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Review

Analysis of seed chain and its implication in rapeseed-mustard (*Brassica* spp.) production in India

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ABSTRACT

India is ranked third after Canada and China sharing about 11.0% of the global rapeseed-mustard production (72.41 m t) and 24.7% and 29.4% in terms of area and production, respectively, of oilseeds in India during 2018-19. Of the projected demand of 82-101 m t of oilseeds by 2030, contribution of rapeseed-mustard is projected at 16.4-20.5 m t, considering its share of 20%-25% in production. Near doubling the production of rapeseed-mustard from its current production of 9.26 m t within 10 years is a daunting challenge necessitating multi-pronged strategy. First and foremost approach would be to bridge the exploitable yield reservoir (EP II) of 57.2% in rapeseed-mustard. Seed is the technological carrier and facilitates the realization of potential of variety and crop management technologies. The present paper reviews global scenario of rapeseed-mustard production and Indian scenario of seed sector, seed systems, seed production chain, seed status and its implication in production of rapeseed-mustard. India has a very robust seed system comprising both public sector institutions and private seed companies; this system acts as a driver of growth in agriculture. Of the three seed systems prevalent in India, *viz.,* formal, informal and integrated, formal system wherein guiding principles are to maintain varietal identity, purity and to produce seed of optimal physical, physiological and phyto-sanitary quality is predominant. Seed chain of rapeseed-mustard during 2019-20 was maintained with 55 varieties comprising 35 of Indian mustard, 11 of *toria,* 5 of yellow sarson and 2 each of *gobhi sarson* and taramira. Varietal mismatches in the breeder seed production was only 5.6% during 2019-20. Breeder seed production was higher by two to three folds than the indents during the last 11 years (2009-10 to 2019-20). During the last 10 years there has been a surge in seed requirement from 2.20 lakh q to 2.64 lakh q. Seed availability during this period was always higher by 2.3%-27.8% than the requirement, except during 2016-17 when a marginal deficit (0.8%) was observed. The seed replacement rate (SRR) is above the threshold level (33% for self- and 50% for cross-pollinated crops) and varietal replacement rate (VRR) is also high as contribution of old and obsolete varieties (released up to 1993) has substantially reduced from 49.4% (2014-15) to 1.7% (2019-20) for Indian mustard; 81.1% (2014-15) to 25.1% (2019-20) for *toria* and 64.0% (2014-15) to 18.9% (2019-20) for yellow sarson. Increased availability of seed, adequate SRR with high VRR are some of the contributing factors for enhanced yield from 1143 kg/ha to 1511 kg/ha during 2008-09 to 2018-19 in rapeseed-mustard. This paper also highlights some of the issues and strategies for quality breeder seed production.

Keywords: Breeder seed, Global scenario, Rapeseed-Mustard, Seed production chain, Seed replacement rate, Seed systems, Varietal replacement rate

India is the 4th largest vegetable oil economy in the world next to USA, China and Brazil. Oilseeds in India accounted for 16.7%, 12.9% and 18.3% of the total arable land, gross and net cropped area, respectively, during 2016 (Anonymous, 2019a). There is a continuous surge in demand of edible oils even at the current level of consumption (17.7 kg/capita/annum) because of increasing population, changing food habits, improved purchasing power, etc. The demand of vegetable oils is likely to grow by about 3.5-6.0% annually over the next 10 years which translates in to total requirement of 29.0-34.0 million tonnes (m t) of oils that works out to be equivalent to 82-102 m t of oilseeds by 2030 from the level of production of 33.50 m t during 2019-20 (DRMR, 2011; NAAS, 2017; Anonymous, 2020a). Rapeseed-mustard is an important group of oilseed crops in India. It contributes 24.7% and 29.4%, respectively, to total area and production of oilseeds during 2018-19. Further, considering 20% contribution from secondary sources and 20-25% from rapeseed-mustard; the projected demand for this crop would be around 16.4-20.5 m t by 2030 from the current production of 9.26 m t. This requires multi-pronged strategies such as horizontal expansion of the crop by inter cropping in wide-spaced crops, mixed cropping and extending it to new niches; vertical enhancement in yield through continuing varietal improvement programme, realizing the exploitable yield reservoir by narrowing yield losses due to biotic and abiotic stresses, using quality inputs and adopting efficient crop management technologies. It is in the latter context, where seed comes to the forefront and mere replacement of seed may enhance crop yield up to 20%. The present paper reviews the status of the crop in the world *vis-a-vis* India and seed sector, seed systems, seed production

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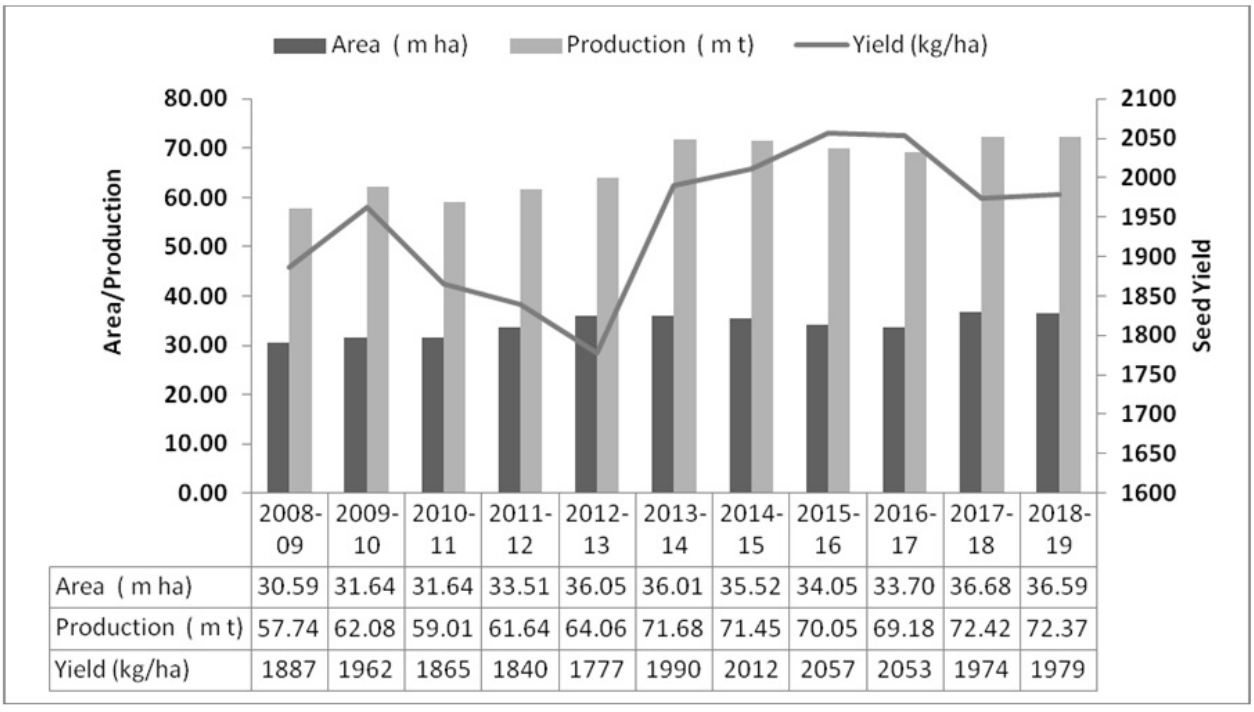
chain, seed status and its implication in production of rapeseed-mustard in India during the last 11 years.

