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Phenological trait evaluation and correlation studies for yield and its components in parents and F_2 progeny lines of Indian mustard (*Brassica juncea* L.)

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Abstract

Brassica juncea commonly known as Indian mustard is economically very important crop because of its high oil content and superior oil quality. It is utilized worldwide as an oilseed, a condiment, vegetable, green manure, forage and fodder and cultivated primarily in tropical and sub-tropical countries. Study of Indian mustard parental genotypes of diverse origin RB50 and Kranti and their 157 F_2 progeny lines for various yield related different characters revealed considerable variability for all the characters under study. Yield and yield related attributes like number of primary branches/plant, number of secondary branches/plant, number of silique/plant, main raceme length, number of siliqua on main raceme, siliqua length, number of seeds/siliqua, 1000 seeds weight and seed yield were recorded for estimation of yield attributes in F_2 generation. Physiological traits of relative water content and electrolyte leakage were taken to study the effect of various yield affecting physiological traits on potential yield in parent and progeny lines for better selection of good yielding genotypes. 21 lines were selected as promising lines on the basis of their good yield (more than both the parental genotypes) and better physiology as they have more relative water content and less electrolyte leakage. Therefore, they survive stress conditions more effectively and can serve as good genetic material for further progeny analysis and generation of higher yielding genotypes in future generations.

Key words: *Correlation coefficient, electrolyte leakage, genetic variability, phenotypic correlations, yield parameters*

Introduction

Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is the second most significant oilseed crop of the world as well as India after groundnut. The genus *Brassica* is an important member of the cruciferae family. It comprises of numerous economically important species which provides edible roots, stems, leaves, buds, flowers and seed as condiment. Most of the species are used as oilseed crop and as forage crops. Among rapeseed and mustard, rai (*B. juncea*) is very popular among the farmers due to higher yield and greater tolerance against lodging, shattering, drought condition, heat and relative diseases as well as the saline sodic conditions (Tripathi *et al.,* 2013). Mustard (*B. juncea*) is one of the major oil seed crop in Indian sub-continent, and is widely grown not only in India but also in the various areas of neighbouring countries. In India, *B. juncea* occupies second largest area after groundnut with 6.7 million hectares of area under cultivation producing about 7.0 million tones of seed annually, securing fourth position in world after European Union (34 %), China (23 %) and Canada (19 %). The major oilseed *Brassica* in Indian subcontinent is Indian mustard. *B. juncea* is a tetraploid species having 2n= 36 chromosomes and AABB genome, is an amphidiploid which combines the chromosome sets of low chromosome number species. Indian mustard is a naturally self pollinated species, but regular out crossing occurs in this crop 5 to 30 per cent which varies upon the environmental conditions and pollinating insect population. It has greater yield potential for semi-arid conditions and known to be more drought tolerant and shattering resistant than *B. napus* and *B. campestris*. In India, mustard and rape seed are being grown largely in states like, Uttar Pradesh, Rajasthan, Haryana, Assam, Gujarat, Punjab, West Bengal and Madhya Pradesh. India occupies first position both in acreage and production of rapeseed and mustard in Asia. Yield itself is a complex trait which is characterized by low heritability and affected by genotype and environment of crop species. The study of association of plant characters with seed yield has great importance for selecting a desirable drought tolerant genotype with improved yield. Greater the diversity in the material, better are the probabilities for the selection of desired plant types (Vavilov, 1951).

Materials and Methods

Plant materials and generation of F_2 lines: The seeds of parental genotypes RB50 and Kranti were grown in the research area of Oilseeds section, Department of Genetics and Plant breeding, CCSHAU Hisar. Both parents were sown with inter row spacing of 30 cm and plant spacing of 15 cm under two irrigations. Both the contrasting parents were crossed to get F_2 progeny lines in subsequent years. F_2 progeny lines along with parental genotypes were planted and irrigated up to field capacity. Out of F_2 progeny lines 157 lines were chosen for phenological and morphological trait evaluation. The cross between cv. RB 50 and cv. Kranti was made in 2012 and the progeny lines were full-grown to get F_2 generation in subsequent years for data analysis.

Phenotypic evaluation of RB 50 × Kranti derived F_2 population

Phenotypic evaluation of plants grown in field was done in RB 50 × Kranti derived F_2 populations for various phenological, growth related, yield related and physiological parameters during *rabi* seasons of 2013. Phenological traits influencing yield including days to flower initiation, days to total siliqua development and maturity duration were taken in parents and F_2 generation of *Brassica juncea*. Growth related traits including dry matter weight and plant height were recorded for evaluation of growth related parameters. Yield and yield related attributes like number of primary branches/plant, number of secondary branches/plant, number of silique/ plant, main raceme length, number of siliqua on main raceme, siliqua length, number of seeds/siliqua, 1000 seeds weight and seed yield were recorded for estimation of yield attributes. Physiological traits of relative water content and electrolyte leakage were taken for evaluation of genetic variability and its related parameters in parents and population F_2 genotypes.

