cultivation through frontline demonstrations in Haryana

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Indian mustard (*Brassica juncea* L.) is a major oilseed crop in India, contributing significantly to edible oil production, farm income and rural livelihoods, particularly in northern states like Haryana. Despite its importance, productivity remains constrained due to low adoption of high-yielding varieties, disease incidence and limited awareness of improved agronomic practices. To address these challenges, CCS Haryana Agricultural University, Hisar has developed several high-yielding and climate-resilient mustard varieties. FLDs serve as a vital tool for bridging the gap between research and farmers by demonstrating improved technologies under real field conditions. During the *rabi* season of 2024-25, a total of 100 FLDs on mustard were conducted by CCS HAU, Hisar across 44 villages in major mustard-growing districts of Haryana, including Hisar, Bhiwani, Mahendergarh, Jind, Charkhi Dadri, Fatehabad, Sirsa, Jhajjar, Karnal, and Ambala. The demonstrations were implemented under the All India Coordinated Research Project on Rapeseed-Mustard (AICRP-RM) in collaboration with ICAR-IIRMR, Bharatpur. Improved varieties were grown under timely-sown conditions following a full package of recommended practices, including integrated stem rot management. Farmers' practices (FPs) were maintained as control plots. Yield, economic parameters and benefit-cost ratios were recorded and compared between FLDs and FPs. The FLDs resulted in a substantial yield improvement ranging from 10.2% to 32.2% over FPs. The highest yield (3450 kg ha^{-1}) was recorded with variety RH-1975 in Hisar district, demonstrating its superior adaptability and productivity under irrigated conditions. Economic analysis revealed significantly higher gross and net returns under FLDs, with additional net monetary returns. The benefit-cost ratio improved markedly under FLDs (3.74-4.76) compared to FPs (3.16-3.99). RH-1975 emerged as the most widely adopted and remunerative variety, accounting for 76% of demonstrations. Yield variability across districts highlighted the importance of site-specific varietal selection and input management. FLDs significantly enhanced mustard productivity and profitability in Haryana by promoting the adoption of high-yielding varieties and scientific management practices. Variety RH-1975 proved most promising in terms of yield stability and economic returns. Wider dissemination of such technologies can support sustainable intensification of mustard cultivation and improve farmers' livelihoods.

Keywords: *FLD, rapeseed-mustard, rice fallow area, yield gap analysis*

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Performance of different improved varieties of rapeseed–mustard under front line demonstration in rice–fallow areas of Assam

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Rapeseed–mustard is a major oilseed crop of Assam and plays an important role in enhancing oilseed production and cropping system sustainability in the region; however, its productivity is often constrained by varietal choice and moisture availability. The present study evaluated the four-year (2020–21 to 2023–24) overall performance of improved rapeseed–mustard varieties under irrigated and rainfed conditions across fifteen districts of Assam through Crop Demonstrations. A total of 2579 crop demonstrations under irrigated situations and 12,326 FLDs under rainfed situations were conducted using the varieties DRMR-150-35, PM-28, NRCHB-101 and TS-38. Among the tested entries, DRMR-150-35, PM-28 and NRCHB-101 belong to Indian mustard (*Brassica juncea* L.), whereas TS-38 represents Toria (*Brassica rapa* var. toria). Under irrigated conditions, the improved varieties recorded significantly higher seed yields under improved practices (IP) compared to farmers' practices (FP). Seed yields under IP ranged from 1159 to 1381 kg ha^{-1}, whereas yields under FP varied from 751 to 864 kg ha^{-1}. Under irrigated situations, the highest average seed yield of 1381 kg ha^{-1} was recorded for DRMR-150-35, evaluated through 516 crop demonstrations, followed by NRCHB-101, which produced 1364 kg ha^{-1} across 681 crop demonstrations. An average yield of 1356 kg ha^{-1} was recorded for PM-28 across 775 crop demonstrations, while TS-38 registered 1159 kg ha^{-1} across 607 crop demonstrations. The corresponding yield increase over FP was 60.02, 57.87, 57.12 and 54.32 per cent, respectively, clearly demonstrating the superiority of improved varieties under assured moisture conditions. Under rainfed situations, considerable variation in varietal performance was observed. The highest average seed yield of 1111 kg ha^{-1} was recorded for PM-28, evaluated through 3431 crop demonstrations, followed by DRMR 150-35, which produced 1044 kg ha^{-1} across 2289 crop demonstrations. An average yield of 1003 kg ha^{-1} was recorded for NRCHB-101 across 2293 crop demonstrations, while an average seed yield of 975 kg ha^{-1} was recorded for TS-38 across 4313 crop demonstrations. The yield advantage over FP under rainfed conditions ranged from 50.0 to 61.36 per cent, indicating the effectiveness of improved varieties even under moisture-stress environments. Overall, the study conclusively demonstrates that adoption of improved rapeseed–mustard varieties through crop demonstrations significantly enhances productivity under both irrigated and rainfed agro-ecological conditions of Assam. DRMR-150-35 and PM-28 performed consistently well across moisture regimes, while NRCHB-101 exhibited distinct superiority under rainfed conditions. The findings underscore the importance of varietal interventions through crop demonstrations as an effective strategy for improving oilseed productivity and promoting sustainable utilization of rice–fallow lands in Assam.

Keywords: *Front line demonstration, improved varieties, Indian mustard, toria, yield enhancement*

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Impact of different improved varieties under front line demonstration

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The Front Line Demonstration (FLDs) programme plays a crucial role in assessing the field-level performance of improved crop varieties and accelerating their adoption among farmers. The present study evaluates the impact of different improved Indian mustard (Brassica juncea) varieties demonstrated

under FLDs across diverse agro-climatic regions of India during three consecutive rabi seasons from 2022–23 to 2024–25. The demonstrations were conducted under irrigated conditions in one-acre plots across several states, including Uttar Pradesh, Rajasthan, Jammu & Kashmir, Bihar, Punjab, Madhya Pradesh and Haryana, with a comparison against farmers' prevailing practices (FP). Four improved mustard varieties, namely DRMR 1165-40, Giriraj, Radhika and Brijraj, were evaluated for their yield performance and productivity enhancement. Among these, DRMR 1165-40 was the most widely demonstrated variety (3963 FLDs), followed by Giriraj (1497 FLDs), Radhika (494 FLDs) and Brijraj (487 FLDs). The impact of improved varieties was assessed in terms of average seed yield and percent yield improvement over farmers' practices using standard evaluation procedures. The FLDs on DRMR 1165-40 and Giriraj were conducted under timely sown, irrigated conditions, whereas FLDs on Brijraj and Radhika were carried out under late-sown, irrigated conditions. The results revealed that all improved varieties significantly outperformed farmers' practices. Under timely sown conditions, DRMR 1165-40 recorded the highest mean seed yield (2,184 kg ha^{-1}), resulting in a 19.27% yield improvement over FP, followed by Giriraj, which achieved an average seed yield of 2,067 kg ha^{-1} with a 20.03% yield advantage. While Brijraj recorded the highest mean seed yield (1,788 kg ha^{-1}) with a 47.89% increase over farmers' practice, followed by Radhika, which recorded a mean seed yield of 1,520 kg ha^{-1} with a 23.27% yield improvement over farmers' practice, under late-sown irrigated conditions. The consistent yield advantages observed across locations and years highlight the superiority of improved mustard varieties under irrigated conditions. The FLDs programme effectively demonstrated the production potential of these varieties at farmers' fields and bridged the gap between research and practical adoption. The findings underscore the importance of promoting high-yielding mustard varieties such as DRMR 1165-40, Giriraj, Radhika and Brijraj through FLDs to enhance productivity, profitability and sustainability of rapeseed-mustard cultivation in India. Overall, the study confirms that Front Line Demonstrations are an effective extension tool for technology dissemination and varietal replacement, contributing significantly to increased oilseed production and farmers' income across diverse agro-climatic regions.

Keywords: *Front line demonstration, Indian mustard, improved varieties, seed yield, yield enhancement*

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In-situ imaging of Orobanche development for assessing growth and infestation intensity in Indian mustard

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Most of the mustard dominated areas are suffering from severe infestation by Orobanche, a parasite weed. Identify the infestation period and vulnerability of infestation in different soil is very important. In-situ observations were recorded at different locations from mustard growing areas to identify the Orobanche root development and intensity which resulted into yield loss. For this, root imager was calibrated and used to identify the root development and biomass. Long cylindrical glass tube (1 meter) was inserted in field at different locations just after the sowing of the mustard crop. Data collected by inserting the root scanner into the hollow glass tube; and high optical scanning/ X-ray computed tomography (CT) image is captured and processed by specialized software to analyze it for morphological and architectural traits. Experimental results showed that Orobanche root attachment was mostly found in upper layer (up to 20 cm) in most of the soils. It indicated that the germination of Orobanche seeds started with the primary roots of mustard and growing with the crop growing periods. The root behavior also analyzed and indicated that Orobanche root behavior pattern changed with time; and biomass also increased with the increasing biomass of the mustard root. Number of Orobanche and its biomass was more in sandy soils as compared to heavy soils. Reported results also indicated that number of Orobanche more in Jhunjhunu area as

compared to Bharatpur. This study is very much useful for in-situ identification of Orobanche germination and to study the root development phases and predict the yield loss.