Global scenario of rapeseed-mustard

Brassicas comprise many diverse types of plants, which are consumed as vegetables, fodder, sources of oil and condiments. The *oleiferous Brassica* species, commonly known as rapeseed-mustard are one of the economically important agricultural commodities. Rapeseed-mustard with a production of 72.41 m t, contributed 12.1% to the global oilseed production (597.27 m t) during 2018-19 (Anonymous, 2020b). These crops are grown in 67 countries in Asia, Europe, America, Africa and Australia. Rapeseed comprising colza (*Brassica napus* L.ssp. *oleifera* DC var. annua L. and turnip rape) (*Brassia rapa* L.) are extensively grown in most of the countries. Of these, about 26 countries also grow mustard consisting of (*Brassica juncea* (L.) Czern. & Coss.); black mustard (*Brassica nigra* [L.] Koch); Ethiopian mustard or *karan rai* (*Brassica carinata* A. Braun) and white mustard (*Sinapis alba* L.). In South Asian countries, India and Pakistan, Indian mustard and Ethiopia in Africa, Ethiopian mustard are predominatly grown (Chauhan *et al.,* 2013; FAOSTAT, 2018). Mustard accounted for about 17.3% and 10.3% of the global rapeseed-mustard area and production, respectively, during 2017-18 (FAOSTAT, 2018). From 2008-09 to 2018-19, the area under rapeseed-mustard in the world increased consistently from 30.59 million ha (m ha) during 2008-09 up to 36.05 m ha (2012-13), an increase of 17.8% but gradully declined thereafter up to 33.70 m ha (2016-17) but still higher by 10.2% over the base year and again increased by 19.9% during 2017-18 and 19.6% during 2018-19 (Fig.1). The production during this period ranged from 57.74 m t (2008-09) to 72.42 m t (2017-18) showing an increase of 25.4% which was marginally declined to 25.3% during 2018-19. Nevertheless, the trend was inconsistent and production peaked during 2013-14 and 2017-18 (Fig.1). Similar pattern was observed for yield (kg/ha) which ranged between 1777 (2012-13) and 2057 (2015-16) registering an increase of 15.8% but this increase was 9.0% over the base year. The yield increase during 2016-17, 2017-18 and 2018-19 over the base year (2008-09) was 8.8%, 4.6% and 4.9%, respectively. An anaysis on the basis of quinquennium (2013-14 to 2017-18) revealed that Canada, China and India together had a share of 62.7% and 55.3% in global rapeseed-mustard area and production, respectively. India ranked 3rd and 4th in area and production of rapeseed-mustard, respectively.



	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
Area (m ha)	30.59	31.64	31.64	33.51	36.05	36.01	35.52	34.05	33.70	36.68	36.59
Production (m t)	57.74	62.08	59.01	61.64	64.06	71.68	71.45	70.05	69.18	72.42	72.37
Yield (kg/ha)	1887	1962	1865	1840	1777	1990	2012	2057	2053	1974	1979

Fig.1. Global trends in rapeseed-mustard area, production and yield from 2008-09 to 2018-19

European Union contributed the highest (30.9%) to production with only 19.1% share in area. The yield/ha varied from 0.54 t in Tajikistan to 3.89 t in Chile (FAOSTAT, 2018). Other countries with higher level of yield (> 3 t/ha) were Ireland (3.86 t), Belgium (3.79 t), Switzerland (3.66 t), United Kingdom & Northern Ireland (3.45 t), Denmark (3.43 t), Czechia (3.43 t), Turkey (3.30 t), Luxembourg (3.23 t), Slovenia (3.11 t), France (3.06 t) and Hungary (3.02 t). All these countires are in Europe and grow long duration winter rape (*Brassica napus*) that takes about 8-9 months from seed-to-seed and use very high dose of nitrogen fertilizer up to 250 kg/ha. Several other European contries had yield of more than 2.5 t /ha. In India, several short duration *Brassicas* are grown that take 100-150 days from seed-to-seed, i.e., about half of the duration than that of European countries with low nitrogeneous fertlilier use (60-120 kg/ha) under diverse agroecological conditions. Indian average seed yield was 1258 kg/ha as compared to global average yield of 1996 kg/ha (FAOSTAT, 2018). India also ranked 3rd after Canada and China with a share of about 11.0% in the global rapeseed-mustard production (72.41 m t) during 2018-19 (Anonymous, 2020b).

Rapeseed-mustard in India

Rapeseed-mustard in India consists of eight different species. Of theses, toria (*Brassica rapa* L. var. toria), brown sarson (*Brassica rapa* L. brown sarson), yellow sarson (*Brassica rapa* L. var. yellow sarson), gobhi sarson (*Brassica napus* L. ssp. *oleifera* DC var. annua L.) and taramira (*Eruca sativa*/vesicaria Mill.) are together termed as rapeseed; and Indian mustard (*Brassica juncea* (L.) Czern. & Coss.); black mustard (*Brassica nigra* [L.] Koch) and Ethiopian mustard or karan rai (*Brassica carinata* A. Braun) are collectively called mustard. They are grown under diverse agroclimatic conditions ranging from north-eastern/ north western hills and plains to down south under irrigated/rainfed, timely/late sown, saline soils and mixed/inter-cropping situations. In India, the major rapeseed-mustard growing states are Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh, West Bengal, Assam and Gujarat accounting for 92.7% of the area and 95.8% of production during 2017-18 of which Rajasthan alone account for 36.6% and 40.9%, respectively, of the area and production (Anonymous, 2019a). Indian mustard is predominantly grown in Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh and Gujarat. Toria is a short duration crop cultivated largely in Odisha, Assam, West Bengal and Bihar as a main crop while as a catch crop in Haryana, Madhya Pradesh, Punjab, Himachal Pradesh, Uttarakhand and western Uttar Pradesh. Yellow sarson is now mainly grown in Odisha, Assam, West Bengal, Bihar and eastern Uttar Pradesh. Brown sarson is cultivated on a limited scale in colder regions of the country like Jammu & Kashmir and Himachal Pradesh. Gobhi sarson is a longer duration crop confined only to limited areas of Punjab and Himachal Pradesh.Taramira is grown in certain drier parts of north western states like Rajasthan, Haryana and Uttar Pradesh (Chauhan *et al.,* 2013). However, area under these (brown sarson, yellow sarson and taramira) crops has been shrinking of late due to crop diversification or availability of shorter duation varieties of Indian mustard which have replaced these crops.

