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Strategies and technologies for

enhancing rapeseed-mustard production and farmer income

Pankaj Sharma[1], Hari Om Sharma[2] and P. K. Rai[3]

Directorate of Rapeseed-Mustard Research, Bharatpur (Rajasthan) 321 303

India is the largest producer of oilseeds in the world and accounts for 7.4% of oilseeds output; 6.1% of oil meal production; 3.9% oil meal export; 5.8% of vegetable oil production; 11.2% of oil import and 9.3% of the edible oil consumption. Globally India continues to be at third position after Canada and China in acreage (19.3%) and after China and Canada in production (11.1%) of rapeseed-mustard. Estimated area, production and yield of rapeseed-mustard in the world during 2016-17 was 36.68 million ha (m ha), 72.42 million tonne (m t) and 1974 kg/ha, respectively. There has been a considerable decrease in productivity from 1,950 kg/ha during 2009-10, but a steady rise has been recorded in 2015-16 (2,057 kg/ha).

Key words: Farmer, Income, Oilseeds, Production, Rapeseed-mustard

WITH its rich agro-ecological diversity, India is ideally suited for growing all the major annual oilseed crops. Among the nine oilseed crops grown in the country, seven are edible (soybean, groundnut, rapeseed-mustard, sunflower, sesame, safflower, and niger), and two non-edible oils (castor and linseed). Among these oilseed crops, the share of rapeseed-mustard is about one-fourth of total area and one-third of total oil production in the country. Rapeseed-mustard is the major source of income especially for the marginal-and small-farmers in rainfed areas which are about 25% of the total cultivated area.Due to low water requirement and feasibility of rapeseed-mustard, it suits and adapts well in different cropping systems. It is cultivated across the country mainly in Rajasthan, Madhya Pradesh, Uttar Pradesh, Haryana, West Bengal, Asom and Gujarat which contribute maximum to its production (>93%) and acreage (>91%) and now its cultivation is also being extended to non-traditional areas of Karnataka, Tamil Nadu, Telangana and Andhra Pradesh.

During the last decade years, rapeseed-mustard area was highest during 2010-11 (6.9 m ha) However, highest production (8.18 mt) and productivity (1,324 kg/ha) were achieved during 2016-17. This quantum jump attained in production is attributed to the development and wide spread adoption of high-yielding varieties, and improved agro-production technologies in specific situations. The decline in the acreage and production earlier had been largely due to abiotic stresses like high temperatures at germination, juvenile and terminal stages, droughts, cold spell, frost/fog, and intermittent rains, and biotic stresses like diseases and pests in many northern parts of the country for the last several years.

In India,the cultivation of brown

sarson (*Brassica rapa* var. brown *sarson*), which once dominated the entire rapeseed-mustard growing region, has now almost gone obsolete. There are two different ecotypes of brown *sarson*: *lotni* (self-incompatible) and *toria* (self-compatible). The *lotni* predominantly cultivated in colder regions of the country, particularly in Kashmir and Himachal Pradesh. The *toria,* on the other hand, is cultivated in limited areas of eastern Uttar Pradesh. Yellow *sarson* (*Brassica rapa* var. yellow *sarson*) is now mainly grown in Asom, Bihar, north-eastern states, Odisha, eastern Uttar Pradesh and West Bengal. *Toria* (*Brassica rapa* var. *toria*) is a short duration crop cultivated largely in the eastern states Asom, Bihar, Odisha and West Bengal, mainly as a winter crop. In Haryana, Himachal Pradesh, Madhya Pradesh, Punjab, Uttarakhand and western Uttar Pradesh, it is also grown as a catch crop; but the area has declined due to shift in the cropping pattern. *Taramira* (*Eruca sativa*) is grown in the drier parts of north-west India comprising Rajasthan, Haryana, and Uttar Pradesh. *Gobhi sarson* (*Brassica napus*) and *Karan rai* (*Brassica carinata*) are the new emerging oilseed crops, having a limited area of cultivation. *Gobhi sarson* is a long duration crop and is confined to Haryana, Himachal Pradesh, and Punjab.