Keywords: *Mustard, Orobanche, root imager*

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Farm level impact of cluster frontline demonstration program in sub tropic of Jammu region

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CFLD programme was started in 2015-16 with the objective to demonstrate newly released crop production and protection technologies and its management practices in the farmers' field under different agro-climatic regions and farming situations. CFLD provides a direct interface between scientists and farmers where farmers are guided by the Krishi Vigyan Kendra (KVK) scientists during demonstrations in implementation of the improved technologies like seed treatment, integrated pest management (IPM), integrated nutrient management (INM), land preparation. The demonstration fields are regularly monitored by the scientists. The CFLD program was also implemented in Jammu and Kashmir in 2016. The present study was undertaken to assess the impact of cluster front line demonstration program (CFLD) in sub tropics of Jammu region of Union Territory of Jammu and Kashmir. Three districts namely Jammu, Samba and Rajouri were selected as maximum no. of demonstrations on oilseed crops under CFLD program were conducted in these districts. Forty farmers each were selected randomly from each districts making a sample size of 120. The results of the study revealed that there was approximately 20 percent increase under oilseed cultivation over time. The total area under oilseed crops was 11.10 hectare (ha) before CFLD program that increased to 13.30 ha after the intervention. The average area under oilseed crop was 0.09 ha before intervention that increased to 0.1 ha over time. Thus, the average area under oilseed crops increased by 22.2 percent. The increase in total area and average area under oilseed crops in the study area clearly indicated that CFLD program was able to convinced the farmer to cultivate oilseed crops on their fields. Thus, it is recommended that CFLD program should be extended in other area for popularization of oilseed cultivation.

Keywords: *CFLD, impact, oilseed*

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Effectiveness of social and digital media for efficient dissemination of soybean production technology

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The digital and social media created opportunities for increasing the effectiveness of the technology dissemination and has become increasingly popular among the farming community. The ICAR-National Soybean Research Institute is using six social media platforms for dissemination of technologies and technical know-how on soybean viz. (i) Soya-Expert-Farmer Group on WhatsApp, (ii) Soya-Expert-Farmer Group Telegram (iii) ICAR-NSRI Facebook page (iv) ICAR-NSRI YouTube channel (v) ICAR-NSRI Twitter handle, and (vi) ICAR-NSRI Instagram channel. The institute also has also developed android based mobile app "Soybean Gyan" which recently was upgraded with advanced AI mechanisms facilitating multilingual features for the farmers growing soybean crop across the country. The institute is publishing "Extension Bulletin" a small booklet containing latest and up-to-date information on agronomic package as well as ways and means of protecting the soybean crop from biotic as well as abiotic factors to avoid yield losses. In order to have uniform flow of information through all the social media, the technology and know-how information available in "Extension Bulletin" is taken for composing the content (text/graphic/video/audio) for all the social media used by ICAR-NSRI. To ensure the estimation of active users/subscribers/followers of institute's social media, the institute is engaged in production of short videos covering different issues useful for soybean stakeholders especially soybean farmers and is uploaded on single platform i.e. Institute YouTube Channel. After the video is uploaded on the YouTube channel, the link of the same is immediately shared on Facebook page, WhatsApp, Telegram, Twitter handle, and Instagram (in the form of reels). Nowadays, the institute has also started making short videos/reels for YouTube, Instagram and Facebook and are quite popular among the farmers. The videos uploaded on the YouTube channel are categorized into different categories (playlists) which are unique in nature. The innovative programmes like ICAR-*Madhya Bharat Samachar*, Weekly Soya Advisory, *Soya Samwad* are first of its kind and are appreciated by all the soybean stakeholders. The institute's YouTube channel hosts more than 1000 videos and are viewed by more than 9 millions viewers so far. The data available on YouTube Studio indicated choice of viewers watching videos on different insect-pest (23%) followed by new and improved soybean varieties (17%), interactive session with progressive soybean growers (14%), agronomic practices (6%). It is heartening to see that the social and digital media has been widely accepted by the soybean stakeholders. The subscribers of the institute's YouTube channel have increased to 44K within only 5 years of its launch and ranks third among ICAR institutes having their YouTube channel. Similarly, other social media like Facebook (25.8K followers) and Instagram (10.6K followers) are also gaining popularity and are contributing for efficient dissemination of soybean production technology in addition to other digital tools like Mobile App and weather based weekly soybean advisories.

Keywords: *Digital media, soya samwad, soya-expert-farmer*

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Soybean Gyan: An AI-powered mobile application for enhanced soybean cultivation

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Soybean is a vital oilseed and protein-rich crop that plays a key role in ensuring food security, nutritional balance, and farm income. Despite its importance, soybean productivity is often constrained by pest and disease incidences, weather uncertainties, limited access to real-time advisories, and inadequate dissemination of research-based cultivation practices. Advances in Artificial Intelligence (AI) and mobile computing offer significant opportunities to address these challenges by delivering intelligent, timely, and farmer-centric digital solutions. Soybean Gyan – an AI-powered mobile application developed by ICAR–National Soybean Research Institute (ICAR-NSRI) – is designed as a comprehensive digital platform to support soybean farmers with advanced, user-friendly, and multilingual advisory services. The application is developed using the Flutter framework and Dart programming language, with compilation performed on Android Studio, ensuring a robust, scalable, and accessible Android-based solution. The app provides a user-friendly interface delivering comprehensive information on soybean production, protection technologies, and instant advisories on recommended cultivation practices. To ensure wider outreach and inclusivity, Soybean Gyan offers multilingual support, enabling farmers from diverse regions to access information in their preferred languages. A major innovation of the platform is its AI-based pest and disease diagnosis system, which enables instant crop health decisions using field images, complemented by weather-based alerts that support timely and preventive crop management decisions. An AI-powered chatbot, provides instant, personalized responses to farmers' queries enhancing accessibility to expert knowledge. The application further includes dedicated modules on Good Agricultural Practices (GAPs), weekly advisories, farmer advisory systems, and real-time market and mandi price information, empowering farmers to make informed agronomic as well as marketing decisions. For experiential and visual learning, the app provides direct navigation to the official YouTube channel of ICAR–National Soybean Research Institute, offering practical video-based demonstrations of soybean cultivation technologies. The application is easily downloadable from the Google Play Store, making it readily accessible to soybean cultivators and other stakeholders. Soybean Gyan serves as a comprehensive digital extension and decision-support platform that bridges knowledge gaps between research institutions and the farming community. By integrating AI-driven intelligence, institutional expertise, and multilingual outreach, the application promotes scientific, sustainable, and profitable soybean cultivation and demonstrates the transformative potential of digital technologies in modern agriculture.

Keywords:*Artificial intelligence, soybean gyan, mobile apps*

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Realizing the potential of Agri-Business Incubation in soybean value addition, byproduct utilization, and allied sectors for startup & entrepreneur development

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The Agri-Business Incubation (ABI) Centre at ICAR–National Soybean Research Institute, Indore, established in 2021 under the National Agricultural Innovation Fund (NAIF), serves as a key platform for promoting innovation-led entrepreneurship and accelerating the commercialization of ICAR technologies in soybean and allied sectors. The centre supports agri-startups, incubatees, Farmer Producer Organizations

(FPOs), and rural youth through structured incubation, business development services, and entrepreneurship skill enhancement. The centre focuses on priority areas including soyfood processing and value addition, soybean by-product utilization, biofertilizer production, soil chemical and nutrient testing services for agri-clinics, and quality seed production. It enables the conversion of innovative ideas into commercially viable enterprises by providing access to common processing facilities, technical backstopping, business mentoring, and market and financial linkages. The centre also acts as an effective interface among ICAR research institutions, startups, industries, FPOs, and financial institutions to facilitate rapid technology transfer and scaling. Under this project, key infrastructure and capacity-building milestones were achieved, including establishment of soyfood and biofertilizer production units and a dedicated skill development and training center. Over the last five years, the ABI Center trained 1691 progressive farmers from 302 Farmers Producers Organization (FPOs), strengthening their technical, entrepreneurial, and market-oriented capabilities. In addition, 64 aspiring entrepreneurs received structured entrepreneurship training, and 24 incubatees were formally incubated across soybean value addition, certified seed production, soil chemical analysis, and biofertilizer manufacturing sectors. Several incubatees have successfully established enterprises, generating sustainable income and local employment. Overall, the ABI Centre at ICAR-NSRI has emerged as a pivotal driver of soybean-based agri-startup development by promoting value addition, waste-to-wealth through by-product utilization, and circular economy approaches. Strengthening ABI-led interventions can significantly enhance farmer income, rural livelihoods, and sustainable agri-enterprise growth.

Keywords: ***A****gri-startups, biofertilizer production, by-product utilization, entrepreneurship development, FPO,s NAIF, seed production, soybean value addition, soyfood processing*

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Demonstration of early and medium duration soybean cultivars under the soybean-wheat cropping system in Madhya Pradesh

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Soybean (*Glycine max* (L.) Merrill) is the premier oilseed crop of India and the world as well. It is a protein-rich food (42%) crop beside other nutraceutical properties, having great potential in alleviating malnutrition of Indian population. The crop is also having national importance as it contributes significantly to the vegetable oil economy of the country. Madhya Pradesh has been a leading soy producer of the country since the crop was re-introduced during seventies and therefore enjoy the coveted position of "Soy State" as it contributes more than 55% in total area as well as total soybean produced in the country. The crop is predominantly grown during *Kharif* season by the millions of small and marginal farmers of Madhya Pradesh especially Malwa which has witnessed socio-economic transformation occupying vast *kharif* fallow land. The irrigation facilities resulted intensification of the cropping pattern. Soybean-wheat cropping systems is most common in the area. However, the average soybean productivity of the state is stagnated to nearly 900-1100 kg/ha since last few years. The reason being preference of the soybean growers towards early maturing soybean varieties facilitating cultivation of 2-3 crops in succession. The other reason is early maturing soybean variety JS 95-60 predominantly grown by the farmer which is of late not able to withstand the load of insect-pests and diseases as it is around 19 years old and need to be replaced. Considering this background, the work on "Demonstration of Early and Medium Duration Soybean Cultivars under the Soybean-Wheat Cropping System in Madhya Pradesh" has been initiated in the soy state of Madhya Pradesh during 2024-25 by laying out a total of 180 demonstrations during *Kharif* 2024 across 18 districts to demonstrate the yield performance of short and medium duration soybean varieties. A total of four soybean varieties namely NRC 130 and NRC 131 (short duration) as well as NRC 142 and JS 20-69 (medium duration) were evaluated under the improved technology. The

overall average yield of 12.7 q/ha across the district was realized under Improved Technology. The overall average yield of 12.7 q/ha across the district was realized under Improved Technology. Out of 18 districts, 10 districts have reported additional yield ranging from 2-6 quintal/ha by growing of medium duration soybean varieties. A set of 90 demonstrations involving early soybean varieties (NRC 130 and NRC 131) have recorded an average yield of 10.63 q/ha whereas the medium duration soybean variety NRC 142 which was demonstrated under 90 plots have yielded around 14.56 q/ha. The average grain yield under improved technology (IT) was 1,271 kg/ha, while under traditional farmers' practice (FP), it was 1,056 kg/ha, reflecting a mean yield increase of 28.9%. The average yield gap (difference between IT and FP yields) was 216 kg/ha. The highest yield under IT was observed in Sehore (1,840 kg/ha), while the lowest yield under IT was recorded in Khandwa (830 kg/ha).