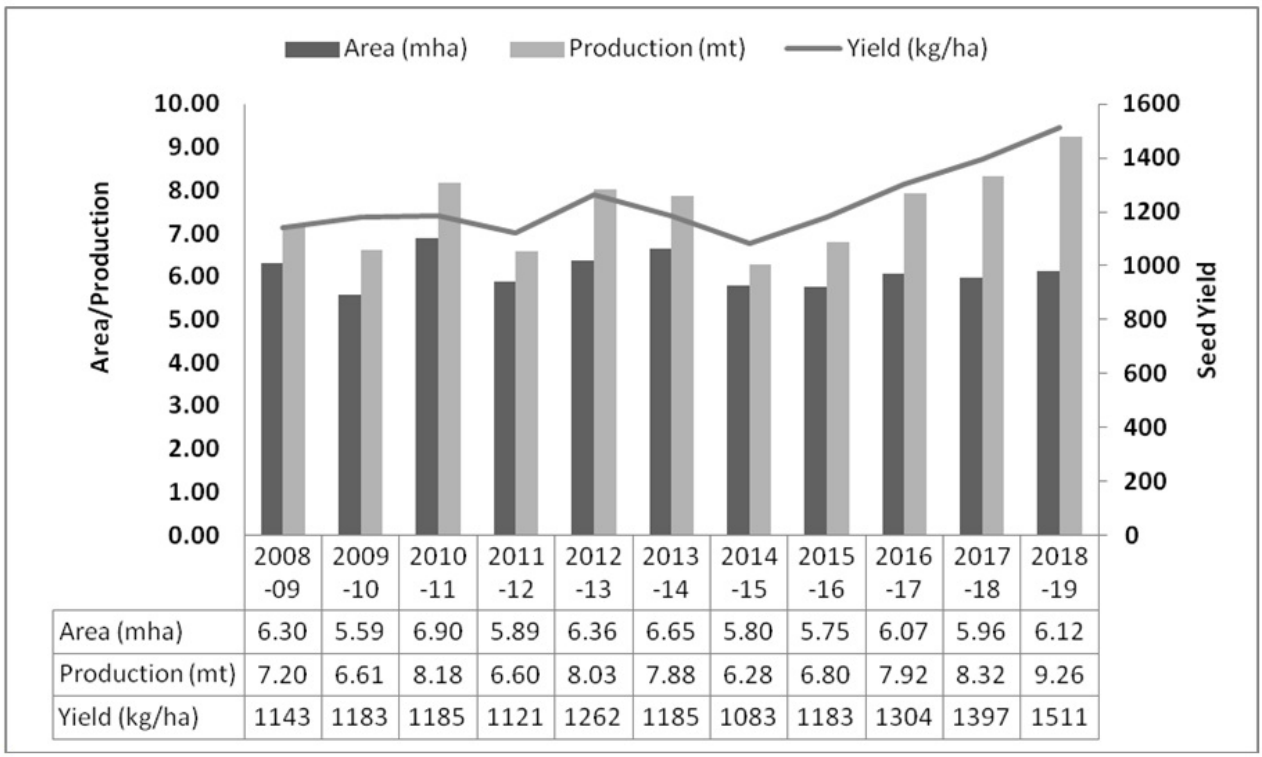
Rapeseed-mustard production in India during 2008-09 to 2018-19 increased by 28.6% (7.20 m t from 6.30 m ha in 2008-09 to 9.26 m t from 6.12 m ha during 2018-19) but area decreased by 2.9% (Anonymous, 2019a; 2020a). Yield levels showed an enhancement from 1143 to 1511 kg/ha, an increase of 32.2% during the same period. The arrea under rapeseed-mustard peaked thrice during the period, highest (6.90 m ha) in 2010-11 but showed variable and declining trend during the rest of the years ranging from 5.75 m ha during 2015-16 to 6.65 m ha during 2013-14 m ha (Fig. 2). The irrigated area during this period enhanced from 71.9 % to 76.6 % (2014-15).

Rapessed-mustard production also did not show a definite trend during this period, which increased by 13.6% during 2010-11 over the base year (2008-09), thereafter declined by 1.8% (2012-13) to 23.2% (2014-15) until 2016-17 and registered an incease of 1.7% and 13.2% during 2017-18 and 2018-19, respectively, (Fig. 2) over the highest ever achieved during 2010-11.

Indian seed sector, seed systems and supply chain

The journey of seed system/sector development started way back in 1928 with the report of Royal Commission of Agriculture. Since then over a period of 92 years, it traversed a long way with mile stones such as establishment of Central Seed Testing Laboratory at IARI, New Delhi in 1960; National Seed Corporation Ltd., New Delhi in 1963; Seed Act enactment in 1966; establishment of Tarai Development Corporation, Pantnagar and State Farms Corporation of India, New Delhi in 1969; setting up of National Commission on Agriculture in 1971; Joint Working Party and launching of National Seed Project in 1974; New Policy on Seed Development in 1988; Protection of Plant Varieties & Farmers' Rights Act in 2001; National Seed Policy in 2002; establishment of ICAR-Directorate of Seed Research, Mau (UP) in 2004; introduction of Seed Bill in parliament in 2004; launching of ICAR-Mega Seed Project during 2005-06; joining of OECD Seed Schemes by India in 2008 and presently 249 varieties of 20 crops have been enlisted for seed export under the scheme; launching of export-import policy 2009-14; Modified New Policy on Seed Development 2011; ISTA accreditation of first public sector laboratory in 2015; up gradation of ICAR-Directorate of Seed Research to ICAR-Indian Institute Seed Science, Mau in 2015; Cotton

Seeds Price (Control) Order, 2015 and Licensing and Formats for GM Technology Agreement Guidelines, Government of India in 2016 (Chauhan *et al.*, 2016; 2017). Seed Sector in India has evolved gradually from a pre-dominantly public sector holding (until the 1980's) into a multi-faceted sector with the involvement of about 600 national and multinational seed companies/firms with increasing emphasis on research and development activities besides a strong network of public sector institutions and organizations. Currently, public seed sector comprises National Agriculture Research, Education and Extension System (NAREES) having 64 ICAR Research Institutes, 6 Bureaux, 15 National Research Centres, 13 Directorates/Project Directorates, 3 Central Agricultural Universities and 5 Deemed Universities, 82 All India Coordinated and Network Projects [59 All India Coordinated, 21 Network and 2 other projects], 11 Agricultural Technology Application Research Institutes (ATARI), 716 Krishi Vigyan Kendras, 4 Central Universities with Agriculture faculty, 63 State Agricultural Universities (https://www.icar.org.in, visited on July 24, 2020), National Seed Corporation (NSC), New Delhi with 10 Regional and 66 Area offices, 16 State Seed Corporations, 25 State Seed Certification Agencies and 134 State Seed Testing Laboratories; 18 ISTA member and six (one public and five private sector) ISTA accredited laboratories. These concerted efforts have led to a vibrant and globally competitive Seed Sector in India. At present, India has a very robust seed system (production, processing, marketing and distribution) comprising both public sector institutions as well as private seed companies that guarantees food security of the country and acts as a driver of growth in agriculture.



