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Climate smart strategies for sustainable production of rapeseed-mustard in India

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Abstract

The mean annual temperature of India has shown significant warming trend. In developing countries, climate change will cause yield declines for the most important crops. The effects of an increase in carbon dioxide would be higher on C3 crops (such as mustard) than on C4 crops (such as maize). India is among the largest vegetable oil economies in the world. Although there has been a significant increase in oilseed production since 1960s in India but, the demand for oilseeds production continuously growing. The productivity of all oilseeds in India is just 50–60% of the world average, which need to be enhanced. Indian mustard is sharing 24.3 % area and contributes about 24.7 % of total edible oilseed production of the country. Though states like Haryana and Gujarat has realized a yield level of 1869 and 1521 kg/ha respectively, which is commendable. The reasons for this success are better input (soil, water, varieties, fertilizers, seed, plant protection etc) management and sound extension system of these states, which helps the farmers to reduce the climate associated risk. The strategies for sustainable production of rapeseed - mustard in India need a paradigms shift on genetic enhancement, innovative agro techniques for enhanced mustard productivity especially land and seedbed preparation, seed and sowing- seed priming, efficient cropping systems, water management, efficient nutrient management, integrated weed management, resource conservation technologies and contingency crop planning (CCP).

Key words: *Climate smart strategies, cropping systems, contingency crop planning, resource conservation, rapeseed-mustard*

Introduction

India is one of the largest oilseed economy of the world. The contribution of oilseeds to the agricultural economy of India ranks second only to food grains. Among all sectors of Indian agriculture, the oilseed is one, which still largely depend on import from other country to meet the requirement of edible oils and these are the crops mainly grown under various biotic and abiotic stresses. Although there has been a significant increase in oilseed production since 1960s in India but, the demand for oilseeds production continuous grow. Rapeseed-Mustard is one of the important edible oil seed crop comprising an area, production and productivity of 5.76 Mha, 6.82 mt and 1184 kg/ha respectively during 2015-16 (Anonymous, 2016). Due to low productivity, the country has imported about 9.2 Mt of vegetable oils costing around Rs 38,000 crores during 2010–11. The productivity of all oilseeds in India is just 50–60% of the world average, which need to be enhanced.

In India, rapeseed–mustard is grown in diverse agro-climatic conditions ranging from north-eastern/north-western hills to down south under irrigated/rainfed, timely/late sown and mixed cropping. Indian mustard accounts for about 75-80% of the 6.90 million hectare (mha) under these crops in the country. Taramira is grown in the drier parts of north-west India comprising the states of Rajasthan, Haryana and Uttar Pradesh. The average contribution of rapeseed-mustard to the total oilseed acreage and production in India is 22.2% and 22.6%, respectively. Rajasthan, UP, Haryana, MP, Gujarat and West Bengal states together accounted for 91% of the rapeseed-mustard production in the country, the productivity of Haryana, Gujarat, Rajasthan, UP and MP was above 1000 kg/ha. The major part of mustard 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.

Climate change and rapeseed-mustard growth and productivity in Indian perceptive

The response of mustard is different to the rising seasonal temperature and varies depending upon the locations. Uprety *et al*. (1996) reported that with the type of climate change in the north India (variation in temperatures and CO_2 conc.), the production of *Brassica* crop is likely to be shifted in some more relatively drier areas than where it is grown presently. The maximum decrease in seed yield was noticed in Haryana where the grain yield decreased by 2.01 q/ ha, per degree rise in seasonal temperature, whereas decrease of 0.98 and 0.92 q per ha in seed yield was observed in UP and Rajasthan respectively. The effect of delay in sowing on yield of mustard shows that 20 days delay may reduce the yield to half of the attainable yield and there will be a further drastic reduction in yield after one month delay in sowing from the optimum date (Kalra *et al*., 2008). Optimum yield of mustard is expected when the average seasonal (winter) temperature stands between 17°C and 22°C, and the days to maturity are affected by increase in temperature. The forced maturity (rate of hastening of maturity is 1.72 days per degree rise in temperature) might reduce the yield significantly. This kind of quantified relation would help in deciding the shifting of optimal date of sowing as well as the best agronomic management options in view of change and aberrations in winter climate. Uprety *et al.* (2001) reported that CO_2 elevated to 600 mol mol^{-1} increased the length of epidermal cell and length of palisade parenchyma cells, and induced larger chloroplasts and more oval shaped starch granules in comparison with plants grown at ambient normal CO_2 concentration. This boost in structural sink size helped in check feedback inhibition by excessive photo-assimilate which was subsequently used to compensate the adverse moisture stress effect in *B. juncea* leaves.