Keywords: *Cropping pattern, Madhya Pradesh, soybean, soybean-wheat cropping system, yield*

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Yield gap of frontline demonstrations (FLDs) on soybean conducted under the National Mission on Edible Oils - Oilseed (NMEO-OS)

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Soybean (*Glycine max* (L.) Merrill) is the premier oilseed crop of India and the world. It is a protein-rich food crop (40%) and also contains 20% oil, along with other nutraceutical properties, making it highly valuable in alleviating malnutrition among the Indian population. The crop also holds national importance as it contributes significantly to the country's vegetable oil economy. Frontline Demonstrations (FLDs) on soybean were conducted across India during the *Kharif* seasons of 2023, 2024, and 2025 by ICAR-National Soybean Research Institute, Indore, to evaluate the performance of improved varieties and agronomic practices. During *Kharif* 2025, a total of 308.36 quintals of soybean seed were distributed, and three farmer training programs were successfully conducted. FLD registration and geo-plotting through the Krishi Mapper app recorded 942 and 736 entries, respectively, out of the allocated 1180. The number of FLDs conducted and the area covered showed a consistent increase over the three years: 869 FLDs covering 346.9 ha in 2023-24, 1040 FLDs covering 416 ha in 2024-25, and 1170 FLDs covering 454 ha in 2025-26. The mean grain yield of soybean under improved technologies (IT) was consistently higher than that under farmers' practice (FP). During 2023–24, IT recorded an average yield of 1867/ kg/ ha, surpassing FP at 1519/ kg/ha. In 2024–25, IT maintained a higher mean yield of 1886/ kg/ha compared to FP (1510/ kg/ha). However, in 2025–26, both treatments experienced a decline, with IT yielding 1785/ kg/ha and FP 1408/ kg/ha, indicating a downward trend in productivity. The corresponding yield gaps between IT and FP were 348/ kg/ha (2023–24), 376/ kg/ha (2024–25), and 377/ kg/ha (2025–26). District-level analysis indicated significant variation in yield gaps: Raipur (IGKVV) recorded the maximum gap of 779 kg/ha in 2023-24, whereas Bengaluru (UAS) showed the minimum gap of 141 kg/ha. In 2024-25, CoA Sehore reported a maximum gap of 835 kg/ha and PAU, Ludhiana a minimum of 132 kg/ha, while in 2025-26, SKUAST Kashmir had a maximum gap of 615 kg/ha and PAU, Ludhiana the minimum of 118 kg/ha. The FLDs were conducted in 38, 53, and 49 districts over the three respective years. The study demonstrates that frontline demonstrations effectively enhance soybean productivity, reduce yield gaps, and promote adoption of improved agronomic practices across diverse agro-climatic regions of India.

Keywords: *Frontline demonstrations, farmer practices, improved technology, soybean, yield gap, yield*

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Assessing women's participation, empowerment and decision-making in groundnut farming: Gender analysis from Saurashtra region of Gujarat

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Groundnut is a highly labour-intensive crop, particularly during operations such as manual weeding, harvesting, pod stripping, and post-harvest processing, where women constitute the primary workforce. However, their contribution often remains confined to manual operations with limited influence over productive and economic decisions. Assessing whether women's participation translates into empowerment is essential for designing gender-responsive extension and technology transfer strategies. The present study examines women's participation, empowerment, decision making power, and constraints in groundnut farming using index-based analytical frameworks. The study was conducted by the ICAR–Indian Institute of Groundnut Research (ICAR-IIGR) in the Saurashtra region of Gujarat, primarily covering women groundnut farmers from Jamnagar district. A total of 100 women engaged in groundnut cultivation were selected for the study. Women's participation was measured using a Women Participation Index (WPI) based on 23 groundnut production, post-harvest, and marketing activities, with weighted scores assigned for independent and joint participation. Women's empowerment was assessed using the Women's Empowerment in Groundnut Index (WEGI), which was constructed across five domains: production empowerment, resource empowerment, income empowerment, leadership and group participation, and mobility and social norms. Decision-making patterns were analysed descriptively across major farm and income-related decisions. Constraints faced by women were prioritized using a Constraint Severity Index (CSI). Descriptive statistics, ranking techniques, and domain-wise analysis were employed. Activity-wise WPI analysis revealed that women's participation was concentrated in labor-intensive operations such as manual weeding (62.0%) and pod plucking (57.5%). In contrast, women's involvement was minimal in strategic and market-oriented activities, including marketing and sale of produce (5.5%) and decisions regarding time of sale (4.5%). At the individual level, 59 percent of women exhibited medium participation, while only 17 percent belonged to the high participation category. The mean WEGI score indicated moderate empowerment, with 74 per cent of respondents falling in the medium empowerment category. Domain-wise analysis showed that resource empowerment (0.56) and leadership and group participation (0.54) ranked relatively higher, whereas income empowerment emerged as the weakest domain (0.43). Decision-making analysis indicated that key decisions related to variety selection, input use, plant protection, and marketing were predominantly taken by men (66–85%), with women's independent decision-making remaining limited. Constraint analysis identified labour shortage (CSI = 2.85) and pest and disease incidence (CSI = 2.84) as the most severe constraints faced by women. The findings demonstrate a clear disconnect between women's labour participation and their empowerment in groundnut farming. Although women contribute substantially to production and post-harvest activities, their limited role in decision-making and income control restricts the translation of participation into meaningful empowerment. This imbalance contributes to persistent drudgery without commensurate gains in empowerment. The study emphasizes the need for knowledge-centric, gender-responsive extension strategies that go beyond labour engagement to strengthen women's decision-making ability, income control, and market participation in groundnut farming. IIGR is working on integrating empowerment indicators into technology transfer programmes and allied extension systems for promoting inclusive and sustainable development in major groundnut-growing regions.

Keywords: *Decision-making, empowerment, groundnut farming, gender analysis, Gujarat, Saurashtra region, women's participation*

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Model value chain development in oilseeds focusing on SC communities

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Scheduled Castes (SCs) in India are socio-economically disadvantaged sections due to historical practices of untouchability, lack of infrastructure, and social exclusion. Despite the high priority given to their socio-economic development, SCs face significant challenges. Most of the SC farmers fall into the small and marginal category of land holding with limited access to land, inputs, information, credit, and markets, leading to lower farm income. To provide small and marginal oilseed farmers with access to affordable, mechanized oil extraction services, promoting local value addition, availability of quality oil locally and enhancing the income and livelihood security of farming communities, Oilseeds Value Addition Units (OVAUs) were established at various locations in major oilseeds growing areas under the Scheduled Caste Sub Plan implemented by ICAR-IIOR during 2019-20 to 2024-25. Major oilseed growing areas were identified in Andhra Pradesh, Chhattisgarh, Gujarat, Karnataka, Maharashtra, Telangana and West Bengal and suitable locations were selected in collaboration with the AICRP centres and farmers groups for establishment of OVAUs. The objective was to promote SC entrepreneurs, who can add value to oilseeds and encourage farmers for cultivation of oilseeds. A total of 12 OVAUs were established at various locations. The OVAUs consisted of oil expellers, cleaning unit and filtration units. The idea was to facilitate farmers utilizing the OVAUs for oil extraction and sell at remunerative prices, capturing more of the value chain and increase their income. The services of OVAUs were provided to farmers at nominal charge of Rs.15.00/kg on custom hiring basis. The output was marketed as premium cold pressed and pure oil, which commands premium price compared to other oils. The oil has good demand and a niche market. On an average farmers obtained 60% higher net returns on marketing oil instead of oilseeds. The services are being availed by an average 4000 oilseed producers annually from each unit at a reasonable price. It enabled them to get higher price for their produce and enhanced the availability of quality oil. This was proved to be successful and motivating factor especially in oilseed growing areas in the respective states. Value addition enhanced the income of the farmers as evident from the data on safflower, where oil fetched Gross Monetary Returns (GMR) of Rs. 42,000/ac as compared to seeds (Rs.20,300/ac). In sesame, the GMR obtained by sale of oil was Rs. 56,000/ac whereas seed fetched Rs.20,300/ac and in groundnut, GMR obtained due to sale of oil was Rs.1,06,400/ac as compared to Rs. 49,000/ac with seed. This clearly showed that value addition through oil extraction helps farmers to get higher returns as compared to direct selling of seeds.