Yield gap analysis

Rapeseed-mustard is predominantly cultivated in Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana, Gujarat and West Bengal. The results of frontline demonstrations (FLDs) on rapeseed-mustard organized during the last ten years indicate the average productivity gap of 10 to 25% between the improved and farmers' practices while national average productivity gap of 20 to 63% between FLDs yield and states average.Yield gap-I [between improved practices (IP) and farmers practices(FP)]as a result of demonstration of improved technology ranging from 10.8% in Madhya Pradesh to 25.8% in West Bengal, whereas, the yield gap-II (between IP and state average productivity) was ranging from 20.3 in West Bengal to as high as 63.0% in Uttar Pradesh.

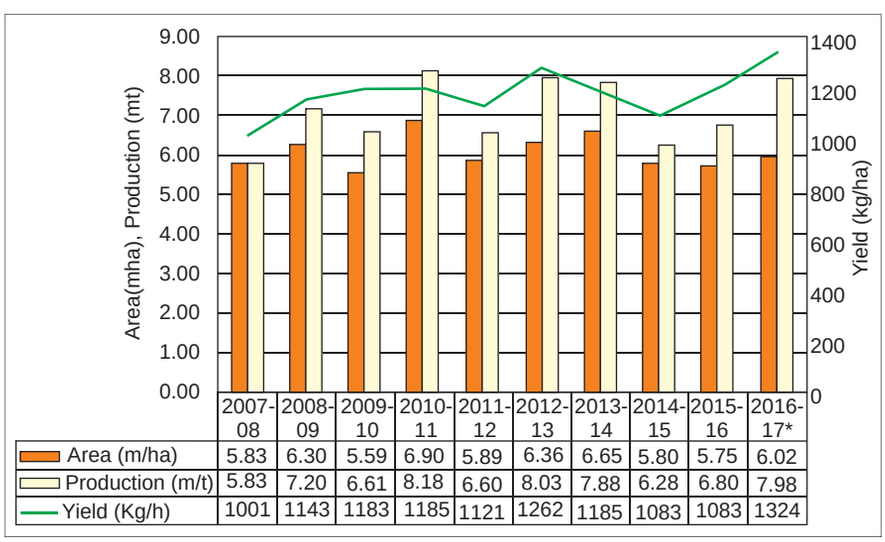
Rapeseed-mustard productivity at national level could be improved by bridging the yield gaps. This indicates the presence of significant yield reservoir which can be exploited through spread of appropriate technology among the farmers. Therefore, there is an urgent need for effective transfer of improved rapeseed-mustard production technologies to convince them to adopt such technologies so that yield gaps can be bridged and rapeseed-mustard production in the country can be stepped up.

Various constraints in production

The annual edible oilseed crops are diverse in their agro-climatic requirements and crop management practices. Rapeseed-mustard, which contributes nearly 80% of the total *rabi* oilseed production, is a vital component in the edible oil sector. Enhancing the production and productivity of rapeseed-mustard assumes significance; not only from the farmers' view point but also for the edible oil industry and other vertically and horizontally linked enterprises.

The major constraints faced by this crop include among other things.

- The uncertainty of acreage of the crops due to several factors: climatic, biological, natural resources, policy decisions etc.
- Low and erratic rainfall are leading to continuous moisture stress/ drought over the years. High temperature during crop establishment (mid-September to early November), cold spell, fog and intermittent rains during crop growth caused considerable yield losses by physiological disorder.
- Depleting availability and deteriorating the quality of water as well as build-up of soil salinity in most of the areas of Rajasthan and parts of Uttar Pradesh, Haryana, and Punjab.
- Biotic stresses caused by insects (painted bug,aphids), fungal (*Sclerotinia* stem rot,white rust, downy mildew and *Alternaria* blight), bacterial and viral pathogens, parasitic weeds (*Orobanche)* and other weeds collectively result in approximately 45% yield loss annually.
- Farmers' reluctance in adoption of high-yielding varieties suited to varied conditions, balanced dose of fertilizers, adoption of suitable production, plant-protection measures and harvesting at optimum time .
- Non-availability of quality seeds of improved varieties suitable for various micro-farming situations.
- Late sowing due to late harvest of *kharif* (*aman*) paddy, inadequate moisture at sowing time particularly in rice-fallow lands and flood affected area leading to delayed land preparation and club root disease problem(West Bengal).