The varieties rapeseed- mustard should have alternate genetic make-ups to adapt into area- and specific cropping patterns to minimise climate change impact. Higher temperatures are expected to improve or hinder seed germination, plant growth and/or plant development, depending on the relative sensitivity or tolerance of crop genotypes. The increased CO_2 concentration will have a positive effect on productivity, albeit in a crop genotype-dependent manner. To take advantage of faster growth under higher temperatures, the new varieties, especially of the Rabi cropping season should have characteristics of early flowering (photo- and temperature-insensitivity, but development-related onset of flowering) and early maturity and high produce. The elevated CO_2 concentration markedly increased net photosynthetic rate and under moisture stress, elevated CO_2 concentration increased water potential and relative water content and reduced transpiration rate in *Brassica*. The greater allocation of biomass to the roots that serves as a powerful sink for assimilated Carbon under increased CO_2 concentration and also helped in better root growth. In other study by Boomiraj *et al.* (2010) reported that future climate change scenario analysis showed that mustard yields are likely to reduce in both irrigated and rainfed conditions.

Strategies for bridging the gap of potential and realised yield of rapeseed-mustard

The rapeseed-mustard, which contributes nearly 80% of the total *Rabi* oilseed production, is a vital component in edible oil sector. The potential productivity of mustard is 25-35 q/ha but due to poor management of resources in it cultivation, the average productivity is only about 11.0 q/ha. The constraints for low mustard productivity are frequent weather aberrations, un- availability of superior varieties, quality seed, lack of sound crop protection measures, poor transfer of technologies, farmer's unawareness for recent production technologies, lack of price support policies, poor water, fertilizer management. There is great opportunity to enhance average productivity of mustard crop in the country through use of improved cultivars and production technologies. There exists a commercially exploitable yield reservoir to the tune of nearly 73% of the national production, which can be harnessed by the adoption of currently available improved technologies (Hegde, 2012). Followings approaches will help in harnessing the exploitable yield reservoir by enhancing the rapeseed-mustard productivity in the country.

Table 1**:** Varieties tolerant to various abiotic and biotic stresses of Indian mustard (*Brassica juncea*)

Specific abiotic/ biotic stress	Tolerant verities
Rainfed	Aravali, Geeta, GM 1, PBR 97, PusaBahar, Pusa Bold, RH 781, RH 819, RGN 48, Shivani, TM 2, TM 4, Vaibhav, RB 50
Salinity tolerant	CS 52, CS 54, CS 56, Narendra Rai (NDR 8501), NRCDR02
Frost tolerant	RGN 13, RH 819, Swaranjyoti, RH 781, RGN 48
High temperature tolerant	Kanti, Pusa Agrani, RGN 13, Urvashi, NRCDR 02, Pusa mustard 25 (NPJ 112), Pusa mustard 27 (EJ 17)
White rust resistant	Basanti, JM 1, JM 2
Alternaria blight tolerant	Jawahar Mustard 3, Him Sarson 1 (ONK 1), Ashirwad (RK-01-03)

Genetic enhancement

Since, there is a vast variability in the climatic and edaphic conditions in the mustard growing areas of India, development of appropriate cultivars is important. Introduction of relatively short duration cultivar found favor with the environment where effective growing seasonal length is short. Improved varieties of mustard stabilizes oil and seed yield through insulation of cultivars against major biotic and abiotic stresses, enhances oil and seed meal quality. Donor for drought (RH 819, Aravali mustard, Vaibhav, RH 30), salinity (CS 54, CS 52, Narendra rai, BPR 541-4, BPR 540-6, RM 11, RGN 48, RH 8814, SKM 9927), frost (RH 781, Urvashi, RGN 48, DHR 9701), high temperature tolerance at seedling stage (NRCDR 02, RH 8814, BPR 543-2, NPJ 92, NPJ 93, DHR 9701) and high temperature tolerance at terminal stage (BPR 541-4) were identified. Tolerant rapeseed-mustard varieties to various abiotic and biotic stresses have been developed (Table 1).