***Keywords**: Model value chain, Net returns, Oilseeds, SC communities*

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Bridging the yield gaps in sesame through front line demonstrations under farmers' field conditions

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Sesame (*Sesamum indicum* L.) is an important oilseed crop valued for its high-quality oil, nutritional significance, and adaptability to diverse agro-ecological conditions. However, its productivity in India remains low as compared to its yield potential. The existing yield gap (>50%) is largely attributed to poor adoption of recommended crop management practices by farmers. Improving productivity therefore

necessitates the promotion of scientific crop management and location-specific production technologies. In this context, Front Line Demonstrations (FLDs) play a crucial role in validating and disseminating improved practices at the farmers' level and help in bridging the yield gap. Base line data was collected based on inputs from the farmers before implementation of Front Line Demonstrations in selected villages, in a participatory approach. Appropriate FLDs modules were planned and implemented at farmers' fields using improved production technologies. The performance of improved technological interventions was then evaluated through systematic recording of yield data and compared with the corresponding farmers' practice to assess the yield gap and quantify the yield advantage of various modules. A total of 3646 FLDs were laid out under different modules on sesame during 2020-21 to 2024-25 under the All India Coordinated Research Project on Sesame & Niger (AICRP-SN) across major sesame-growing states of India. Module-wise pooled analysis revealed considerable variation in yield performance. Whole package demonstrations recorded an average yield of 699.2 kg ha^{-1} over farmers' practice 519.9 kg ha^{-1}, resulting in a 36.8 percent increase in seed yield. Improved variety demonstrations recorded an average yield of 631.8 kg ha^{-1} over farmers' practice 511.7 kg ha^{-1}, resulting in a 26.16 percent increase. Weed management demonstrations recorded 624.7 kg ha^{-1} over farmers' practice 451.1 kg ha^{-1}, resulting in a 40.19 percent increase. seed treatment demonstrations recorded 615.8 kg ha^{-1} over farmers' practice 464.8 kg ha^{-1}, resulting in a 32.67 percent increase, while fertilizer and nutrient management demonstrations recorded 640.5 kg ha^{-1} over farmers' practice 486.7 kg ha^{-1}, resulting in a 35.07 percent increase. Plant protection demonstrations recorded 597.9 kg ha^{-1} over farmers' practice 465.6 kg ha^{-1}, resulting in a 32.83 percent increase, whereas method of sowing demonstrations recorded 540.4 kg ha^{-1} over farmers' practice 394.6 kg ha^{-1}, resulting in a 36.68 percent increase in seed yield. Based on the five-year results it can be concluded that integrated interventions, particularly whole package demonstrations, resulted in more stable and higher yield gains than single-component technologies. Wider adoption of complete recommended production packages, along with strengthened extension support and timely availability of quality inputs, is essential for reducing yield gaps and sustainably enhancing sesame productivity across diverse agro-ecological regions.

***Keywords**: Front line demonstrations, sesame, tield, whole package demonstration*

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Performance of sesame in Rajasthan - Agro eco region approach

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Sesame (*Sesamum indicum* L.) is an important ancient oilseed crop in India with high oil content, nutritional value, and adaptability to marginal environments. Despite India's position as one of the leading producers of oilseeds, the country remains heavily dependent on edible oil imports, emphasizing the need to enhance domestic oilseed production. Rajasthan is a major sesame growing state where the crop contributes significantly to the livelihoods of small holder agriculture. The productivity is low and highly variable across agro-ecological regions. The present study analyses the long-term performance of sesame cultivation across different agro-ecological zones of Rajasthan to identify growth patterns and changes in production. The study is based on secondary data on area, production, and productivity of sesame for the period 1997–98 to 2022–23, collected from the Directorate of Economics and Statistics, Government of India. Compound Annual Growth Rates (CAGR) were estimated to assess temporal growth trends and decomposition analysis was employed to quantify the relative contribution of area effect, yield effect and their interaction to changes in sesame production. Zone-wise and district-level averages were also analysed to capture spatial variations in performance. The results reveal considerable heterogeneity in sesame growth across agro-ecological zones. The Transitional Plain of Luni Basin dominates in average area and production, though its yield remains moderate, while Irrigated North Western Plains and Flood Prone Eastern Plains witnessed the highest yields. Growth trends show strong production and area expansion in

Flood prone eastern plains, Semi-arid eastern plains, Transitional plain of luni basin and Arid Western Plains indicating improving efficiency despite constraints. In contrast, Irrigated north western plains, Internal drainage dry zone and Sub-humid southern plains exhibit deceleration in area and production. Except Sub-humid southern plains all other zones exhibit acceleration growth in yield. Decomposition analysis revealed, that in internal drainage dry zones and arid western plains, production growth was largely driven by area expansion, whereas in Sub-humid southern plains and Hyper arid partially irrigated zone yield effect is major contributor for change in production highlighting the importance of technology-led growth. In Semi-arid eastern plains and Flood prone eastern plains, the change in production was due to interaction effect. In terms of area and production, Rajasthan stands in top 4th and 5th position respectively, while overall state productivity remained substantially below the national average, indicating a significant yield gap. The study concludes that sesame production growth in Rajasthan has been uneven and remains constrained by low productivity. There exists substantial scope to enhance sesame's contribution to edible oil security through dissemination of high-yielding and locally adapted varieties, promotion of improved crop and resource management practices, expansion of summer sesame under irrigated conditions, and zone-specific research and extension strategies. Targeted interventions addressing region-specific constraints can significantly improve sesame productivity, farmer incomes, and the role of minor oilseeds in achieving Atmanirbhar Bharat in edible oils.

***Keywords**: Agro-ecological zones, growth patterns and changes, production, Rajasthan, sesame*

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Developing smart FPOs for strengthening the oilseeds value chain

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FPOs are membership-based organisations with an objective to develop and deploy the aggregation mechanism of farmers with common interest agree to pool their resources together to form a group, jointly deal with various issues of farming; be it credit, input sourcing, deployment of farm technology and good agricultural practices, post-harvest handling or onward sale of agricultural produce. The collectivisation of producers, especially small and marginal farmers, into producer organisations has globally emerged as one of the most effective pathways to address various challenges in agriculture. A bench mark survey was conducted in two mandals of Chinnakodur and Narayanraopet, Siddipet, Telangana. The mandals comprised of 35 villages. The resource inventory of the villages on major crops, varieties grown, input utilization, output marketing, potential for crop diversification, value addition and business opportunities were documented. For mobilizing the membership in the FPOs, personal contacts, small group meetings, focussed group discussions and local leaders were used. The baseline data were collected from each member by personal interview method through a semi-structured interview schedule. The business plan was developed in consultation with the expertise available in the ICAR and other institutes. ICAR-IIOR has facilitated in getting the required licenses (seed, pesticide and fertilizer) for doing business by the FPO and in procuring the equity grant. Capacity building programmes for office bearers and members were organized by ICAR-IIOR in collaboration with various agencies. The business plan for the FPO included, input aggregation, output marketing, foundation seed production of groundnut varieties (Girnar 5, Kadiri Lepakshi), hybrid seed production of sunflower (Tilhan Tech SUNH-1) certified seed production of paddy and crop diversification during rabi season with sunflower, bee keeping in sunflower, capacity building of board of directors and members and custom hiring of machinery. The economics of these activities indicated that the FPO has earned a profit of more than rupees nine lakhs during the first year itself, which clearly indicated the potential benefits of collectivization of farmers. The FPOs have successfully adopted "Wonder software" to streamline its core financial and operational activities. This user-friendly accounting and inventory management tool enables efficient handling of transactions, reporting, and compliance requirements, enhancing overall productivity and accuracy. The software has the purchases

and sales management, supplier data management, customer credit and sales tracking, GST compliance and reporting modules. By leveraging Wonder software, the FPOs have achieved greater operational efficiency, reduced manual errors, and improved financial transparency. This digital transition supported the mandate under government-led agricultural initiatives, enabling scalable growth for the farmer members. The FPOs are implementing the custom hiring centres (CHCs) under the CSR funding of the ICICI Foundation for Inclusive Growth. A kiosk and app based farm machinery booking was developed in collaboration with "Crop Sync" a startup. The application ensures equity, transparency and timeliness in the delivery of CHC services. The FPOs are moving ahead with the pragmatic deployment of the digital applications towards smart FPOs.

***Keywords**: Farmer producer organization, oilseed, sunflower*

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Reaching farmers digitally: Innovations in oilseeds information sharing

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Timely access to reliable agricultural information is critical for enhancing oilseeds productivity and improving farmers' livelihoods, particularly under changing climatic and market conditions. Rapid advancements in digital technologies have created new opportunities for effective dissemination of oilseeds-related knowledge directly to farmers. Study highlights recent innovations in digital information sharing systems aimed at strengthening outreach, adoption of improved practices, and decision-making among oilseeds growers. Various Information and Communication Technology (ICT) tools, including mobile-based advisory services, social media platforms, interactive voice response systems, web portals, mobile applications, and decision support systems, are increasingly being utilized to deliver location-specific, real-time advisories on crop management, pest and disease surveillance, weather forecasts, and market intelligence. Digital platforms also enable two-way communication, facilitating feedback from farmers and strengthening research–extension–farmer linkages. The integration of digital tools with traditional extension approaches has shown significant potential in improving awareness, adoption of improved oilseeds varieties and production technologies, reducing information gaps, and enhancing resilience to climatic risks. The institutional support, capacity building, and digital literacy play important role in maximizing the impact of these innovations. Strengthening digital outreach mechanisms can play a pivotal role in achieving sustainable oilseeds production and contributing to national edible oil security.

***Keywords:** Digital extension, information sharing, digital literacy*

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Exploring entrepreneurial behaviour among rapeseed–mustard farmers: empirical insights from Assam

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Entrepreneurship in agriculture plays a crucial role in improving farm productivity, income, and overall rural development, particularly in oilseed-based farming systems. Rapeseed-Mustard is one of the major oilseed crops cultivated by small and marginal farmers in India, where entrepreneurial behaviour significantly influences production efficiency and market participation. The study was conducted in Sivasagar district of Assam using an ex post facto research design with a sample size of 120 farmers. A multistage sampling

procedure was followed to select the respondents, and primary data were collected through a pre-tested structured interview schedule. Entrepreneurial behaviour was measured by developing a scale comprising dimensions such as innovativeness, risk orientation, achievement motivation, decision-making ability, market orientation, information-seeking behaviour, leadership ability and self confidence. The results of the study revealed that the majority (52.34 %) of the farmers had a medium level of entrepreneurial behavior. The study underscores the importance of strengthening extension services, improving access to institutional credit, and promoting market-oriented advisory support to enhance entrepreneurial behaviour among rapeseed-mustard farmers. Policy interventions aimed at capacity building and fostering an enabling environment for agripreneurship can contribute significantly to sustainable agricultural development and livelihood improvement in oilseed farming regions.