Physiological traits :

RWC of leaf was calculated by method suggested by Kumar and Elaston (1992). RWC (%) of leaves according to the following formulae.

RWC (%) = [(Fresh weight- Dry weight) / (Turgid weight- Dry weight)] x100

Electrolyte leakage (%)

The relative intactness of plasma membrane was calculated as the leakage percentage of electrolytes, as described by Gong *et al*. (1998). The leakage percentage of electrolytes was calculated as

Electrolyte leakage= (1- EC1/EC2) X 100.

Where EC1=Initial electrical conductivity and EC2=Final electrical conductivity

Statistical Analysis

Statistical analysis was done using OPSTAT software by using the phenotypic data recorded from both parents and F_2 generation progeny lines. The mean and range (Maximum and minimum) values for each character were calculated.

Correlation Coefficient:

Phenotypic r (P) correlation coefficients for all possible pairs of characters were calculated from the variance and covariance's was estimated

r(P)= ó x y (P)/[ó x (P) X ó y (P)]
Where,
ó x y (P) = Phenotypic covariance between characters x and y
ó 2 x (P) = Phenotypic variance of character x
ó 2 y (P) = Phenotypic variance of character y

The phenotypic correlation coefficients were tested against standardized tabulated significant value of r with (n-2) degree of freedom as per the procedure by Fisher and Yates (1963).

Results and Discussion

Phenotypic evaluation of RB 50 × Kranti derived F_2 populations and parental genotypes: RB 50 × Kranti in F_2 generation under irrigated conditions showed large variation for phenological traits of no. of days to total siliqua development having range 95-106 and maturity duration (130-145). Plant height has a minimum value of 110 and maximum of 247 cm with dry matter weight having a range (3.1-163.1 g). Dry matter weight has a minimum value of 3.1 and maximum of 163.1 g. Yield related parameters also showed wide variations in their mean and range values. No. of secondary branches/plant are in range of 2-21, no. of siliqua/plant have a range of 30-521, no. of seeds/siliqua have a range of 4.8-20.8, 1000 seed weight (2.8-6.9 g) and seed yield/plant have a minimum value of 0.9 and maximum of 48 g. Physiological traits of relative water content show a wide range in population having a minimum value of 60.2 to a maximum of 81.6 % and electrolyte leakage having minimum value 12.22 and maximum 42.30 %. Plant height has a mean value of 168.74 in F_2 generation progeny lines and has a range of 110-247 cm. Parental genotype Kranti has a higher yield than mean yield in F_2 progeny lines and RB 50. Genotype Kranti has early maturity with early siliqua development and took less days to flowering initiation than the parent RB 50. Genotype Kranti has more no. of secondary branches/plant, siliqua/plant, no. of siliqua on the main raceme, thousand seed weight and hence seed yield/plant than the RB 50. Progeny lines have days to flower

Table 1: Phenological, growth related, yield related and physiological traits in RB 50 × Kranti derived F_2 population of Indian mustard

Parameters	RB 50	Kranti	RB50 × Kranti derived F_2 Population	
			Mean	Range
Phenological traits				
Days to flower initiation	43.4±0.17	38.80±0.13	43.93	40-48
Days to total siliqua development	102±0.10	99.60±0.11	99.80	95-106
Maturity duration	143.2±0.07	139.40±0.10	137.81	130-145
Growth related traits				
Plant height (cm)	192.8±0.15	186.80±0.6	168.74	110-247
Dry matter weight (g)	71.12±0.44	65.96±0.31	61.95	3.1-163.1
Yield related traits				
Number of primary branch/plant	4.4±0.26	3.40±0.30	4.52	2.0-11
Number of secondary branch/plant	12.4±0.25	14.40±0.44	11.50	2.0-21
Number of siliqua/plant	228.2±0.50	257.20±0.58	220	30-521
Main raceme length (cm)	86.4±0.38	82.0±1.65	56.7	31-92
Number of siliqua on main raceme	49.2±0.40	53.20±0.20	35.4	17-57
Siliqua length (cm)	4.84±0.12	3.78±0.16	4.64	2.8-9.4
Number of seeds/siliqua	13.72±0.24	16.92±0.17	13.59	4.8-20.8
1000 seed weight (g)	5.28±0.04	5.43±0.02	5.05	2.8-6.9
Seed yield/plant (g)	15.05±0.24	20.50±0.14	18.46	0.9-48
Physiological traits				
Relative water content (%)	83.17±0.09	80.2±0.11	74.33	60.2-81.6
Electrolyte leakage (%)	18.22±0.09	22.66±0.27	23.72	12.22-42.30