	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
Area (mha)	6.30	5.59	6.90	5.89	6.36	6.65	5.80	5.75	6.07	5.96	6.12
Production (mt)	7.20	6.61	8.18	6.60	8.03	7.88	6.28	6.80	7.92	8.32	9.26
Yield (kg/ha)	1143	1183	1185	1121	1262	1185	1083	1183	1304	1397	1511

Fig. 2. Trends of rapeseed-mustard area, production and yield in India from 2008-09 to 2018-19

Global seed market in terms of value was about US$ 71.4 billion in 2019 with Compound Annual Growth Rate (CAGR) of 7% during 2011-18 and expected to register US $ 90.37 billion in 2024 with likely CAGR of 7.9% during 2020-24 (www.imarcgroup.com, visited on July 20, 2020). Indian seed market is the 5th largest in the world after USA, China, France and Brazil. Indian seed market (US$ 2.3-2.7 billion) had been growing at rapid rate with CAGR of 19.0% (2009-14); 8.4% (2012-16) and projected at 11% (US $ 3.0 billion) for field crops and 14.6% (US$ 700 million) for vegetable seed during 2020 (NAAS, 2018; www.ifca.org.in, visited on Feb.5, 2019). During 2017, India imported 29,456 tonnes of seeds of vegetables, flowers and field crops worth US$ 121 million of the total global import of 3.98 m t of seeds worth US$ 11,289 million and exported 33,036 tonnes of seed worth US$ 101 million against global export of 3.79 m t worth US$ 11,924 million, respectively, (International Seed Federation; https://www.worldseed.org, visited on July 30, 2019).

Seed system, a framework of institutions/farmers group organized together by their involvement or influence on the seed multiplication, processing, quality assurance and marketing of seeds, could be formal, informal or integrated. Guiding principles in the formal system are to maintain varietal identity, purity and to produce seed of optimal physical, physiological and phyto-sanitary quality. It is characterised by large scale production of seeds of officially released and notified varieties as per Section 5 of Seed Act 1966 with strict quality assurance mechanism. The formal seed system follows the three stages, viz., breeder, foundation and certified seed production. It is very well organized and systematic. The seed supply chain involves multiple stakeholders both from public and private sectors including NGOs and farmers (Fig. 3). Quality of seed and pricing are regulated as per the Seed Act (1966), Seed Rules (1968), Seed (Control) Order 1983, the legal instruments to regulate the quality of seeds available in the market and other notifications from time to time (Chauhan *et al*., 2016a; 2017; Prasad *et al*., 2017). The responsibility for seed law enforcement is vested with the State Governments. The Seed Act/Rules are applicable only to notified seeds. Labelling of seed is compulsory as per the Seed Act 1966 but certification is voluntary.

Informal seed system caters to the need of only a small scale supply of locally known varieties without any government interference in quality control. Farmers themselves produce, disseminate and access seed: directly from their own harvest; through exchange / barter among friends, neighbours, relatives; and through local grain markets. Informal system is characterized largely by a wider range of variations in seed system and flexibility. Varieties may be landraces or mixed races and may be heterogeneous or modified through on-farm breeding. The seed is of variable quality and the same general steps are involved in the local system as in the formal system (variety choice, variety testing, introduction, seed multiplication, selection, dissemination and storage) but they take place as integral parts of farmers' production systems rather than as discrete activities (Reddy *et al*., 2007). There is not always necessarily a distinction between seed and grain. Quality control is exercised by local technical knowledge, local social structures and norms.

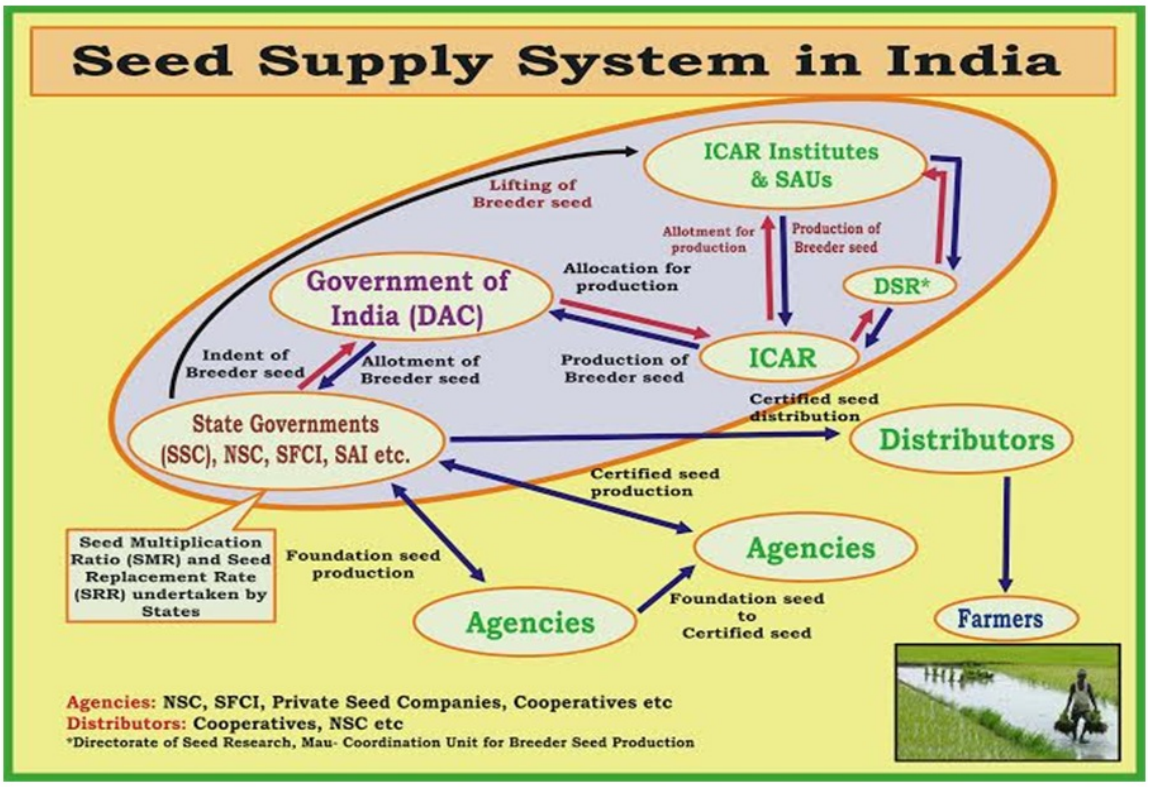


Fig.3 Existing formal seed production and supply system in India (Source: Prasad *et al.,* 2017)

In integrated system, however, a farmer will use the formal system for some crops and informal system for others. He may buy seed from the formal system once in order to obtain a particular variety and produce own seed from then onwards and share the new variety with neighbours and relatives. Community based seed production refers to production of the varieties preferred by the farmers for themselves in their own locality by organizing themselves into small groups (Fig. 4) is also a regular feature. These groups cultivate the same variety avoiding cross pollination and follow the recommended cultivation practices particularly seed selection procedures. These farmers are given the appropriate training, and supplied with good quality foundation seed for multiplication, so that they become the source of improved seed for the entire village. Each season, the farmers are supplied with foundation seed of different crops.