Use of innovative climate smart agro techniques for enhanced mustard productivity

Improved agro-techniques under irrigated and rainfed conditions, emphasized the need for timely sowing, line sowing, spacing, seed rate, balanced plant nutrition, thinning at appropriate time, irrigation management, weed management, etc .

Land and seedbed preparation

The seed bed for rapeseed-mustard should be firm, moist and uniform which allows good seed-to-soil contact, even planting depth and quick moisture absorption leading to a uniform germination. Minimum tillage, with or without straw, enhances soil moisture conservation and moisture availability during crop growth. As a consequence, the root mass, yield components and seed yield increases. Zero tillage is found to be good management practice for mustard as it conserves more moisture in the soil profile during early growth period (Rathore *et al*., 2014). The soil under zero tillage system contains higher amount of organic matter

Seed and sowing- Seed priming

Seed priming through controlled hydration and dehydration enhances early germination of mustard seed in less time, even in compacted soil. The soaking of mustard seeds in 0.025% aqueous pyridoxine hydrochloride solution for 4 hours improved germination. The differential response of varieties for imbibition gives advantage to some of them to germinate early as compared to others. At Hisar, maximum rate of imbibition was reported in 'NRCDR-2' (41.7%) and minimum in 'NRCDR-509' (7.5%). Such drastic difference in rate of imbibition is important for identification of suitable varieties under abiotic stress conditions viz. drought, frost and temperature abnormalities.

Sowing time

Sowing time is the most vital non-monetary input to achieve target yields in rapeseed-mustard. Soil temperature and moisture influence the sowing time of rapeseed-mustard in various zones of the country. Mustard sown on 14 and 21 October took significantly more days to 50% flowering (55 and 57) and maturity (154 and 156) compared to 7 Oct planting (Kumar *et al*., 2002). Delayed sowing resulted in poor growth, low yield and oil content. Date of sowing influence the incidence of insect-pest and disease also. Sowing on 21st Oct resulted in least Sclerotinia incidence. The maximum (20.5-25.4^{o}C) and minimum (3.9-10.7^{o}C) temperatures at the flowering stage of crops established through sowing on 21st Oct were negatively correlated with the development of Sclerotina rot. Mustard aphid (*Lipaphis erysimi* (*Kaltenbach*) has been reported as one of the most devastating pests in realizing the potential productivity of Indian mustard. Normal sowing (1st week of Nov) also helps in reducing the risk of mustard aphid incidence.

Planting technique

Sowing technique depends upon land resources, soil condition and level of management and thus broadcast, line sowing, ridge and furrow method and broad bed and furrow method are common sowing techniques. Under normal and conserved moisture regime, seed placement in moist horizon under line sowing becomes beneficial. Ridge and furrow sowing was superior to conventional flat sowing for growth parameters and yield of *B. juncea* (Khan and Agarwal, 1985). Under saline condition, seed yield of canola in ridge sowing was higher by 45, 31 and 28% than broadcast, drill and furrow sowing methods respectively.

Crop geometry

The optimum plant population density/unit area varies with the environment, the genotype, the seeding time and the season. Uniform distribution of crop plants over an area results in efficient use of nutrients, moisture and suppression of weeds leading to high yield. In wider row spacing (45-60 cm), solar radiation falling within the rows gets wasted particularly during the early stages of crop growth whereas in closer row spacing upper part of the crop canopy may be well above the light saturation capacity but the lower leaves remain starved of light and contribute negatively towards yield. An increase in rows up to 30 cm correspondingly prolonged maturity days followed by optimum 45 cm and wider rows 60 cm spacing. The plants receiving narrow row spacing increased vegetative growth. The recommended spacing for mustard is 30x10 cm and for hybrids it is 45x10 cm.

Plant population and inter-plant shading

The dense plant population reduces the yield due to reduction in the photosynthetically active leaf area caused by mutual shading. The specific leaf weight (SLW), crop growth rate (CGR) and net assimilation rate (NAR) was more adversely affected by 50% shading at 71-90 days after sowing (DAS). On an average 50% shading at 91-110 DAS was more deleterious than 25% shading at 91-110 DAS i.e. at terminal seed development stage.