initiation, electrolyte leakage and no. of primary branches/plant more than both the parental genotypes. Parent genotype RB 50 shows higher value of RWC and lesser value of electrolyte leakage showing its good physiology and resistance to stress conditions as compared to Kranti. Seed yield and its contributing traits showed enormous variation in F_2 generation with parental genotype Kranti having more yield potential than RB 50 under irrigated conditions (Table 1).

Experiments were carried out to evaluate RB 50 x Kranti derived F_2 populations for yield, physiological, growth related and phenological parameters under irrigated conditions and huge variation was observed for all the traits. Such variability for more than one character has been reported by Singh and Singh (1997). In all the experiments Cv. Kranti, out yielded RB 50 under irrigated conditions in F_2 population.

Ara *et al.* (2013) observed seed yield and yield contributing characters; it was confirmed that there were considerable variation present among all the genotypes used in the experiment. Our progeny lines also showed considerable variations among all the genotypes under study hence showing considerable similarity with above said results.

Phenotypic correlation coefficient was calculated to assess the association between various traits. Phenotypic correlation coefficient analysis of F_2 populations showed significant correlation between morpho-physiological and yield related traits. In this generation number of primary branches/plant (0.400), number of secondary branches/plant (0.723), main raceme length (0.316), number of siliqua on main raceme (0.341), number of seeds/siliqua (0.276), 1000 seed weight (0.418), number of siliqua/plant (0.798), plant height (0.296), dry matter weight (0.999), days to total siliqua development (0.601), maturity duration (0.603) and relative water content of leaf (0.622) exhibited a significant positive correlation with seed yield/plant. Days to flower initiation (-0.556) and electrolyte leakage (-0.220) revealed significant negative correlation coefficient with seed yield/plant. Number of primary branches/plant (0.352), number of secondary branches/plant (0.350), main raceme length (0.257), number of siliqua on main raceme (0.208), thousand seed weight (0.189), number of siliqua/plant (0.367), seed yield/plant (0.296), dry matter weight (0.308), days to total siliqua development (0.232), maturity duration (0.239) and relative water content of leaf (0.179) revealed a significant positive correlation with plant height (Table 2).

The attributes like number of seeds/siliqua, weight of 1000 seeds, total seed weight/ plant as well as harvest

Table 2: Correlation coefficient analysis of morpho-physiological traits and yield attributes in F_2 generation under irrigated conditions

	PB	SB	RL	RS	SL	S/S	TSW	S/P	SY/P	PH	DMW	DFI	DSD	DM	RWC	EL
PB	1															
SB	0.623**	1														
RL	0.362**	0.430**	1													
RS	0.337**	0.406**	0.659**	1												
SL	0.278**	0.174*	0.222**	0.097	1											
S/S	0.093	0.204**	0.175*	0.310**	0.121	1										
TSW	0.178*	0.308**	0.187*	0.153	0.183*	0.241**	1									
S/P	0.425**	0.657**	0.250**	0.265**	0.160*	0.264**	0.451**	1								
SY/P	0.400**	0.723**	0.316**	0.341**	0.1	0.276**	0.418**	0.798**	1							
PH	0.352**	0.350**	0.257**	0.208**	-0.023	0.063	0.189*	0.367**	0.296**	1						
DMW	0.397**	0.718**	0.324**	0.345**	0.101	0.274**	0.416**	0.797**	0.999**	0.308**	1					
DFI	-0.218**	-0.368**	-0.286**	-0.265**	-0.012	-0.173*	-0.326**	-0.424**	-0.556**	-0.15	-0.559**	1				
DSD	0.174*	0.389**	0.226**	0.243**	0.052	0.164*	0.278**	0.470**	0.601**	0.232**	0.613**	-0.427**	1			
DM	0.213**	0.545**	0.309**	0.232**	0.138	0.182*	0.419**	0.521**	0.603**	0.239**	0.606**	-0.365**	0.407**	1		
RWC	0.357**	0.618**	0.257**	0.206**	0.093	0.218**	0.330**	0.584**	0.622**	0.179*	0.619**	-0.287**	0.294**	0.520**	1	
EL	0.05	0.002	-0.037	-0.054	-0.012	-0.255**	-0.108	-0.205**	-0.220**	-0.025	-0.230**	0.215**	-0.256**	-0.08	-0.128	1

* Significant at 5 %, ** significant at 1 % level, PB-No. of primary branches/plant, SB-No. of secondary branches/plant, RL-Main Raceme length, RS-No. of siliqua on main raceme, SL-Siliqua length, S/S-No. of seed/siliqua, TSW-1000 seed weight, SY/P-Seed yield/plant, PH-Plant height, DMW-Dry matter weight, DFI-Days to flower initiation, DSD-Days to total siliqua development, DM-Days to maturity, RWC-Relative water content, EL-Electrolyte leakage.