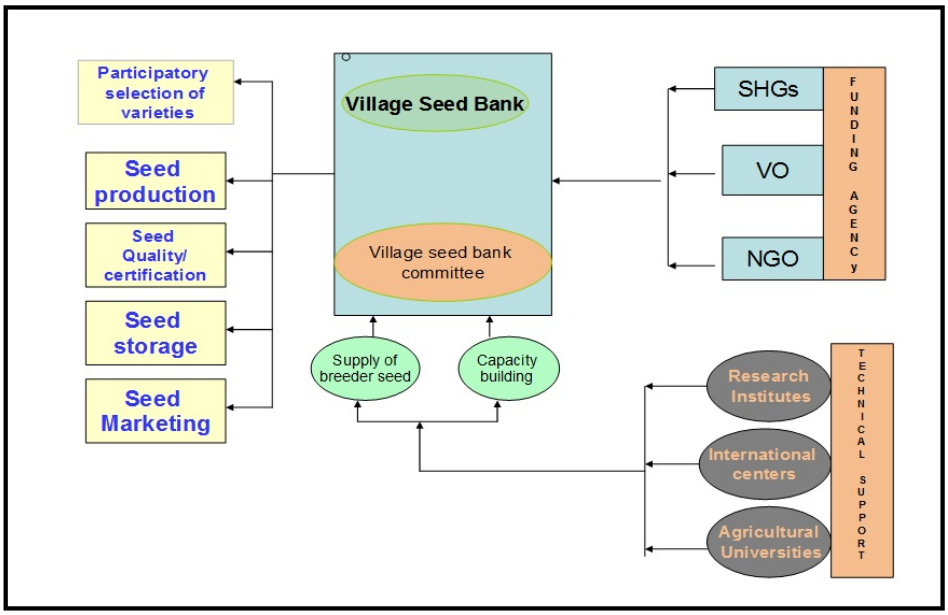


Fig. 4. An integrated seed system model: Interlinking different stakeholders (farmers, public and private organizations): Source: Chauhan *et al.* (2017)

Seed production

Seed chain: The present paper is based on analysis of formal seed production system. Seed production chain commences with the indenting of varieties for breeder seed production by the concerned stakeholders. A total of 201 varieties of rapeseed-mustard have been released during 1969-2019 of which 44 were released during the last five years and majority of them were of Indian mustard (Table 1). During this period, 4 (2 each of yellow sarson and Indian mustard) varieties have also been de-notified. Thus 197 varieties/hybrids currently qualify for formal system of seed production as per Seed Act 1966.

Varietal diversity in seed chain: During 2014-15 to 2019-20, only 27.9% to 39.6% of the varieties that are qualified for formal seed production were in the seed chain. These comprised mustard (59%-68%) and rapeseed (32%-41%). Number of varieties in the seed chain varied from 55 to 78 (Table 2).

Varietal replacement: Varietal replacement rate was assessed by analyzing breeder seed indents for the last six years (2014-15 to 2019-20) to know the trend of induction of recently released varieties and exclusion of old obsolete varieties in the seed chain. The varieties were grouped on quinquennium (5 years) basis according to their release and notification years to assess their contribution to indent of breeder seed.

The indented Indian mustard varieties for breeder seed production were 50, 50,46,43, 36 and 35 during 2014-15, 2015-16, 2016-17, 2017-18, 2018-19 and 2019-20, respectively (Table 3), and the contribution of top 5 varieties to the total indent of the crop was 69.3%, 50.7%, 38.9%, 41.2%, 42.6% and 52.2% respectively, during the corresponding period. Further, share of top 10 varieties in breeder seed varied from 58.1% during 2016-17 to 84.3% during 2014-15. Among the leading varieties in the seed chain, except for Varuna (1976), Pusa Bold (1985), Pusa Mahak (2004) and Jawahar Mustard 3 (2005), the rest were released within 10 years. The varieties, Varuna (1976) and

RH 761(2019) were the earliest and latest release in the seed chain. Contributions of varieties released during the last 10 years as per the guidelines of National Food Security Mission (NFSM), DAC&FW, Govt. of India, New Delhi to promote recently released high yielding varieties, varied from 21.2% from 21 varieties (2014-15) to 65.0% from 15 varieties (2018-19) and from 0.3% from a single variety (2015-16) to 27.8% from 16 varieties (2019-20), for the varieties released between 2009-13 and 2014-18, respectively (Table 3). Share of very old varieties (released prior to 1993 and / or for which date of notification was not available) was substantially reduced from 49.4% from 7 varieties during 2014-15 to only 1.7% from a single variety during 2019-20. The share of varieties released during the past 10 years (2009-18), to breeder seed indent varied from 44.1% in 2015-16 to 88.3% during 2019-20. The highest indent, in general, except for the year 2014-15, was for the varieties (13-21) released during 2009-13, contributing from 43.8% (2015-16) to 65.0% (2018-19). Of the 25 varieties released during 2015-19, 16 were indented for breeder seed production during 2019-20. The variety Pusa Bold was the leading variety with a share of 7.4%-30.7% to breeder seed indent until 2017-18. Thereafter, NRCHB 101, JM 3, Pusa Mahak, Pusa Mustard 25, Pusa Mustard 30 and DRMRIJ 31(Giriraj) were the leading varieties in the seed chain with a contribution of 5.9%-15.8%, 9.7%-19.1%, 5.3%-8.4%, 5.3%-10.8%, 11.1%-11.4% and 10.1%-11.6%, respectively, to the total indent.