Rapeseed- Mustard based efficient cropping systems

Physiography, soils, geological formation, climate, cropping pattern and development of irrigation and mineral resources greatly influence selection of variety and cropping system. Urdbean-mustard; greengram-mustard, guar-mustard and pearl-millet-mustard are potential cropping systems. Productivity measured in terms of land equivalent ratio (LER) was higher for intercropping of chickpea and mustard in the 4:1 row ratio than for sowing of chickpea and mustard in sole stands (Singh and Rathi, 2003). The cropping sequences involving rapeseed-mustard for different states have been given in Table 2. In rainfed areas, it is desirable to select a crop and variety, which produce fairly good yield under limited soil moisture conditions. Under irrigated conditions, at Bharatpur, the seed yield equivalent of mustard was in intercropping of mustard+potato (1:3), mustard + wheat (1:5), mustard + barley (1:5) than pure mustard. Intercropping of mustard with chickpea, field pea or linseed proved superior over their cultivation as a pure crop.

Table 2: Cropping sequences for different states

State	Crop sequence	
	Irrigated	Rainfed
Gujarat	· Bajra/ Groundnut/ Sesame-Mustard · Moong / Urd-Mustard	---------
Haryana	· Early fodder-Mustard · Groundnut / Bajra-Mustard	· Fallow-Mustard · Maize/ Bajra-Mustard
Punjab	· Cotton-Mustard / Gobhi Sarson · Kharif fodder-Toria / Winter maize (Transplanted) · Kharif fodder-Toria / Wheat · Maize-Toria- Sugarcane · Rice-mustard/ gobhi sarson	· Bajra-Mustard · Fallow-Mustard
Rajasthan	· Fallow-mustard · Maize / Bajra / Moong / cluster bean/ Cowpea-Mustard / Taramira	· Bajra+Cowpea-Mustard · Sorghum (Fodder)- Mustard · Bajra-Mustard · Urd / Moong / Cowpea-Mustard

Water management

Rapeseed-mustard crop have comparatively low water requirement but sensitive to water shortage at critical stages. Irrigation is very important for getting the optimum productivity potential of mustard, but equally important is the quality of irrigation water. In general, two irrigations, one at flowering stage and at siliqua formation stage increased seed yield. Increase in the amount of water increased leaf water potential, stomatal conductance, light absorption, leaf area index, seed yield and evapo-transpiration and decreased canopy temperature. Crop receiving two irrigations at pre-flowering and pod-filling stages produce about 33 percent more seed than un-irrigated crops. Single irrigation given at vegetative stage is found to be most critical, as irrigation at this stage produces the highest yield. If the quality of irrigation water is poor, it needs certain treatment and management before being utilized for crop production. The increasing levels of salinity of the irrigation water applied at pre-sowing and flower initiation reduces the plant height, the branching pattern and the pod formation (Chauhan *et al.*, 2004). Irrigation with saline water (12 and 16 dS/m) decreased the dry matter yield significantly when applied at pre-sowing or later. The saline irrigation at the pre-flowering stage or later reduced the grain yield by 50% and 70%, respectively. As a result of saline water irrigation, the soil water infiltration was reduced up to 7%. The EC and exchangeable sodium percentage (ESP) were increased by 2.2 dSm^{-1} and 9.0 respectively. The yield of mustard crop could be further increased by better leveling the plots, reducing the level difference to less than 10 cm. The ill effects of saline water can be overcome with proper N management. Non-saline water can be substituted by applying N and saline water.

Enhancing water use efficiency

Water use efficiency is dependent on a host of factors. Considering the fact that most of the oilseed crops are grown on water scarce environments under rain-fed conditions, the improvement in water use efficiency is vital. Major changes in irrigation management and scheduling in order to increase the efficiency of use of water are a requirement in the present scenario. Some of the promising irrigation techniques as micro irrigation (sprinkler, drip, micro sprinkler) have already proved to be highly efficient with irrigation efficiency at ranges of more than 90 per cent. Agronomic measures such as varying tillage practices, mulching and anti-transparent can reduce the demand for irrigation water. Another option is deficit irrigation, with plants exposed to certain levels of water stress during either a particular growth period or throughout the whole growth season, without significant reduction in yields. Deficit (or regulated deficit) irrigation is one way of maximizing water use efficiency (WUE) for higher yields per unit of irrigation water applied. Trickle fertigation permits application of nutrients directly at the site of high concentration of active roots. Since nutrients are applied to a limited soil volume, the fertilizer use efficiency is also high. Maximum biological, seed and oil yields were harnessed from mustard grown under micro irrigation systems (micro-sprinkler and drip). Overall, significantly higher production efficiency, better