	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17*
Area (m/ha)	5.83	6.30	5.59	6.90	5.89	6.36	6.65	5.80	5.75	6.02
Production (m/t)	5.83	7.20	6.61	8.18	6.60	8.03	7.88	6.28	6.80	7.98
Yield (Kg/h)	1001	1143	1183	1185	1121	1262	1185	1083	1083	1324

Fig. 1. Trends in area, production, productivityof rapeseed-mustard in India

Table 1. Productivity potential (kg/ha) of improved technology of rapeseed-mustard

States	FLDs Mean yield (kg /ha)		Yield gap-I	State average	Yield gap-II
	IP	FP	(%)	yield (kg/ha)	(%)
Rajasthan	1,843	1,593	15.7	1,256	46.7
Uttar Pradesh	1,830	1,576	16.1	1,123	63.0
Haryana	2,076	1,762	17.8	1,601	29.7
Madhya Pradesh	1,742	1,572	10.81	1,122	55.25
Gujarat	2,163	1,857	16.5	1,437	50.5
West Bengal	1,237	983	25.83	1,028	20.33

Improved package of practices of rapeseed-mustard

Land preparation: Preparation of the land is important for maintaining a proper tilth and other soil characteristics required for the crop. Deep ploughing during summer should be done, which helps to destroy pests.Under irrigated condition, first ploughing should be done with soil turning plough followed by 3 to 4 harrowing or ploughing and planking after every ploughing.Under rainfed conditions, disc harrowing should be carried out after every effective shower in monsoon to conserve soil moisture. Planking should always follow the - harrowing or ploughing to avoid clod formation and moisture loss.Apply 25 kg 1.5 % quinalphos dust/ha at the final ploughing to minimize the problem of soil inhabiting insects particularly painted bug.

Sowing time: It is between 10 and 25 October for sowing.It is better to complete by 20 October under irrigated conditions. For yellow *sarson*, the recommended time of sowing is the first fortnight of October. *Toria* should be shown during the first fortnight of September. The maximum temperature during sowing should not be more than 32° C. However, it is advised to delay sowing if the temperature is high in rainfed conditions.

Seed rate and spacing: The maintenance of an optimum plant population is a pre-requisite for a good harvest of the crop. The use of recommended seed rate and spacing will ensure the proper plant population in the field. In general, the optimum seed rate is 3.0-3.5 kg/ha. Line sowing at 45 cm × 15 cm gives optimum plant population. For sowing use of quality seeds of improved varieties suitable for different agro-climatic conditions are recommended (Table 1). In late sown crops a closer inter-row spacing adopted where the row spacing is maintained at 30 cm. For *Toria* and Yellow *sarson* the row-to-row spacing should be kept at 30 cm. The method of line sowing using seed drills gives a higher yield per unit area when compared to broadcasting of seeds. Seed treatment with metalaxyl (apron 35 SD) @ 6g/kg seed can reduce the yield losses due to white rust and downy mildew. For control of soil borne pathogens seed treatment with *Trichoderma* @ 6g/kg seed is advised.