Table 1 Varieties of rapeseed-mustard released during the last five years

Crop	2015	2016	2017	2018	2019	Total
Rapeseed						
Toria	0	2	3	3	0	8
Brown sarson	0	0	0	1	2	3
Yellow sarson	0	1	1	0	1	3
Gobhi sarson	2	0	0	0	0	2
Taramira	0	0	2	0	0	2
Mustard						
Indian mustard	5	9	2	3	6	25
Ethiopian mustard	0	1	0	0	0	1
Total	07	13	8	7	9	44

Table 2 Rapeseed-mustard varieties in seed chain during the last six years

Crop	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Rapeseed						
Toria	14	13	13	13	13	11
Brown sarson	0	0	2	0	0	0
Yellow sarson	6	6	7	6	7	5
Gobhi sarson	6	4	3	3	3	2
Taramira	2	1	2	0	2	2
Mustard						
Indian mustard	50	50	46	43	36	35
Ethiopian mustard	0	1	0	0	0	0
Total	78	75	73	65	61	55

In case of toria, 14 varieties were indented for breeder seed production during 2014-15 whereas, the number declined to 13 in the next year and remained the same until 2018-19 and further declined to 11 during 2019-20 (Table 3). Top five varieties contributed 40.4% (2016-17) to 82.5% (2019-20). Contribution of varieties released during the last 10 years (2009-18) varied from 1.1% from one variety in 2014-15 to 75.0% from five varieties in 2019-20 (Table 3). The highest indent, in general, was for the varieties (5-9) released up to 1993, ranging from 44.1% from 6 varieties (2015-16) to 81.8% from 9 varieties (2014-15) until 2018-19 (Table 3). However, the old varieties were completely

replaced by those released during 2009-13 and 2014-18 and their contribution was 34.8% and 40.2%, respectively, during 2019-20. Three pre-released varieties (TS 36, TS 38 and TS 46) were also indented for breeder seed production in substantial quantity for all the six years, which should not have been the case since breeder seed could not be produced for un-notified varieties as per Seed Act 1966. The predominant varieties of toria in the seed chain were Uttara, M 27, Anuradha and Sushree contributing 9.3%-40.6%; 2.9%-16.7%; 2.9%-8.1% and 11.5%-16.2%, respectively, to the seed indent during the six years. M 27 is the oldest variety released in 1978 and Tapeswari, Tripura Toria are the latest released (2018) varieties in the seed chain during 2019-20 (Table 4). Of the eight varieties released during 2015-19, four were in seed chain during 2019-20.

Table 3 Recent trends of varietal replacement of selected rapeseed-mustard in seed chain from 2014-15 to 2019-20

Crop	Year	Indent (q)	Varieties	Up to 1993	1994-98	1999- 2003	2004-08	2009-13	2014-18	2019-23
Indian mustard	2014-15	98.5	50	7 (49.4%)***	4 (3.4%)	8 (3.0%)	10 (23.1%)	21(21.2%)	-	-
	2015-16	82.1	50	7 (21.4%)	3 (3.0%)	8 (1.0%)	9 (30.5%)	22 (43.8%)	1 (0.3%)	-
	2016-17	51.8	46	8 (27.4%)	4 (6.6%)	4 (1.5%)	9 (20.2%)	20 (42.7%)	1 (1.6%)	
	2017-18*	61.3	43	8 (21.1%)	4 (6.1%)	1 (0.08%)	9 (17.8%)	17 (52.0%)	4 (2.8%)	
	2018-19*	57.6	36	6 (14.3%)	2 (5.2%)	1 (0.5%)	6 (12.8%)	15 (65.0%)	4 (2.2%)	-
	2019-20**	59.5	35	1 (1.7%)	-	-	4 (9.9%)	13 (60.5%)	16 (27.8%)	1 (0.08%)
Toria	2014-15	18.6	14	9 (81.8%)	1 (0.3%)	2 (16.2%)	1 (0.6%)	1 (1.1%)	-	-
	2015-16	16.6	13	6 (44.1%)	1 (18.1%)	2 (21.1%)	1 (0.6%)	1 (9.2%)	2 (6.7%)	-
	2016-17	35.2	13	9 (71.3%)	-	2 (15.6%)	1 (0.1%)	1 (12.9%)	-	-
	2017-18*	12.7	13	8 (54.2%)	-	1 (3.9%)	-	1 (9.2%)	1 (40.2%)	-
	2018-19*	17.4	13	8 (54.3%)	-	1 (2.9%)	-	1 (30.0%)	3 (12.8%)	-
	2019-20**	12.4	11	5 (25.1%)	-	-	-	1 (34.8%)	4 (40.2%)	-
Yellow sarson	2014-15	9.2	6	2 (64.0%)	-	-	-	4 (36.0%)	-	-
	2015-16	6.9	6	2 (63.0%)	-	-	-	4 (37.0%)	-	-
	2016-17	11.0	7	3 (49.8%)	-	-	-	4 (50.2%)	-	-
	2017-18*	7.8	6	2 (45.3%)	-	-	-	4 (54.6%)	-	-
	2018-19*	8.6	7	1 (47.5%)	1 (1.8%)	-	-	4 (50.1%)	1 (0.6%)	-
	2019-20**	1.9	5	1 (18.9%)	-	-	-	4(81.1%)	-	-

*,**Source: https://seednet.gov.in/readyrecknor/Seed_III_VI.aspx visited on 13.12.2018 and 16.11.19
***: Figures in parenthesis is the contribution of varieties to the crop indent

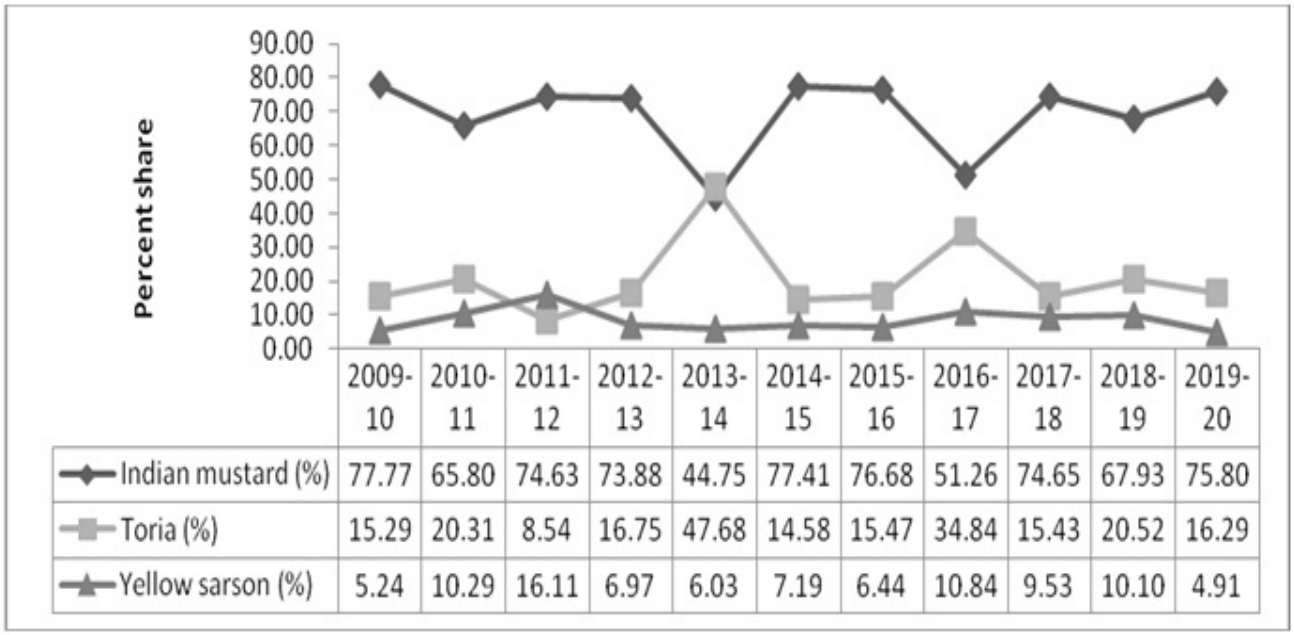
In yellow sarson, the number of varieties indented was highest (7) in the year 2018-19 and the lowest (5) in 2019-20 (Table 3). Top five varieties contributed from 97.1% (2015-16) to 100.0% (2019-20). Except Benoy (1982) and Jhumka (1998), all other predominant high yielding varieties in the seed chain during the last six years have been released within 10 years (Table 4). Benoy, Pitambari and Pant Pili Sarson 1 were the leading varieties with a contribution ranging from 18.9% to 62.3%, 6.0% to 51.1% and 4.9% to 29.6%, respectively. Until 2015-16, varieties developed up to 1993 were the main contributors to the seed indent with share ranging from 63.0% (2015-16) and 64.0% (2014-15). Thereafter, varieties developed during the period 2009-13 were predominant in the seed chain during 2016-17, 2017-18, 2018-19 and 2019-20 contributing 50.2%, 54.6%, 50.1% and 81.10%, respectively, to the seed indents (Table 3). Of the three varieties released during 2015-19, seed indent of only one variety was received during 2019-20 with a contribution of only 0.6%.