Table 3: Effect of irrigation methods and fertigation on yield attributes, yield, protein and oil content of Indian mustard *cv. Rohini*

Irrigation systems	Seed Yield, Kg ha^{-1}		Oil yield, Kg ha^{-1}		Sustainability index		Production efficiency (Kg $ha^{-1}day^{-1}$)		Irrigation water use efficiency (Kg ha^{-1}-mm)	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
CB	1260^{a}	1759^{a}	550.0^{a}	716.0^{a}	0.45	0.46	8.1a	11.3^{a}	10.5^{a}	14.9^{e}
DS	1680^{c}	1897^{ab}	731.0^{c}	790.0^{b}	0.64	0.51	11.0c	12.2^{ab}	28.0^{c}	31.6^{c}
MS	1660^{c}	2086^{bc}	711.0^{c}	859.0^{c}	0.63	0.58	11.0c	13.5^{b}	27.7^{c}	34.8^{a}

Note: Within column, value represents with different letter indicate significant difference (P=0.05); CB Check basin, DS-Drip system, MS-micro-sprinkler system

sustainability was recorded under micro-irrigation irrigation systems compare to check basin irrigation systems (Table 3). Micro irrigation scheduling based on soil moisture and ET demand, resulted in improvement in growth, physiological and yield attributes, ultimately enhanced seed and oil yield, irrigation water use efficiency, sustainability, yield index and production efficiency (Rathore *et al.*, 2017).

Efficient nutrient management

Integrated nutrient management (INM) provides balanced nutrition and improves the nutrient uptake by mustard, hence enhances the use efficiency of various nutrients from the soil. The incorporation of 25% nitrogen through FYM+ 75% by chemical fertilizer + 100% sulphur significantly enhanced the uptake use efficiency and of nitrogen and sulphur in both seed and stover of crop followed by 100% NS and 50% N through FYM + 50% by chemical fertilizer+ 100% S (Bhat *et al.*, 2005). The highest mustard-equivalent yield, which includes converted yield of other crops in to mustard seed yield based on market price of the crops (24.88q/ha), net monetary returns (Rs. 15,537/ha), B: C ratio (2.07) and agronomic efficiency (16.1) were recorded with the application of 100% recommended N in the rainy season through FYM and 100% recommended NP in the winter season through inorganic fertilizers (Kumpawat, 2004).

At Bharatpur and Jobner, 17.8 and 8.6 % increase in seed yield was recorded with 50% RDF + 50% N through FYM and vermi-compost. Sole organic treated plot recorded 29.9% lesser seed yield over RDF at Jobner (AICRP-RM, 2008). Amount of available phosphorus increased over initial value when organic manures and crop residues were incorporated. Organic carbon status builds up in organic source-incorporated plots. The application of 10t FYM/ha in addition with recommended dose of fertilizer (RDF) improved soil physical condition by improving aggregation, increased saturated hydraulic conductivity and reducing bulk density and penetration resistance of the surface soil (Hati *et al.*, 2006).

The interactions among nutrients occur when the supply of one nutrient affects the absorption, distribution or function of another nutrient. Identification and exploitation of positive nutrient interactions hold the key for increasing returns in terms of crop yield, produce quality, and nutrient use efficiency. The interaction of N with Sulphur, a critical nutrient for all oilseed crops is a researchable issue. The use of high analysis straight fertilizers to supply N and P, the high cropping intensity and the inherent nature of the soil have led to wide spread S deficiency and a negative soil budget. While N directly affects the photosynthesis efficiency of the plants affects photosynthesis efficiency indirectly by improving the Nitrogen Use Efficiency (NUE) of the plant.