Nutrient management: Rapeseed-mustard is an energy rich oilseed crop which requires adequate quantity of nutrients. The crop is capable of removing large amount of nutrients depending on seed yield biomass production. It is estimated that 64.5 kg N, 20.6 kg P_20_5, 53.4 K_20, 16 kg S, 56.5 kg Ca, 9.5 kg Mg, 0.068 kg Zn, 0.63 kg Fe, 0.2 kg Mn and 0.02 kg Cu are removed in producing one metric tonne of mustard seed. The fertilizer should be applied based on soil-test which will reduce excess use of fertilizer and increase profitability.Application of N: P: K @ 80:40: 40 kg/ha under timely sown condition and @ 100:50:50 kg/ha under late sown condition along with sulphur @ 40 kg/ha, zinc sulphate @ 25 kg/ha and borax 10 kg/ha. Half of the nitrogen to applied as basal dose and half at 30-45 days after sowing at the first irrigation. For rainfed crop apply the full-recommended dosages of nutrients at the time of sowing.Replacing of diammonium phosphate with single super phosphate (SSP)(250kg/ha) resulting in availability of sulphur. Neem-coated urea is recommended to use as source of nitrogen. It is advised that gypsum @ 200 kg/ha should be applied as basal dressing, if SSP is not used as the source of phosphorus. Nitrogen-fixing bacteria (*Azotobacter*), Phosphate Solubilizing Bacteria and Mycorrhizae are the most commonly used bio-fertilizers which are recommended for rapeseed-mustard. Use of *Azotobacter* can reduce the nitrogen requirement up to 25-30 kg/ha provided bacterial strain is efficient and soil is rich in organic matter.

Inter-culture operations: To keep an optimum plant population and uniform plant growth, thinning operation should be done at 15 to 25 days after sowing. Weeds cause 15-30% yield loses in rapeseed-mustard. Two mechanical weeding using hand hoe is recommended at 15-20 and 35-40 days after sowing (DAS). The Pendimethalin pre-plant incorporation @ 1kg/ha also found effective. For effective control of *Orobanchae,*crop rotation and foliar spray of glyphosate @25 and 50g/acre at 30 and 55-60 DAS is recommended.

*Irrigation management:*The rapeseed-mustard crop requires about 190-400 mm of water.Crop is very sensitive to water stress at critical stages. Two irrigations, one at pre-flowering stage (35-45 days after sowing) and another need-based during siliquae formation stage increase seed yield. The mustard crop seed yield increases by 24% using micro-sprinkler (irrigation efficiency 60-70%) and by 18% using drip irrigation (irrigation efficiency 80-90%) over check basin (irrigation efficiency 30-40%). In the areas of limited irrigation or where the quality of irrigation water is low (example: brackish water) only the first irrigation is advisable.No irrigation between 25 December and 15 January is helpful to manage *Sclerotinia* rot disease.

Management of insect pest and disease: Among the major insect pest in rapeseed-mustard, painted but (*Bagrada cruciferarum*), mustard aphid (*Lipahisery simi*), saw fly (*Athalia proximia*) and Bihar hairy caterpillar (*Spilosoma oblique*) cause significant damage to crop. Further more, the important diseases affecting its productions are sclerotinia rot (*Sclerotinia*

Table 2. Important insect pest and disease of rapeseed-mustard and their control measures

Insects pests	Control measures
Painted bug	• Timely sowing of the crop. Application of 25 kg 1.5 % quinalphos dust/ha at the final ploughing; Apply quinalphos 1.5% @ 20-25 kg/ha after appearance of the insect attack; Spray the crop with Malathion 50 EC @ 1ml/lit of water.
Mustard aphid	• Destroy the infested twigs to prevent the aphid multiplication. Application of Oxydemeton methyl 25 EC or Dimethoate 30 EC or NSKE @ 1ml/lit of water. Release of predators such as Coccinellids, Syrhid and lacewing to minimize the incidence.
Mustard sawfly	• Malathion 50 EC @ ml/1 lit of water.
Bihar hairy caterpillar	• Collect the infested leaves and destroy them; Spay of Malathion 50 EC @ 1ml/litre of water.
Disease	***Symptoms/ control measures***
Sclerotinia stem rot	• Stem of the infected plant show white mycelia growth, rotting and stem breaks down.
	• Seed treatment with Carbendazim @ 0.2% or *Trichoderma* 6 g/kg seed; Foliar spray of Carbendazim 2g/lit of water at 65-70 days after sowing no irrigation during 25 December to 15 January.
White rust and downy mildew	• Initially milky white dry eruptions appear on the lower surfaces of the leaves. Later on flowering shoots become malformed.In downy mildew white downy growth appears on lower surface of cotyledons, true leaves and inflorescence. Infected plants show necrotic patches with white cottony growth
	• Seed treatment with Metalaxyl (Apron 35 SD) @ 6 g/kg seed. Foliar spray of Ridomil MZ 72 WP 2g/lit of water after appearance of diseases.
Alternaria blight	• Infected leaves show circular, light brown to black spots with concentric rings. Pod infection in the form of black spots
	• Collect and burn the diseased plants, application of Mancozeb (Dithane M-45) 2g/lit of water
Powdery mildew	• White powdery superficial growth on all plant parts observed.
	• Spray of Dinocap1g/lit of water or wettablesulphur2g/lit of water as disease appears.