Keywords: *Entrepreneurial behaviour, Rapeseed-mustard farmers*

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Productivity and yield gap of toria (var. TS-38)- A cluster-based analysis in Tinsukia district of Assam

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Assam is one of the major rapeseed–mustard producing states in India, where the crop accounts for over 92% of the total oilseed area (2.85 lakh ha) and production (1.83 lakh tonnes). The state contributes 4.82% of the national area and 2.46% of total rapeseed–mustard production. Despite its wide cultivation, productivity in Assam (660 kg ha{ ¹) is substantially lower than the national average (1443 kg ha{ ¹), indicating significant scope for yield enhancement through improved technologies and management practices. Cluster Frontline Demonstrations (CFLDs) were conducted during 2023–24 in five clusters, namely Ledo, Sadiya, Kundil, Kakopathar, and Khamanpathar, in Tinsukia district of Assam, covering a total area of 240 bigha. The demonstrations aimed to evaluate the performance of the improved rapeseed variety TS-38 along with recommended production technologies in comparison with prevailing farmers' practices. Data on yield and yield-attributing parameters were collected from both the demonstration plots and farmers' practice. The technology gap, extension gap, and technology index were subsequently computed using standard procedures. The average yield under demonstration plots was 10.56 q ha{ ¹, which consistently outperformed farmers' practices across all clusters. Yield advantages ranged from 18.01% in Kundil cluster to 37.61% in Khamanpathar cluster. The potential yield was assumed as 12.00 q ha{ ¹. Demonstration yields ranged from 9.37 to 11.05 q ha{ ¹, while farmers' practice yields varied between 7.85 and 8.26 q ha{ ¹, resulting in an average yield advantage of 29.42% under improved practices. The technology gap ranged from 0.95 to 2.63 q ha{ ¹, whereas the extension gap varied from 1.43 to 3.02 q ha{ ¹, indicating substantial scope for yield enhancement through better dissemination and adoption of recommended practices. The technology index (7.92–21.92%) reflected varying degrees of feasibility of the demonstrated technologies under farmers' field conditions, with lower values indicating higher adaptability. Economic analysis further revealed higher benefit–cost ratios under demonstration plots (1.53–1.80) compared to farmers' practice (1.52–1.60). Overall, the CFLDs proved effective in enhancing productivity and profitability of rapeseed and mustard and highlighted the need to bridge extension gaps for realizing potential yields at the field level.

Keywords: *Rapeseed & mustard, demonstration yield, technology gap, extension gap*

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Impact of krishi vigyan kendra interventions on adoption of improved agricultural practices and farmers' livelihoods in Kotputli-Behror district, Rajasthan

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The present study examines the impact of Krishi Vigyan Kendra (KVK) interventions on agricultural development and farmers' livelihoods in Kotputli-Behror district, Rajasthan. KVKs play a pivotal role in transferring agricultural technologies, enhancing farmers' knowledge, and promoting sustainable farming practices through frontline demonstrations, training programs, and advisory services. This research evaluates the effectiveness of KVK activities in improving crop productivity, adoption of improved cultivation techniques, input use efficiency, and socio-economic conditions of farming households. Primary data were collected through structured interviews and questionnaires administered to a representative 150 sample of farmers benefitting from KVK programs, supplemented by secondary data from official KVK records and agricultural reports. The study also identifies key constraints faced by farmers in adopting KVK-recommended practices and suggests strategies to further strengthen KVK outreach and impact. Results indicate that 72% of the respondents had medium to high exposure to KVK interventions such as trainings, demonstrations, field days, and advisory services. About 68% of farmers adopted improved crop varieties, 61% adopted integrated nutrient management practices, and 57% adopted integrated pest management techniques after participation in KVK programmes. In terms of farm mechanization and water management practices, adoption levels were observed at 53% and 46% respectively.

The study further indicated a positive impact on livelihood indicators, where 64% of respondents reported an increase in agricultural income, 58% experienced improvement in crop productivity, and 46% diversified their income sources through allied activities such as dairy and horticulture. Social empowerment aspects showed that 52% of farmers enhanced their decision-making ability and 47% improved their access to institutional support and credit facilities.

The study concludes that KVK, Bansur has played a crucial role in enhancing agricultural productivity and livelihood security in Kotputli-Behror district. Strengthening market linkages, follow-up extension support, and convergence with line departments can further enhance the impact of KVK interventions.

Keywords: *Livelihood, mechanization, dairy, horticulture*

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Performance and yield gap of sesamum variety (RT-351) under KVK cluster front line demonstrations

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Sesamum (*Sesamum indicum* L.) is one of the most important traditional oilseed crops of Rajasthan, particularly suited to the arid and semi-arid agro-climatic conditions of the state. Sesamum is predominantly grown in districts such as Tonk, Jaipur, Sawai Madhopur, Bundi, Kota, Bhilwara, Nagaur, Alwar, and Banswara. The crop thrives well in light to medium-textured soils, especially sandy loam and loam soils with good drainage. Its short duration (85–100 days), low input requirement, and tolerance to moisture stress make it a suitable crop for resource-poor farmers. Front Line Demonstrations (FLDs) implemented by Krishi Vigyan Kendras (KVKs) have emerged as an effective extension strategy to showcase the

potential of improved sesame varieties coupled with recommended crop production practices under real farmer conditions. The present study evaluated the performance of improved sesamum variety (e.g., RT-351) under KVK CFLDs conducted in the Alwar district of Rajasthan (2022-23), and synthesized comparative data from multi-location demonstrations to assess yield, percentage yield improvement, technology gap, extension gap, and economic returns.

Across 25 CFLD units covering 10 ha, sesame yields in demonstration plots ranged from 3.0 to 3.8 q/ha, significantly higher than the corresponding farmers' practice yields of 2.4 to 2.7 q/ha. The percentage increase in yield over farmers' practice varied from 25.00% to 40.74%, clearly demonstrating the positive impact of improved varieties and agronomic interventions on productivity.

Economic analysis across the studied demonstrations showed that CFLD plots not only improved yield but also enhanced profitability. Net returns per hectare and benefit–cost ratios were notably higher in CFLDs than in farmers' practice, reinforcing the value of improved varieties and integrated crop management in boosting farmer income.

In conclusion, KVK-led Cluster Front Line Demonstrations on improved sesamum variety significantly enhance productivity (up to 40.74%), profitability, and technology adoption in semi-arid and rainfed production systems. Wider replication and targeted extension support are essential to bridge remaining gaps and to achieve sustainable increases in sesame production at the village level.

Keywords: *Sesamum, CFLD*

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THEME - V

MARKET AND POLICY IMPERATIVES

Enhancing productivity and sustaining area growth in Brassica spp.: Insights from recent advances in India

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By 2050, the total demand for edible oil is expected to rise by 52-76% (NIAP, 2025) and India might be continuing to import about 15-20 million tons of edible oils annually under the behavioristic approach-scenario-I (NITI AYOG, 2024). India's oilseed sector suffers not from lack of price incentives alone, but from structural constraints in productivity, technology and risk management. Rapeseed-mustard (Brassica spp.), a pivotal winter oilseed crop in India, plays an indispensable role in sustaining edible oil supply amid climatic deviations and escalating import dependence on Southeast Asia, Latin America & Russia. Per capita consumption of mustard oil increased significantly from 1.92 kg in 1993-94 to 4.12 kg in 2022-23 in comparison to other edible oils. This study aimed to investigate the current pattern of sowing and highlight the recent trends for sustaining area growth in Brassica spp. in India. With India ranking as the third-largest global producer, rapeseed-mustard contributed 12.67 million tons in 2024-25, accounting 29.47% of domestic oilseed production and underscoring its primacy in bridging the yawning demand-supply gap for vegetable oils (FAOSTAT, 2024). Advance technologies including hybrids, high-yielding & climate-resilient varieties, agronomic innovations and integrated pest management contributing to boost the domestic production with enhanced resource use efficiency. A total of 256 varieties of rapeseed-mustard has been released and notified till 2025 in India (ICAR-IIRMR, 2025). Recent policy interventions such as the National Mission on Edible Oils–Oilseeds (NMEO-OS), National Food Security Mission-Oilseeds (NFSM-OS), Minimum Support Price (MSP) and Model Mustard Farm Project and targeted mustard promotion programs focusing on quality seed availability, accessibility, affordability and even seed traceability among the farm households. Consequently, across successive decades, the crop has exhibited remarkable expansion, with area increasing from 2.07 million hectares in 1950–51 to 8.67 million hectares in 2025–26 alongside a sharp rise in productivity from 368 kg/ha in 1950-51 to 1463 kg/ha in 2024–25 with an annual compound acceleration of 1.72% & 2.08%, respectively (DES, DA&FW, GOI,2025). This growth has been driven by technological advancements as well as concerted government initiatives. As per the estimates of the area under rapeseed-mustard during Rabi 2025-26, it showed encouraging progress in tapping the potential diversification (CWWG, DA&FW, GOI, 2025-26). The analysis revealed that main sowing window (24th October to 24th November) covered 5.40 million hectares (60.45%); while 1.98 million hectares (22.14%) covered in early sowing window (before 24th October) and rest 1.56 million hectares (17.41%) covered in late sowing window (After 24th November to 2nd January 2026). Accordingly, these insights need a strategic, institutionally coordinated approach to ensure timely quality input supply through strengthened backward linkages focusing the seed chain and critical nutrients including the Sulphur. By harnessing the cutting-edge innovations, rapeseed-mustard cultivation in India is poised to achieve resilient productivity enhancement and sustained areal expansion, thereby fortifying national food and nutritional security while contributing to ecological diversification and climate adaptation in vulnerable agro-climatic zones

Keywords: *Edible oil, government, oilseeds, rapeseed-mustard, technology, yield*

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Mutations for biochemical traits in *Brassica juncea*

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Low erucic acid (Two) varieties of Indian mustard (*Brassica juncea* L.) were taken. The seeds of both the varieties were treated with different doses of gamma rays (1000 & 1500 Gy) in combination with different concentration of chemical mutagen EMS (0.25%, 0.50% & 0.75%). The shortlisted plants with the desired traits were then screened at biochemical and molecular level to assess whether the changes have happened at genetic level too along with environmental effects. Biochemical analysis includes oil stability index, total protein content, glucosinolate content, phytic acid and â-carotene content. HPLC analysis showed that p-hydroxy benzoic and sinapic acid are the most common phenolics present in almost all the varieties. Majority of the rapeseed proteins are made up of 70% of globulins, up to 15-20% of alcohol soluble prolamins, and 10% to 15% albumins. For molecular analysis, seven genes from glucosinolate pathway and six genes from phytic acid pathway were selected upon literature survey. However, the phytic acid pathway seemed to be less affected by the mutations at the genetic level and majorly influenced by the environmental effects.