Micro nutrient management

The role and importance of micronutrients in enhancing production and productivity is one of the areas in which

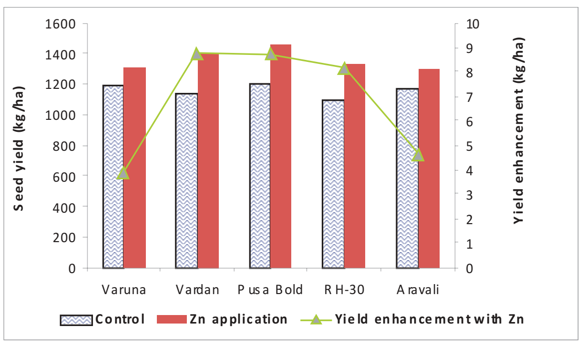

Fig 1. Influence of zinc application on seed yield of different cultivars of mustard.

adequate attention has not been given in the case of oilseed crops. The continuous promotion of straight fertilizers and the importance given to macro nutrients like N,P and K led to the neglect of the importance of micro nutrients. Micronutrient deficiency is now widely prevalent in the country including many of the oilseed growing tracts. Mustard, in general is very sensitive to micronutrient deficiency, specially zinc and boron. The harvest index (HI) was significantly affected by Zn application, although seed yield showed diminishing return with additional $ZnSO_4$ doses. However, genetic ideotype greatly influence response to zinc and Indian mustard varieties 'Pusa Bold' and 'Vardan' were found more responsive to zinc application under various trails of AICRP-RM, 2000 in different locations (Fig 1).

The concentration of Zn at flowering, pod formation stage, concentration and uptake of Zn in straw and grain at maturity and uptake of Zn in grain and straw at maturity of Indian mustard increased significantly with increase in Zn levels (Gupta and Kaushik, 2006). Similarly, the seed yield increased significantly (16-47%) with the application of boron. The average response to boron application ranged from 21-31%. The yield increase was due to 27% and 10% increase respectively in seeds/siliqua and 1000-seed weight, indicating the importance role in seed formation (AICRP-RM, 2005).

In oilseed crops the link between yield and availability of micronutrients in the soil has not been exhaustively studied. Table 4, presents the quantity of macro and micronutrients removed by oilseed crops from soil for

Table 4. Removal of nutrients from soil by oilseed crops

OilseedCrops	Kg/ tonne of produce						g/ tonne of produce			
	N	P	K	S	Ca	Mg	Zn	Fe	Mn	Cu
Groundnut	58	20	30	8	21	13	109	2284	93	36
Mustard	65	21	53	16	57	10	58	635	169	21
Soybean	71	31	58	9	14	8	77	354	83	30
Sunflower	60	19	126	12	68	28	58	19	25	32

Source: Pasricha and Tandon (1993)

unit production of economic produce. From the table it is clear that availability of micronutrients is essential for sustaining and increasing production and productivity of these crops. Strategies for replenishment of micro nutrients in the soil and further studies including agronomic screening for nutrient efficient genotypes for specific oilseed crops are required to exploit the full yielding potential of the oilseed crops.

Weed management

Weeds cause alarming decline in crop production ranging from 15-30 % to a total failure in rapeseed-mustard yield. The critical period is 15-40 days. Weeds compete with crop plants for water, light, space and nutrients. Therefore, timely and appropriate weed control greatly increases the crop yield and thus nutrient use efficiency. The common weeds of mustard are *Chenopodium album*, *C.*

murale, Cyperous rotundas, Cynadon dactylon, Melilotus alba, Asphodelus tenuifolius, Orobanche spp.and Anagalis arvensis. Broomrape (*Orobanche*) is a major devastating parasitic weed of mustard. Broomrape weed infestation caused 28.2% average reduction in Indian mustard yield. Among *Orobanche* spp., *O. aegyptica* is one of the most important parasitic weed causing severe yield and quality reducing factor in rapeseed-mustard. It is endemic in semi-arid region and may reach epidemic proportions depending upon soil moisture and temperature.