sclerotiorum), white rust (*Albugo candida*), downy mildew (*Hyloperonospora parasitica*) and *Alternaria* blight (*Alternaria brassicae*). An integrated approach including various cultural practices is recommended for effective management of diseases and insect pests. The control measures of these pests and diseases reported in Table 2.

Harvesting and threshing: The proper harvesting, threshing and storage of the crop is important to avoid post-harvest losses. Crop should be harvested when 75% of pods turn to golden yellow. At this stage, majority of seeds are firm when presses between fingers. The crop should preferably be harvested in the morning when the pods are damps with night dew, which minimizes the shattering losses.Threshing should be done preferably by using threshers. Seeds should be sun-dried for at-least one week to reduce the moisture content.

Location specific technology: These are as follows:

- Cultivation of short-duration crop of cluster bean or green manure instead of keeping the land fallow during *kharif* (Rajasthan).
- Intercropping of mustard with chickpea (1:4) and with lentil (1:6) Rajasthan, and Uttar Pradesh.
- Taking the advantage of rains in the first fortnight of September, sowing of *toria* should be done followed by wheat or sugarcane in Uttar Pradesh.
- For the management of *diara land*: Follow rice-mustard cropping system in *Gomti diara* and wheat + mustard and maize-*toria*-wheat cropping systems in *Saryu Diara*.
- Adopt the remunerative intercropping systems. In irrigated condition *toria* + sugarcane (1:1 / 2:1), mustard + wheat (1:9), mustard + potato (1:3) and in rainfed condition, mustard + gram (1:5) combination be adopted in Uttar Pradesh.
- Intercropping: chickpea+ mustard (4:1), wheat + mustard (9:1) and lentil + mustard (5:1) (Haryana, and Rajasthan).
- If monsoon is delayed and the *kharif* crops like maize, pearl millet and paddy suffer severely, *toria* may be sown in Haryana and Rajasthan.
- Use of white rust resistant Indian mustard variety-Jawahar Mustard 1 in the affected areas (Madhya Pradesh).
- Paira cropping of yellow *sarson*-broadcasting yellow *sarson* early in the standing *aman* rice 3 days before its harvest WB.
- Grow short duration varieties such as Pusa Mahak and Sej-2 of Indian mustard on residual soil moisture (West Bengal).
- Grow Jhumka, Ragini and Subinoy varieties of yellow *sarson* in West Bengal.

Way forward

- Improvement of yield, and quality of oil and seed meal.
- Bio-intensive IPM module as a functional component of Integrated Crop Management. It should include insect-pests, diseases and weeds as well.
- Extending of rapeseed-mustard cultivation to non-traditional areas eg Andhra Pradesh, Telangana and Karnataka.
- Farmers to be encouraged to grow quality/canola type (double low; low erucic acid, low glucosinolate) varieties of rapeseed-mustard to fetch premium prices in market and Governmnet need to ensure better prices for these varieties.
- Optimum and judicious use of inputs (seeds, fertilizers, water and tillage) will reduce the cost of cultivation.
- Use of drip irrigation and sprinkler irrigation, which have high water use efficiency, should be promoted over check basin irrigation.