Keywords: *Glucosinolate content, phytic acid, oil stability index, total protein content*

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Sustaining soybean acreage in India through break-even and iso-return analysis of competitive crop dynamics in MP and Maharashtra

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Agricultural resource allocation is fundamentally driven by farmers' rational assessment of anticipated prices, input costs and comparative yields. Despite its historical significance, soybean cultivation in India's primary growing states Madhya Pradesh (MP) and Maharashtra (MH) has recently faced a contraction in acreage as farmers shift toward more remunerative alternatives such as maize and paddy. This study evaluates the competitive dynamics between soybean and its alternatives in Madhya Pradesh (MP) and Maharashtra (MH), which collectively account for 85% of India's soybean area. Using secondary data from the 2023-24 agricultural year, we employed a break-even analysis and iso-return curve framework to assess the profitability thresholds of soybean relative to maize and paddy across Cost A2, Cost A2+FL and Cost C2. The analysis reveals a significant disparity between the Minimum Support Price (MSP) and the break-even requirements for soybean. In MP, given a maize price of 2090/qtl, the Break-Even Price (BEP) for soybean (Cost A2 basis) was calculated at 5710/qtl. This exceeds the actual 2023-24 MSP of 4600/qtl by 1110/qtl, indicating a severe competitive disadvantage. The disparity is more pronounced in MH, where the soybean BEP required to compete with maize stood at 7065/qtl, a gap of 2465/qtl relative to the MSP. Similarly, the soybean-paddy trade-off in MP necessitated a soybean price of 6719/qtl to maintain parity, reflecting a shortfall of 2119/qtl. These profitability deficits explain the observed acreage substitution toward maize and paddy in the 2024-25 season. Furthermore, the study establishes that the price ratio for equal returns is non-constant, varying asymptotically with price levels, yields and regional cost structures. Consequently, despite nominally strong market prices, soybean remained at a relative economic disadvantage, necessitating region-specific policy interventions to stabilize acreage. Price-setting should undertake a cross-commodity parity pricing model. To sustain soybean production and achieve national oilseed security, the Minimum Support Price (MSP) must be dynamically linked to the prevailing returns of competing crops. Furthermore, interventions should prioritize narrowing the yield to cost gap through region-specific technological packages, as the current economic disadvantage directly explains the observed shift in acreage during the 2024–25 planting season.

Keywords: *Soybean, Break-even Price, MSP, Crop Competitiveness, Price Parity*

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Enhanced functionality of soy protein–kappa-carrageenan conjugates using combined pulsed electric field and microwave treatments

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Soybean is a prominent oilseed crop in India that is a great source of plant protein as well. This study investigates a novel, synergistic approach using pulsed electric field (PEF) pre-treatment combined with microwave glycation to enhance the conjugation rate and functional properties of soy protein isolate (SPI) and kappa-carrageenann (KC). Leveraging a Central Composite Rotational Design (CCRD) for optimization, the process targets improved glycation, water-holding capacity, and gel strength, alongside reduced browning. The optimized conditions, including specific PEF parameters and microwave power, aim to maximize conjugation efficiency. Compared to microwave glycation alone, the optimized PEF-

microwave glycated SPI-KC conjugates exhibited significantly higher glycation, water-holding capacity, and gel strength, while also showing reduced browning. Comprehensive characterization, including FTIR and DSC, confirmed favourable changes in microstructure, crystallinity, secondary structure, and chemical shifts, respectively, indicating greater SPI-KC conjugation. Emulsification properties, zeta potential, and thermal stability were also higher for PEF combined microwave glycated samples. XRD, NMR and FESEM analysis explained the reason behind the improvement in functional properties. These findings confirmed that the combined PEF-microwave glycation is a highly effective, cost-efficient, and green technology for producing high-quality protein-polysaccharide conjugates with improved functional characteristics, holding significant potential for commercial food additive manufacturing.

Keywords: *Kappa carrageenan, FESEM, NMR, PEF, SPI, XRD*

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Multi-location evaluation of soybean genotypes based on multiple food grade traits

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Soybean [*Glycine max* (L.) Merr.] is one of the most important crops in the world. Soybean seeds are distinguished from other legume grains especially by their high protein content. Soy milk and its products are regarded as nutritious and cholesterol-free health foods, with considerable potential application. However, information regarding soymilk sensory evaluation and the effect of soybean seed quality traits on soymilk sensory attributes were notably limited. As a result, it is difficult to select suitable cultivars for soy soymilk and tofu processing. Therefore there is need to design system of indices for identification of the varieties on the basis of food grade characteristics. The aim of the experiment was to evaluate the suitability of Soybean genotypes from different location of Central zone (Amravati, Amreli, Kota, Nagpur, Indore, Jabalpur, Sehore, Kota, Parbhani, Morena, Lokbharti) for desired physical traits for soy milk and tofu manufacturing industry. To identify soybean genotypes based on multiple food-grade traits, a BLUP based mixed model called Multi-trait stability index (MTSI) was used in the current study. This model considers both mean performance and stability of each trait simultaneously (default criterion- mean weight-65 and stability weight-35). All the analyses were carried out using R package "metan" (Olivoto and Lúcio 2020). Physical analysis of soybean seed include parameters like 100 seed weight, seed yield, seed size (dimensions), seed colour and lustre, hilum colour. Soy milk and tofu yield as well as sensory parameters are essential for screening of soybean entries for milk analogue preparation. Lesser cooking time and higher hydration ratio indicates better cooking quality. From summary tables we may interpret that cooking time among all genotypes was lesser for JS 25-06 and JS 25-03 followed by JS 25-33. Hull fragility was highest for NRC 150 followed by NRC 138. Maximum protein content of tofu was observed in entries JS 25-06 (54.52%) followed by JS 20-34 (54.51%) and JS 24-33 (53.67%). Milk yield of NRC 130 and NRC 158 was maximum. Sensory evaluation was done by panellist on 9 point hedonic scale by semi-trained panellists. Keeping score 6 as acceptable sensory score, entries NRC 152, JS 24-33, NRC 150, JS 25-06, JS 22-12 and JS 25-03 were acceptable for milk and tofu sensory. Based on the Multi-trait stability index (MTSI) index JS 24-33 was found to be the ideal genotype for food-grade type soybean considering all the traits under study.

Keywords: *BLUP, MTSI, NRC*

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Management of leaf blight and wilt disease of groundnut (*Arachis hypogaea* L.)

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Groundnut (*Arachis hypogaea*) is a major oilseed crop grown in India during the kharif and rabi seasons but mainly in Kharif. Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, Rajasthan, and Maharashtra are the most important groundnut-growing states in India, accounting for over 80% of total area and production. India is the world's leading producer of groundnuts, both in terms of area and production. Groundnut is a key source of edible oil and one of the world's most important oil seed crops. The oil content of the kernel is 40–50% while the protein content is 25–30%. More than 70 diseases caused by fungi, bacteria, viruses, nematodes, and other organisms have been reported, with yield losses of up to 70% estimated (McDonald et al. 1985; Lukose et al. 2008). Groundnut suffers seed, soil and foliar diseases. An experiment conducted at ARS Bikaner for management of leaf blight and wilt disease of groundnut occurring at Rajasthan. Soil application *Trichoderma harzianum* (@ 100 g per 100 meter sq. plot) with spray Carbendazim 12% + Mancozeb 63% WP (Saaf 75% WP)(10 g saaf in 5L water for 100 sq. m area) as well as control was tested at ARS, Bikaner in RBD design in *Kharif*-2019 to 2021 for The result of *kharif*- 2019 to 202. soil application of *Trichoderma harzianum* (@ 100 g per 100 meter sq. Plot) at 30 DAS (T_9) gave minimum disease incidence 6.42 % (60-65 DAS) and 6.52 (80-85 DAS),highest pod yield 3909 kg/ha, highest haulm yield 5419 kg/ha and spray of Carbendazim 12% + Mancozeb 63% WP (Saaf 75% WP)(10 g saaf in 5L water for 100 sq m area) at 30 DAS and 60 DAS(T_4) where disease incidence 8.06.% (60-65 DAS) and 7.17% (85-90 DAS), 3823 Kg/ha pod yield, haulm yield 5278 kg/ha also at par . All the treatment significantly superior as compared to control, where 13.64 % (60-65 DAS) and 13.38 % (85-90 DAS) disease incidence, 3180 kg/ha pod yield and haulm yield 4536 kg/ha were recorded. As regard to ICBR, in different treatments, maximum ICBR ratio (1:17.01) was recorded in treatment consisting (T9): soil application of Trichoderma harzianum (@ 100 g per 100-meter sq. plot) at 30 DAS followed by treatment (T8). Neem cake @ 200 kg/ha(Soil application at sowing and at 30 DAS).