Farmers have adopted herbicides for weed control because the chemicals can increase the profit, weed control efficiency, production flexibility and reduce time and labour requirement for weed management. Hand weeding at 20DAS, fluchloralin pre-plant incorporation@0.75 kg/ha, wooden hand plough between the lines at 35 DAS on Indian mustard was found effective. Polythene mulch was also found effective in controlling the weeds in mustard. Preceding crop of cowpea, black gram, moth bean, sunnhemp, clusterbean and sesame significantly reduced *Orobanche* menace in succeeding mustard crop while sorghum, pearl millet, chilies and green gram did not influence broomrape infestation in mustard (Kumar, 2002). At Bharatpur, S K Nagar and Bawal directed spray of glyphoste (0.25-1.0%) and 2 drops of soybean oil per young shoot of O*robanche*, showed effective control and recorded 91.9% higher seed yield over infected sick plot. Some cultural practices like mulching and hoeing are also helpful to curb some of the major weeds in mustard by providing a shield against sunlight, reducing the soil temperature and acting as a physical barrier for emergence of weeds. Maximum seed yield (2540 kg/ha) was obtained in the treatments where plots were kept weed free followed by the treatment where mulching was done after hoeing.

Resource Conservation Technologies in mustard based cropping system

To assess the impact of various RCTs on growth, yield attributes and yield, soil properties and economics of mustard based cropping systems; an experiment was conducted at DRMR. Five cropping systems, viz. fallow-mustard, green manure-mustard, brown manure-mustard, cluster bean-mustard and pearl millet-mustard were grown under conventional tillage (CT), reduced tillage (RT), zero tillage (ZT) and furrow irrigated raised bed (FIRB) in split plot design. A significant effect of RCTs was found on growth parameters of mustard like crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR) and leaf area index (LAI). The highest amount of water was applied in CT. The poor quality water of irrigation resulted in increase of EC at surface soil under CT. The highest amount of organic carbon was found under ZT; RT being at par with it and both were found significantly superior over CT and FIRB. Maximum seed yield of mustard was recorded under FIRB and though seed yield under conventional tillage was higher but it was at par with the seed yield obtained under zero tillage (Fig 5). Thus zero tillage could be good option to reduce cost of cultivation and improve soil health. Four improved varieties (Rohini, Varuna, Laxmi and NRCDR 2) and 3

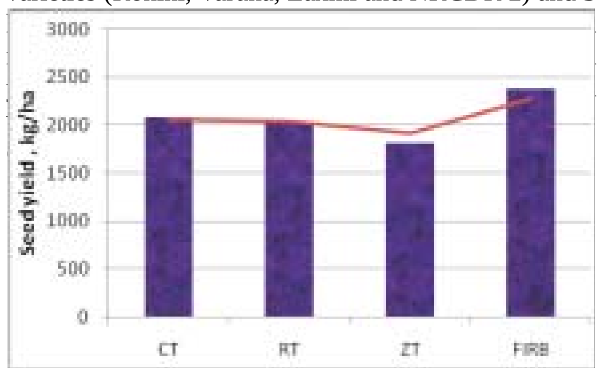

Fig 5: Seed yield of mustard cv. Rohini under various tillage systems

Further research related to the applicability of RCTs to oilseed crops needs to be taken up in the country as most of the RCTs have been tested and understood on the basis of their working in rice – wheat cropping systems. Development of suitable machinery, studies on residue management in oilseed crops, development and agronomic testing of varieties suitable for zero tillage conditions , advantages and impact of land leveling on oilseed crop production , productivity and input use efficiency etc are some of the indicative areas of research gaps which needs to be addressed in rapeseed-mustard.

Contingency crop Planning (CCP)

Contingency Crop Planning refers to alternative crop plan to minimize adverse effect of weather aberrations. Rapeseed-mustard are mostly grown in marginal and resource poor conditions. Weather aberrations are a potentially limiting factor in realizing optimum yield. In such a scenario, the contingency crop planning techniques can be of help. A case in point for the use of this technique is the severe drought conditions experienced during the 2002-03 crop season. The production of oilseeds which was 20.80mt during 2001-02 decreased to 14.84 during 2002-03. Such types of major fluctuations in production and productivity can be avoided by suitable crop contingency planning.

Rapeseed-mustard are mostly amenable to the development to contingency plans and the benefits from such planning are also substantial theses across are affected by one or other type of extreme weather phenomenon. In rapeseed mustard, high temperature at the seedling stage, terminal heat stress, rainfall aberrations and the probability of occurrence of frost are weather aberrations having an influence on yield. The contingency plans take holistic view of the cropping system and aim at optimizing the stability of the production system while minimizing the associated risk elements. Opportunity cropping, mid-season correction, response farming, etc. are some of the commonly used techniques in contingency crop planning.