- Identified rapeseed-mustard growing regions which needs immediate interventions are; Bundi, Pali, Jaisalmer, Jodhpur, Kota, Chittorgarh, Jhalawar, SawaiMadhopur, Tonk (Rajasthan); Barpeta, Darrang, Dheemaji, Karbi Anglog, Sonitpur (Asom); Bhind, Gwalior, Morena, Shivpuri (Madhya Pradesh); Budaun, Barabanki, Kanpur Dehat, Kheri, Mathura,Sitapur (Uttar Pradesh); Bhiwani, Mahendragarh (Haryana); Banaskanta, Mehsana, Patan (Gujarat).
- Enhanced use of Information Technology-based decision support systems for technology transfer and development of application software (Decision Support System/Expert System).
- Public-Private Partnership for crop diversification, value addition, seed production, capacity building, market driven extension, and feedback generation for research system.
- Documentation of Indegenoious Technology Knowledge having a bearing on the productivity, and its validation for inclusion in the package of practices for a particular agro-ecosystem.
- In oil processing industries modernization of the mechanical crushing units can increase the oil recovery from 35% to 40-42%.

SUMMARY

As policy measures to attract the farmers towards oilseeds, in general, and rapeseed-mustard in particularly, favourable support price, higher tariff rate on import of edible oil and effective market intervention would have to be looked. Bee-keeping in rapeseed-mustard crop can increase the yield by 15 to 20% and will generate additional income to farmers. Conduction of more number of on different production and protection aspects for effective dissemination of technology is needed.

[1-2]Principal Scientist [3]Director, corresponding authors' e mail: director.drmr@gmail.com

Integrated hill farming system of Sikkim doubles farmers income

Sikkim, a hilly state in the Eastern Himalayas, has five climatic zones consisting of lower hill, middle and higher hills, alpine zones and snow bound land. Nearly 82% of the land is forest covered and the unique biodiversity of state is well known throughout the world and covers 0.2% of national geographical area only, however harbours 26% of the country's total biodiversity that accounts 7 to 8% of recorded species in the world. In Sikkim, agriculture is done mostly through integrated farming. The pace of agriculture, horticulture and other farming practices are not uniform. Natural climatic conditions, sloping topography of land, narrow strip terrace cultivation, very low per caput land availability are limiting the scope of cultivating any single crop or variety to grow at different slopes. Modern agricultural techniques have opened avenues and scope for promoting high value crops like flower crops.

Even though, East Sikkim has advanced in floricultural crops due to marketing avenues and urbanization, the potential of commercialization has not been fully exploited. The state government agencies laid basic foundation for horizontal expansion with infrastructural facilities like polyhouse cultivation and input material supply. The National Research Centre on Orchids, Sikkim played a crucial role in imparting training and extension for its stakeholders, progressive orchid farmers and staff from state department, on orchid production and protection technologies. Model Floriculture Unit was show-cased and demonstrated at institute on orchids and roses. Large-scale quality plating material of Cymbidium hybrids was distributed to chain group of farmers, apart from providing seedlings of early flowering and scented Zygopetalum orchid. Recently, the village cluster from Rai Goan, East Sikkim was adopted for Orchid technology demonstration and assistance under *'Mera Goan Mera Gaurav'* scheme. Declaration of Sikkim as organic state by the Prime Minister, Shri Narendra Modi, on 18 January 2016 added feather in the cap to the on-going programmes aiming for premium returns through small scale enterprise.

Impact: Apart from revenue from farm produce these new developments led to the Sikkim farmers to produce orchid flowers and seasonal flowers and earned laurels on different occasions.Smt. Anuradha Chettri from Upper Namcheybong, East Sikkim earned revenue of ₹ 13,000/ year from sales of Orchid flowers and plants. She was also awarded Prestigious Pandit Deen Dayal Upadhyay Antyodaya Krishi Puruskar 2015 (Zone-VI).