In gobhi sarson, six varieties and one hybrid were in the seed chain during the six years. Three to six varieties were indented for breeder seed production during the last six years. In all the years, only three varieties per year were indented except 2014-15 when 6 varieties were in the seed chain. Predominant high yielding varieties in the seed chain during the last six years were Sheetal (released in 1995) and Neelam (released in 2001) each contributing to 31.3% during 2014-15, GSC 6 (released in 2008) and Him Sarson 1(released in 2009) contributing to 38.2% and 42.5%, respectively, during 2015-16, GSC 7 (released in 2015) contributing 84.7% during 2016-17, Him Sarson and GSC 7 contributing 28.4% and 57.1%, respectively, during 2017-18,

Sheetal, GSC 6 and GSC7 each contributing 33.3% during 2018-19 and GSC 7 with a contribution of 96% to the seed chain during 2019-20.

During the last six years, only two varieties of brown sarson, *viz.,* BSH 1 (released in 1975) and KBS 3 (released in 1998) were indented during 2016-17 in a small quantity (0.05 q). Similarly, only one variety of Ethiopian mustard, *viz*., Pusa Aditya (released in 2006) was indented (0.02 q) during 2015-16. But no breeder seed was produced even to meet small requirements of these varieties. Four varieties of taramira, *viz*., Karan Tara released in 1995, Narendra Tara released in 2007, Jobner Tara (RTM 1351) and Jwala Tara (RTM 1355) both released in 2017 were in the seed chain during the last six years except for 2017-18. Of these Narendra Tara was the leading variety during 2014-15 and 2015-16 with a share of 87.8% and 100.0%, respectively. Jwala Tara was the leading variety during 2017-18, 2018-19 and 2019-20 contributing to 98.0%; 96.3% and 98.1%, respectively, to the seed indent for taramira. Seed chain of rapeseed-mustard during 2019-20 was maintained with 55 varieties comprising 35 of Indian mustard, 11 of toria, 5 of yellow sarson and 2 each of gobhi sarson and taramira.

Breeder seed: Breeder seed production is demand driven. It is produced after receiving indents from interested stakeholders both from public and private sectors and is supplied to them for further multiplication in the form of foundation and certified seeds which is made available to the farmers. Analysis of indent of breeder seed for the last 11 years (2009-10 to 2019-20) showed inconsistent trend, breeder seed indent declined from 76.30q in 2009-10 to 49.28q in 2011-12 showing a reduction of 34.5%. Then the indents showed upward trend and increased by 7.4% (2017-18) to 66.9% (2014-15) over the base year and peaked during 2012-13, 2014-15 and 2018-19 with an increase of 43.8%, 66.9% and 12.1%, respectively. Rapeseed-mustard had a share of 0.25%-0.71% in the total indent for oilseeds during 2012-13 to 2018-19. Of the seven crops that comprise rapeseed-mustard, Indian mustard had the dominant share in the total breeder seed indent ranging between 44.75% during 2013-14 and 77.77% during 2009-10 (Fig.5). Toria, a short duration rapeseed crop contributed to 8.54% (2011-12) to 47.68% (2013-14) and yellow sarson, another rapeseed crop accounted for 4.91% (2019-20) to 16.11% (2011-12) of the breeder seed indent for rapeseed-mustard. Other crops (brown sarson, Ethiopian mustard, taramira and gobhi sarson) together had a small share in the breeder seed indent of rapeseed-mustard ranging between 0.39% (2017-18) and 3.6% (2010-11). During 2018-19 and 2019-20, Indian mustard, toria, yellow sarson and other crops accounted for 67.93%-75.80, 16.29%-20.52%, 4.91%-10.1% and 1.45%-3.0% of the rapeseed-mustard breeder seed indent, respectively (Fig. 5).



	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Indian mustard (%)	77.77	65.80	74.63	73.88	44.75	77.41	76.68	51.26	74.65	67.93	75.80
Toria (%)	15.29	20.31	8.54	16.75	47.68	14.58	15.47	34.84	15.43	20.52	16.29
Yellow sarson (%)	5.24	10.29	16.11	6.97	6.03	7.19	6.44	10.84	9.53	10.10	4.91

Fig.5. Share of major rapeseed-mustard crops (%) in breeder seed indents during the last 11 years (2009-10 to 2019-20)

In an earlier study, Chauhan *et al.* (2012) analyzed the trend of breeder seed indents of rapeseed-mustard during 25 years, *viz.,* from 1987-88 to 2011-12 and concluded that indent for toria was reduced from 35% during 1986-87 to 1990-91 to 15% during 2006-07 to 2011-12. On the other hand, indents for Indian mustard and yellow sarson increased, to 76% from 56% and to 8% from 4% during this period, respectively. By and large, similar trends continued during the last decade also, *viz.,* the indents during 2019-20 for Indian mustard and toria were almost similar to that of 2006-07 to 2011-12 but reduced substantially for yellow sarson to only 4.91%.

Abundant quantities of rapeseed-mustard breeder seed has been produced, always much higher than the indents. As a matter of fact, during the last 11 years, the breeder seed produced was two-three times higher than the indents (AICRPRM, 2010; 2011; 2012; 2020 and Anonymous, 2019b; 2020c). It ranged between 123.80q during 2011-12 and 304.32q during 2015-16 (Fig. 6). However, despite indent for breeder seed, no seed was produced for brown sarson during 2012-13 and 2013-14. Further, there has been no seed indent for brown sarson and Ethiopian mustard since 2016-17 and 2015-16, respectively (Table 5).