***Keywords**: Carbendazim, groundnut, Trichoderma harzianum, mancozeb, leaf blight, wilt*

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Who gets the price? Groundnut market linkages and farmer returns in Andhra Pradesh

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Globally, groundnuts are cultivated on 327 lakh hectares, with India leading at 54.2 lakh hectares annually ((FAOSTAT), 2021). Andhra Pradesh accounts for 6.20% of India's total groundnut production (Economics, with Anantapur and Annamaya districts forming the production core. This study, conducted by Sambodhi Research and Communications Pvt. Ltd. and commissioned by Rainforest Alliance with GEF support and Rythu Sadhikara Samstha (RySS), evaluates the economic and marketing potential of groundnut following Sustainable Agriculture Practices (SAPs). A mixed-methods approach is used to collect data from 180 farmers across 12 villages in two districts of Andhra Pradesh through stratified multi-stage sampling. The findings show that based on farmers used point of sale, three major value chains have been identified, which are extensively used by farmers in the potential districts. Of them, the best Value chain suggested is VO/FPC driven and by directly selling it to Hullers and MNCs, having primary processing at

village level through VOs/FPCs. Best Priced Received by Selling to MNCs and Hullers of about ¹ 59.56~60 Per KG [5956/ quintal] - to Hullers 59.21 Per KG [5921/ quintal] - to MNCs, having margin of - 1) 40% in branded consumer price, 2) 49% of Local produce consumer price, and 3) 32 % of organic consumer price. While awareness of Sustainable Agriculture Practices (SAPs), such as zero tillage, natural farming, organic methods, and protective cultivation, is low, farmers who adopt them see clear benefits like higher yields, better soil health, and increased income. Despite relatively easy access to credit through SHGs and Grameen banks, high investment costs and weak market linkages for Groundnut limit the entrepreneurial uptake of SAPs. Most farmers depend on local traders due to ease and marginally better prices, but they remain unaware of certification systems and their potential value.

Keywords: *Certification, consumer price, market linkage, producer share, saps, value addition*

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Is groundnut productivity input-driven or technology-driven?: Evidence from state-level TFP analysis

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The groundnut production in the country witnessed a tremendous growth in the recent years despite declining area. It is very crucial to know whether this output growth is driven by inputs or technology. Therefore, the study aimed to analyse the total factor productivity growth of groundnut production in major states. To achieve this objective, cost of cultivation data (2002-03 to 2021-22) sourced from Directorate of Economics and Statistics (DES) was utilized. To estimate the total factor productivity (TFP), growth accounting method of Tornqvist-Theil index was used, and CAGR technique was used to work out input, output and TFP growth rates. The results indicated a significant decline in area in all the selected major states where Andhra Pradesh (–4.95%), Karnataka (-2.91%) and Tamil Nadu (-3.19%) recorded highest decline. Despite area contraction, only Gujarat recorded positive production growth (3.50%) driven by yield improvement. The TFP results revealed a substantial inter-state variation. During Period-I barring Tamil Nadu, all states recorded a positive TFP growth, with Karnataka (4.23%) and Gujarat (1.39%) recording an impressive positive TFP growth despite diminishing input index growth depicting technological progress, better management and efficiency improvements. During Period-II also Karnataka (6.24%) registered highest growth in TFP despite negative input index growth implying state's continued productivity led growth, while Andhra Pradesh (-1.97%) and Maharashtra (-0.70%) experienced TFP decline. Over the overall period, Karnataka recorded the highest TFP growth (5.59%), followed by Gujarat (1.91%), whereas Andhra Pradesh recorded decline and Maharashtra showed stagnation in TFP growth. The output growth was technology driven in Karnataka, Gujarat and Maharashtra and it was input led in remaining states. The study highlights a shift toward productivity-driven growth in groundnut cultivation in Karnataka, Gujarat and Maharashtra and emphasizes the need of technological and efficiency-enhancing interventions in states where output was input intensive.

Keywords: *Groundnut, input-output index, total factor productivity, tornqvist-theil index*

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Policy imperatives for revitalizing India's groundnut sector: Production, markets, and value chain integration

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Groundnut (*Arachis hypogaea* L.) constitutes a vital component of India's oilseed economy, contributing significantly to edible oil availability, farm incomes, and rural employment. Cultivated largely under rainfed conditions across diverse agro-ecological regions, the crop supports millions of small and marginal farmers. However, despite its strategic importance, the groundnut sector continues to face persistent challenges related to yield stagnation, climate risks, fragmented marketing systems, and limited value addition. This policy abstract outlines key priority areas requiring coordinated interventions to strengthen India's groundnut production and marketing ecosystem. On the production front, productivity gaps remain a major concern due to low varietal replacement rates, inadequate access to quality seed, and vulnerability to climatic variability. Although several improved varieties with higher yield potential, disease resistance, and adaptability have been developed by national research systems, their large-scale adoption is constrained by weak seed multiplication and distribution mechanisms. Policy measures should prioritize strengthening the breeder–foundation–certified seed pipeline, supporting decentralized and participatory seed production models, and promoting region-specific varietal deployment to enhance resilience and productivity. Marketing and price realization continue to be critical bottlenecks for groundnut growers. The existing Minimum Support Price (MSP) framework has limited effectiveness due to uneven procurement coverage, inadequate infrastructure, and delayed operations in major producing states. Strengthening procurement mechanisms, expanding storage and warehousing facilities, and integrating groundnut markets with digital platforms such as e-NAM are essential to reduce price volatility and distress sales. The promotion of Farmer Producer Organizations (FPOs) should be a central strategy to improve aggregation, bargaining power, and direct market access for producers. Value addition and processing remain underdeveloped despite growing domestic consumption and export potential. Policy interventions aimed at encouraging investment in processing, quality certification, branding, and export-oriented value chains can significantly enhance farm-level returns. Fiscal incentives, credit support, and public–private partnerships are required to stimulate agro-processing and employment generation in groundnut-growing regions. Trade policies should be calibrated to ensure market stability while facilitating exports of value-added products. In conclusion, revitalization of India's groundnut sector requires a comprehensive and integrated policy approach encompassing seed system strengthening, climate-smart production practices, efficient marketing infrastructure, and value chain development. Evidence-based planning, inter-institutional coordination, and targeted investments will be critical to improving productivity, stabilizing farmer incomes, and advancing national oilseed self-reliance objectives.

Keywords: *Groundnut Sector, markets, policy imperatives, production, revitalizing India, value chain integration*

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Empowering women farmers in groundnut processing under farmers first programme

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Groundnut is an important oilseed crop in India and provides income and employment to many rural households, especially in semi-arid regions. However, most farmers sell groundnut in raw form and receive low returns due to fluctuating market prices and limited marketing options. Value addition through simple processing can help farmers increase their income and improve livelihood security. This study presents the experience of introducing groundnut pod processing as a value addition activity under the Farmers FIRST Programme in Rampur Tanda village of Dharur Mandal, Vikarabad District, Telangana. Under the programme, groundnut pod processing was promoted as a small-scale, group-based enterprise with active involvement of rural women. Farmers were provided with systematic training on basic processing operations, including cleaning, drying, shelling, grading, and packaging of groundnut pods. Primary data were collected over a period of three years (2022–23 to 2024–25) covering the quantity of groundnut processed, pod recovery percentage, processing costs, and prevailing market prices of raw and processed produce. The economic performance of the activity was assessed using simple computations and percentage analysis. The results revealed a consistent expansion of processing activity over the study period. The initiative commenced with processing of only 0.5 quintal of raw groundnut during the first year and increased substantially to 17 quintals by the third year. This progressive increase reflects the economic viability of the intervention and the growing confidence of farmers in the enterprise. On average, processing one quintal of raw groundnut resulted in a recovery of approximately 0.65 quintal of marketable pods. Improved drying and grading practices reduced losses and enhanced product quality, leading to better market demand. Price analysis indicated a clear economic advantage of value addition. During the study period, raw groundnut was sold at an average price of 6,800 per quintal, while processed groundnut pods fetched nearly 16,000 per quintal. After accounting for processing, packaging, transportation, and other costs, farmers realized an additional net income of 2,620 per quintal through pod processing compared to selling unprocessed produce. Moreover, the improved shelf life of processed pods enabled farmers to store the produce and sell it during favorable market conditions, thereby reducing distress sales. Besides economic gains, the activity generated social benefits. It created local employment opportunities, particularly for women, and improved their skills in processing, packaging, and marketing. Participation in group-based enterprises increased confidence and encouraged collective action among farmers. Support from the Farmers FIRST Programme in terms of training, technical guidance, and market linkages played a crucial role in the successful adoption of this activity. Overall, groundnut pod processing is a simple and effective value addition activity that enhances farmers' income and strengthens rural livelihoods. The study highlights the potential of replicating similar interventions in other groundnut-growing regions to promote sustainable farm-based enterprises and women empowerment.