Table 3: Phenological, growth, yield and physiological parameters in parental and promising F_2 progeny lines of RB 50 × Kranti

Yield parameter	PB	SB	RL	RS	SL	S/S	TSW	S/P	SY/P	PH	DMW	DFI	DSD	DM	RWC	EL
RB 50	4.4	12.4	86.4	49.2	4.84	13.7	5.28	228.2	15.1	192.8	71.12	43.4	102	143.2	83.18	18.224
KRANTI	3.4	14.4	82	53.2	3.78	16.9	5.43	257.2	20.5	186.8	65.96	38.8	99.6	139.4	80.2	22.656
B2	7.0	18.0	54.0	53.0	4.4	16.8	5.8	450.0	45.0	207.0	157.0	42.0	101.00	136.0	79.3	16.74
B5	7.0	15.0	70.0	44.0	4.8	9.6	5.2	415.0	44.0	191.0	151.2	41.0	104.00	137.0	71.6	21.48
B6	4.0	13.0	62.0	52.0	4.6	11.6	4.8	425.0	44.5	172.0	151.3	42.0	104.00	139.0	78.0	16.06
B7	5.0	11.0	67.0	57.0	4.4	16.4	5.8	320.0	38.4	172.0	130.6	41.0	104.00	139.0	74.1	21.06
B8	5.0	16.0	52.0	30.0	4.4	12.0	4.9	345.0	38.3	165.0	128.7	40.0	104.00	136.0	71.7	27.38
B13	5.0	19.0	64.0	38.0	4.2	13.4	4.7	420.0	43.4	202.0	148.0	41.0	105.00	140.0	80.0	20.85
B27	3.0	10.0	58.0	38.0	4.0	10.0	5.5	267.0	48.0	183.0	163.1	41.0	106.00	145.0	71.8	18.90
B29	6.0	13.0	54.0	33.0	5.0	8.2	5.4	389.0	36.0	171.0	122.4	44.0	103.00	139.0	79.6	20.79
B33	6.0	11.0	71.0	51.0	4.4	17.2	4.6	213.0	37.2	184.0	126.5	42.0	103.00	141.0	76.8	22.62
B61	6.0	21.0	56.0	42.0	3.8	16.0	4.6	356.0	38.0	181.0	125.4	44.0	98.00	142.0	79.7	20.28
B79	4.0	14.0	66.0	42.0	4.8	16.8	5.8	450.0	45.0	187.0	150.1	44.0	98.00	144.0	80.5	21.45
B83	5.0	17.0	66.0	39.0	5.0	18.0	4.3	430.0	45.0	169.0	148.5	44.0	98.00	139.0	81.3	21.06
B101	6.0	21.0	61.0	45.0	5.4	15.6	5.4	521.0	33.5	160.0	110.6	44.0	103.00	141.0	78.8	30.79
B107	7.0	19.0	65.0	50.0	5.8	20.8	5.4	275.0	35.0	162.0	115.5	44.0	98.00	140.0	77.2	21.06
B108	7.0	18.0	63.0	40.0	6.0	18.7	6.7	326.0	36.0	145.0	118.8	44.0	98.00	141.0	78.6	27.12
B148	3.0	17.0	66.0	41.0	6.0	16.0	6.5	450.0	40.0	185.0	132.0	40.0	98.00	141.0	80.2	20.52
B190	6.0	15.0	61.0	33.0	4.4	14.6	5.2	324.0	32.0	224.0	107.8	44.0	100.00	139.0	80.5	22.09
B194	7.0	17.0	57.0	32.0	5.4	16.8	6.0	345.0	41.6	171.0	140.3	41.0	102.00	139.0	80.4	16.64
B231	4.0	17.0	52.0	40.0	4.8	18.6	5.3	450.0	45.0	136.0	151.7	44.0	104.00	142.0	80.9	20.67
B233	4.0	17.0	73.0	51.0	4.6	12.8	5.2	392.0	32.9	170.0	110.7	41.0	102.00	141.0	78.9	16.74
B246	4.0	19.0	61.0	36.0	6.0	16.8	5.2	406.0	32.4	181.0	109.2	46.0	102.00	140.0	76.5	21.77