Contingency plan for monsoon aberration

For early onset :

Promotion of awareness among the farmers about high temperature tolerant varieties like Kanti, Pusa Agrani, Urvashi, NRCDR 02, Pusa mustard 25 (NPJ 112), Pusa mustard 27 (EJ 17). The seedling stage is sensitive for high temperature and sowing of high temperature tolerant high yielding varieties of rapeseed-mustard will help to harness good productivity.

Late onset of monsoon:

Under this situation, the shorter rainy season and high risk of water stress for long duration varieties. Thus early-maturing varieties, cultivation of early mustard with life saving irrigation from harvested water: Cultivation of early mustard varieties like Kanti, Narendera Ageti Rai 4, Pusa Agrani, Pusa Mahak, Pusa Vijay, Pusa mustard 25 (NPJ 112), Pusa mustard 27 (EJ 17) will be promoted in the upland situation which has been lying fallow year after year due to lack of water. Vardan, Navgold (YRN 6), RGN 145, NRCHB 101, CS 56 (CS 234-2), Pusa mustard 26 (NPJ 113) under prevailing cropping systems :

* Guar-mustard
* Bajra+guar-mustard
* Maize-mustard+ wheat
* Fallow-mustard +chick pea

Early drought:

The germination of mustard seed will become difficult which results in poor crop establishment and need for partial or sometimes complete resowing. Grow drought tolerant short duration varieties. The agronomic practices like breaking of soil crust, balanced nutrition at planting in the form of judicious integrated nutrient management, organic matter application, moisture conservation , water harvesting and life saving irrigation.

Mid season drought (long dry spell, consecutive 2 weeks rainless (>2.5 mm) period)

Crop management practices for mid season drought (long dry spell) are life sowing irrigation, thinning, mulching of crop residues or weed biomass to conserver soil moisture, weeding, spray of 0.1% thiourea + 0.2%, FeSO4 0.5%, K2SO4 / KCI + 1% urea.

Terminal drought

Early cessation of rainfall under rainfed conditions affects grain filling, fewer productive branches, reduced pod size and seed weight and ultimately poor seed productivity. The varieties suitable for growing under terminal drought and heat tolerant should be promoted under arid and semi-arid conditions. Terminal drought (early withdrawal of monsoon), soil moisture stress at pod development stages reduces rapeseed-mustard productivity substantially. Apply life saving irrigation, harvest the crop for fodder purpose, keep the field weed free and in harvested field, prepare the field followed by soil planking to conserve moisture for Rabi rainfed crops. Select the varieties suitable under terminal drought conditions.

Promotion of profitable intercropping systems

Indian mustard cultivars (RH 30, RH 781, Vardan) for profitable intercropping systems

* Mustard+ Wheat
* Mustard+ Pea
* Mustard+ gram
* Mustard + linseed

Frost management

The varieties have been developed for frost tolerance and recommended for cultivation to minimize the effect of frost damage. These varieties are RGN 13, RH 819, Swaran jyoti, RH 781, RGN 48. Along with suitable varieties to avoid frost damage, the agronomic practices like application of irrigation, Spray of 0.1% H_2SO_4, or spray 500 ppm thiourea. Spray of 0.1% H_2SO_4, mass smoking at night, apply light irrigation are effective in minimizing the frost damage to rapeseed-mustard crop.

Conclusion

The production of rapeseed-mustard in the country needs a substantial boost to meet the rising edible oil demand in the country. The production constraints and strategies to increase the productivity of the rapeseed-mustard, listed out can serve as a guideline for future research in these crops. To meet the ever growing demand of oil in the country, the gap is to be bridged through management techniques. Production technologies, recommended for different agro-ecological regions needs to be followed. The attainment of self sufficiency in edible oils is possible. Opportunity cropping, mid-season correction, response farming etc are some of the commonly used techniques in contingency crop planning, which are effectively helping in minimising weather related risk and ensures stable high rapeseed-mustard productivity. CCP as a tool is more pertinent in oilseed crops where a significant acerage comes under rain-fed farming. Resource conserving technology is the most cost-effective strategy to reduce N loss and GHG emission, whereas integrated N management cost high for mitigating GHG emission and sustainably enhancing the rapseed-msutard productivity.

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