Keywords: *Empowerment, groundnut, market, value addition, women farmers*

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Linseed oil based omega-3 fortification of dairy product: Post-harvest value addition approach

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Omega-3 fatty acids (ù-3 FA), particularly á-linolenic acid (ALA), are essential nutrients derived primarily from oilseeds such as linseed/flaxseed; however, their dietary intake remains inadequate due to limited consumer-friendly delivery formats and post-harvest utilization challenges. Despite India being a major producer of oilseeds and milk, value addition of ù-3–rich oils into widely consumed food systems remains underexploited. This study presents a post-harvest value addition approach for flaxseed oil through its incorporation into milk and milk-based beverages using emulsification technology. In the present study, two water-in-oil emulsions—plain flaxseed oil and flaxseed oil enriched with vitamins—were developed to enable stable incorporation of ù-3 FA into plain and flavored milk. The emulsions were characterized for nutritional composition, fatty acid profile, particle size distribution, and storage stability. Emulsion long-term stability was assessed by monitoring ù-3 FA retention over 12 months under refrigerated storage (4–8 °C). Scale-up operation was performed using batch processing with the help of a water-jacketed colloidal mill, simulating industrial production conditions. The functional performance of the emulsions was evaluated in dairy matrices under typical post-processing conditions. Fortified plain milk was subjected to repeated domestic heating and cooling cycles, while flavored milk formulations were autoclaved and stored for up to four months. Notably healthy changes were noted in fatty acid profile of milk. The saturated fatty acid content was comparatively reduced in fortified milk as compared to plain milk. There was significant increase in poly-unsaturated fatty acid and particularly ù-3 FA content in fortified milk as compared to plain milk. Ratio of ù-6 to 3 was approximately 2:1, indicating healthy fatty acid profile of the milk. The emulsified flaxseed oil formulations exhibited excellent stability, with high retention of ù-3 FA during thermal processing and extended storage, indicating their suitability for commercial dairy applications. Importantly, the emulsification approach ensured uniform dispersion without compromising processing stability. This work demonstrates a practical and scalable strategy for post-harvest value addition of flaxseed oil by transforming it into a functional ingredient for the dairy sector. By integrating oilseed-derived ù-3 FA into frequently consumed food matrix. Given the rapid growth of flavored milk and functional dairy beverages in India, this innovation aligns strongly with market demand and policy priorities focused on nutritional security, value addition, and diversification of oilseed utilization. The developed emulsions offer potential for broader application across dairy products, contributing to enhanced market value of oilseeds and sustainable functional food development.

Keywords: *Dairy products, Emulsification technology, flaxseed oil, omega-3 fortification, post-harvest value addition*

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Value addition of linseed for functional bakery applications: Development of omega-3 fortified bread and cake

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Bakery products such as bread and cake are widely consumed due to their convenience and affordability; however, they are predominantly refined flour–based and nutritionally inadequate, lacking essential fatty acids and quality protein. With increasing urbanization and adoption of convenience diets/ready to eat formulations, consumption of bakery products is rising rapidly in India, creating an opportunity for post-harvest value addition of oilseeds. Linseed/flaxseed, a rich source of omega-3 fatty acids (ù-3 FA; á-linolenic acid), remains underutilized in mainstream food systems due to processing and stability challenges. This study presents a scalable approach for value addition of flaxseed through the development of omega-3 enriched bakery products. A specialized flour pre-mix was developed using flaxseed germ as the source of ù-3 FA and soy protein for nutritional enhancement. Multiple delivery formats—including flaxseed oils, flaxseed oil based-emulsions, and flaxseed premixes—were evaluated for compatibility with bread and cake matrices. The premix was characterized for physicochemical properties, storage stability, and suitability for bakery applications. Bread and cake prepared using optimized (5-20%) inclusion levels of the premix exhibited desirable texture, color, and sensory acceptability, while ensuring retention of ù-3 FA and acceptable trans-fat levels. Changes in product quality and stability of key functional components were monitored throughout the shelf life of the products. The developed flaxseed-based premix is gluten-free and contributes to significant increased poly-unsaturated fatty acid levels, including a reduced omega-6/omega-3 ratio, compared to conventional refined wheat bakery products. Importantly, the technology requires no modification of existing industrial baking processes, as the premix can be directly blended with wheat or refined wheat flour, making it highly scalable and cost-effective. The approach represents a sustainable post-harvest utilization strategy by leveraging indigenous oilseed (flaxseed) and protein-rich legume (soy) resources.

Keywords: *Bread and cake, omega-3 fortification, linseed, value addition*

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Biochemical profiling and lipid analysis of niger seed (*Guizotia abyssinica* Cass.) of different germplasms of Gujarat

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Niger (*Guizotia abyssinica* Cass.) an African origin oilseed crop is significant for its ethnical use among tribal people in South Gujarat region of India. In the present study, total of 15 genotypes namely different genotypes namely NMS-1701, NMS-1702, NMS-1703, NMS1704, NMS-1705, NMS-1706, NMS-1707, NMS-1708, NMS-1709, NMS-1710, NMS-1711, NMS-1712, and three check varieties GN-2, GNNIG-3 and IGPN-2004-1 were subjected for biochemical estimation. Highest protein, carbohydrate and fiber content was found as 30.56%, 101.88 mg/g, 23% respectively. The most important character, oil percent was found in between the range of 40 to 46%. There was a huge difference in the range of â carotene content 0.9 to 43.52ppm. The highest â carotene containing genotype was found to be NMS-1706. The check variety IGPN-2004-1 showed good antioxidant activity compared to other genotypes. The highest micro nutrient contents like B(9.33ppm), Zn (45.33 ppm), Mn (32.67 ppm), Cu (46.67 ppm) and Fe

(480.00 ppm) content was found in NMS-1707, NMS-1708, NMS-1701, NMS-1702 and G-2 respectively. The mono unsaturated(oleic) and poly unsaturated fatty acid(linoleic) ranged between 11.73 to 29.53% and 52.77 to 68.28% which is very much important for oil quality characters. The overall results showed that Niger was a rich source of â carotene, and antioxidants, along with important fatty acids.

***Keywords**: â Carotene, Genotypes, Fatty acid, Micro nutrient, Niger*

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Sunflower trend and decomposition analysis after Post-TMO

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Sunflower (*Helianthus annuus* L.) is an important oilseed crop contributing significantly to India's domestic edible oil production, particularly in rainfed regions. Despite its adaptability and high oil content, sunflower cultivation has experienced fluctuations in area, production, and productivity over time. India's growing dependence on edible oil imports has renewed policy focus on enhancing oilseed performance through initiatives such as the Technology Mission on Oilseeds. However, empirical evidence on long-term growth patterns, instability, and the relative contribution of area and yield to sunflower production remains limited. The present study aims to analyses the trends in sunflower area, production, and yield in India, assess instability, and decompose production growth into area and yield effects. The study is based on secondary time-series data on area, production, and yield of sunflower in India, sourced from India Stats and the Ministry of Agriculture & Farmers' For gauging the effect of Technology of mission of Oilseeds (TMO) the period of the study was categorized as pre-TMO period (1985-1986, to 1995-1996) and post-TMO period is (19965-1997) to 2023-2024) with later further divided into Three sub-periods(1996-1997, 2007-2016 and 2017-2024) to assess the short and long term policy effects. Various Parameters such as sunflower cultivation area, production and yield were analysed through CAGR using a semi-logarithmic model. Variability Parameter was assessed through coefficient of variation (CV) and the Cuddy- Della Valle instability Index (CVDI). To isolate the contribution of area, yield and their combined effect on changes in sunflower production through Pre and Post TMO periods. MS excel sheets are used for computation, across policy regimes' enabling an evaluation which determines the efficacy of TMO and succeeding development policies in India. The results revealed moderate growth in sunflower production during the post-intervention period, although the area under cultivation exhibited a declining or stagnant trend in recent years. Yield growth contributed positively to overall production growth, indicating the role of improved hybrids and agronomic practices. Instability analysis showed higher variability in yield compared to area, reflecting the influence of climatic variability and input responsiveness. Production instability increased during the later period, suggesting rising risk in sunflower cultivation. Decomposition results indicated that the yield effect was the dominant contributor to production growth, while the area effect was relatively weak or negative in certain phases. These findings imply that sunflower production growth in India has been largely productivity-driven rather than area-led. Strengthening research on stress-tolerant hybrids, improving input delivery, and ensuring stable price and procurement mechanisms are essential for sustaining sunflower cultivation and reducing production volatility.

***Keywords**: Decomposition analysis, sunflower, trends in area and production, yield effects*

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An Ideal Packing Material for Oil Palm Seed Storage

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The Oil Palm is cultivated in an area of about 5.3 lakh ha in India with Andhra Pradesh and Telangana alone constitutes almost 65% of area. The National Mission on Edible Oils – Oil Palm (NMEO-OP) target to increase the area under oil palm to 10 lakh ha. To cover this vast area, 750 lakh oil palm seedlings are required. Though the pollination, seed processing and sprout production is a continuous process round the year in oil palm, planting is taken up mainly in the rainy season. Further, bunch formation is not uniform throughout the year and demand for oil palm sprout varies among seasons. The oil palm seeds need to be stored for few months, until the demand arises. In such situation, ideal option is to store the processed oil palm seeds, later on dormancy broken and germinated as and when required. In order to identify a suitable packing material to prolong seed viability during storage of oil palm seeds, four different packing materials *viz.* cloth bag, three-layered aluminum foil bag, 400-gauge polythene bag and super grain bag were evaluated. The fresh DXP hybrid seeds of 5 palms were packed and evaluated for viability and moisture in 15 days interval. A set seeds after storage period were placed in heating room at 39 ^{0}C for 70 days to assess the germination and viability percentage. The viability was assessed through TZ test and moisture content was assessed through oven method. The seed moisture was fluctuating in all the packing materials; fluctuations were more in cloth bag varied between 12.2% to 18.3% and minimum in super grain bag (14.4 to 18.3%). The fresh oil palm seeds maintain more than 90% viability in aluminum foil bag and super grain bag and more than 80% viability in 400 gauge polythene bag after 165 days of storage under ambient condition. The more reduction in viability in cloth bag may be due to more fluctuations in moisture content. The oil palm seeds stored in aluminium foil bag and super grain bag retained more than 50% germination after 90 days of storage under ambient condition. Hence, fresh DXP oil palm seeds can be stored for three months in super grain bag or three-layered aluminium foil bags with more than 50% germination under ambient conditions of Palode, Kerala.

Keywords: *Oil Palm, aluminium, DXT*

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