PB-No. of primary branches/plant, SB-No. of secondary branches/plant, RL-Main Raceme length, RS-No. of siliqua on main raceme, SL-Siliqua length, S/S-No. of seed/siliqua, TSW-1000 seed weight, SY/P-Seed yield/plant, PH-Plant height, DMW-Dry matter weight, DFI-Days to flower initiation, DSD-Days to total siliqua development, DM-Days to maturity, RWC-Relative water content, EL-Electrolyte leakage.

index are directly and positively correlated to the yield of any variety/species of oleioferous *Brassica* (Rai *et al*. 2005). Forty-six germplasm accessions of Indian mustard were evaluated for seed yield and its yield components (eleven characters). The study clearly indicates the need for giving due weight age for number of siliquae /plant, number of secondary branches/plant, harvest index and biological yield per plant for improving seed yield in mustard genotypes (Gangapur *et al.,* 2009).

1000-seed weight was positively correlated with siliqua length. 1000-seed weight and total siliquae/plant and also had higher phenotypic and genotypic direct effects on seed yield/ plant in *B. juncea* (Yadava *et al.,* 2011).

Twenty *B. napus* genotypes including a check cultivar Abasin-95 were evaluated to study correlation and path co-efficient analysis to partition the cause and effect relationship into direct and indirect components. Correlation analysis revealed that seed yield had significant positive genetic correlation with flowering, maturity, plant height, primary branches/plant, main raceme length, pods on the main raceme and pods/plant, whereas significant positive phenotypic association with seeds/pod (Khan *et al.,* 2013). Our results are also in line with the present studies. Iqbal *et al*. (2014) showed a significant correlation of plant height, number of seeds/ siliqua, number of siliqua/plant and length of siliqua with seed yield /plant in *Brassica* species.

Results in our study showed that seed yield/plant has highest positive correlation with number of siliqua/plant and no. of secondary branches/plant indicating that seed yield/plant is directly related and dependent on number of siliqua/plant and no. of secondary branches/plant. Seed yield/plant showed positive and significant corelations with primary branches/plant, secondary branches/plant, raceme length, no. of siliqua on main raceme, seed/siliqua and thousand seed weight besides siliqua/plant and secondary branches/plant. Dry matter weight has a highly significant and positive correlation with seed yield/ plant showing that greater the siliqua no. and dry matter greater is the yield potential. Days to flower initiation, days to total siliqua development and days to maturity also shows a positive and significant correlation with yield showing that yield is greater in plants having more no. of days to siliqua development, more days taken to flower initiation and hence more time taken for maturity.

A total of 796 Indian mustard germplasm accessions including 4 checks were evaluated for their performance with respect to high temperature stress tolerance at seedling stage. Correlation coefficients between seed yield per plant and heat stress traits indicated that seed yield per plant was positively associated with membrane stability index and 1000-seed weight. On the basis of *per se* performance, germplasm accessions found to be tolerant to heat stress could be included in the breeding programme of genotypes for high temperature stress conditions (Ram *et al.,* 2014). Our studies show similar results with positive and significant correlations between seed yield/plant and thousand seed weight.

Indian mustard germplasms were evaluated for qualitative and quantitative traits to investigate the genetic diversity and correlation. Among all the traits greatest and highly significant correlation was found between days to maturity, days to flowering (Saleem *at al.,* 2017).

Total 157 F_2 progeny lines evaluated for various yield and other phenological traits showed a wide diversity and variability among the various traits showing diverse and contrasting nature of parental genotypes used in the breeding programme. 21 lines (Table 3) out of 157 used for progeny analysis were selected as promising lines on the basis of their good yield (more than both the parental genotypes) and better physiology as they have more relative water content and less electrolyte leakage and therefore were tolerant than other genotypes. These lines could be used as promising plants for further evaluation of traits in future generations.

Conclusion

In conclusion, the results of this study suggest that large genotypic variation was observed among species for most of the studied traits among all the studied lines showing that the material used has wide diversity and ideal for progeny analysis and further cultivar development in *Brassica juncea*. Significant positive correlations were found between seed yield with number of secondary branches/plant, number of seeds/siliqua, number of siliqua/plant, dry matter weight and relative water content of leaf while electrolyte leakage revealed significant negative correlation coefficient with seed yield/plant in F_2 populations. 21 promising and superior lines have been selected on the basis of their better yield and physiology and these lines perform better than the parental lines with respect to yield and other yield affecting parameters. Selected superior lines could serve as a good breeding material for improving yield in *Brassica* and further progeny development and analysis.

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