Table 4 Share of top 5 varieties to breeder seed indent of major rapeseed-mustard crops and promising varieties in seed chain from 2014-15 to 2019-20

Crop	Share	Prominent varieties (among top 5 in a year) in seed chain**
Indian mustard	38.9% (2016-17) to 69.3% (2014-15)	Jawahar Mustard 3 (2005)a, Pusa Bold (1985), Varuna (1976), Pusa Mahak (2004), NRCHB 101 (2009), Pusa Mustard 25 (2010), Raj Vijay Mustard 2 (2013), Pusa Mustard 28 (2012), DRMR IJ 31 (2013), Pusa Mustard 30 (2013), Pusa Mustard 27 (2011), Chhatisgarh Sarson (2010), RH 725 (2018),CS 60 (2018), RH 761 (2019)
Toria	40.4% (2016-17) to 82.5% (2019-20)	Uttara (2010), Anuradha (2002), M 27 (1978), PT 303 (1985), Parbati (2001), T 9 (1975), JMT 689 (1997), TL 15 (1982), Agrani (1982), Bhawani (1986), Sushree (2015), Tapeswari (2018), Raj Vijay Toria (2017), Tripura Toria (2018)
Yellow sarson	97.1% (2015-16) to 100.0% (2019-20)	Benoy (1982), Pant Pili Sarson 1 (2010), Pitambri (2010), YSH 0401 (2009), Jhumka (1998), NRCYS 05-02 (2009),

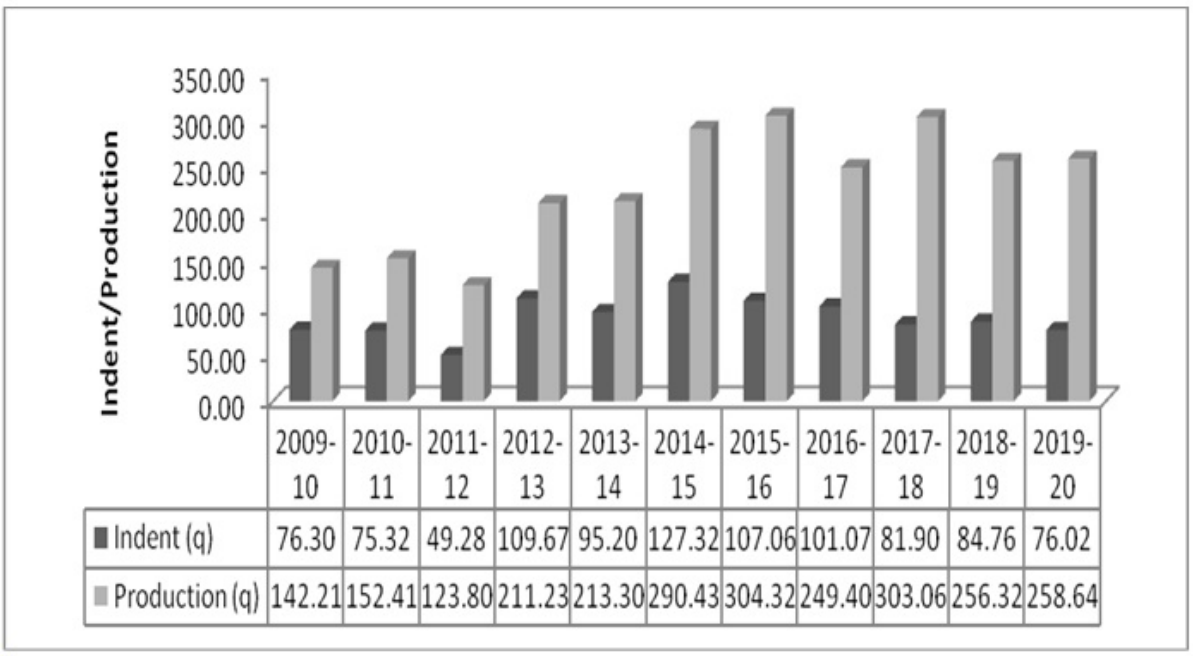
** Varieties indented at least thrice or in 2018-19/2019-20; a: Year of release

Table 5 Breeder seed indent (I) and production (P) in quintals of rapeseed-mustard during the last 11years (2009-10 to 2019-20)*

Year	Indian mustard		Ethiopian mustard		Toria		Brown sarson		Yellow sarson		Gobhi sarson		Taramira	
	I	P	I	P	I	P	I	P	I	P	I	P	I	P
2009-10	59.3	102.7	0.7	1.2	11.7	29.6	0.06	1.0	4.0	6.8	0.04	0.2	0.6	0.8
2010-11	49.7	98.5	0.7	0.2	15.3	30.5	0.1	1.0	7.8	10.0	0.7	1.5	1.2	10.9
2011-12	36.9	91.4	0.0	0.0	4.2	16.2	0.1	0.0	7.9	16.1	0.0	0.0	0.0	0.0
2012-13	81.3	150.8	0.2	0.2	18.4	42.9	0.1	0.0	7.9	13.2	0.6	3.0	1.2	1.8
2013-14	43.5	126.1	0.1	0.1	45.2	50.1	0.1	0.0	5.7	32.6	0.3	2.4	1.3	1.9
2014-15	98.5	212.5	0.0	0.0	18.6	59.2	0.0	0.0	9.2	11.4	0.3	3.7	0.8	3.6
2015-16	82.1	231.0	0.02	0.02	16.6	40.8	0.0	0.0	6.9	18.8	0.3	12.9	0.8	0.8
2016-17	51.8	174.6	0.0	0.0	35.2	38.2	0.1	0.1	11.0	26.2	1.8	9.4	1.0	0.9
2017-18	61.3	186.5	0.0	0.0	12.7	81.4	0.0	0.0	7.8	28.5	0.1	6.6	0.0	0.0
2018-19	57.6	151.9	0.0	0.0	17.4	40.8	0.0	0.0	8.6	60.5	0.2	2.1	1.1	1.1
2019-20	57.6	174.9	0.0	0.0	12.4	34.6	0.0	0.0	3.7	42.7	1.3	1.6	1.0	4.9

*Source: AICRPRM, 2010; 2011; 2012; 2020 and Anonymous, 2019b, 2020c

Seed requirement, availability and certified /quality seed distributed: Analysis of data of seed requirement and availability of certified/quality seed of rapeseed-mustard during the last 10 years (2009-10 to 2018-19) revealed that the requirement for seed of rapeseed-mustard although showed variable trend, yet, it was always higher over the base year by 0.5% (2013-14) to 20.0% (2014-15) varying from 2.20 lakh q to 2.64 lakh q (Table 6). Rapeseed-mustard quality seed distribution has been decreasing consistently since 2011-12 until 2015-16 except 2014-15. The reduction in seed distribution as compared to the base year, 2011-12, (2.56 lakh q) was 26.6%; 36.3%, 16.8%, 55.1% and 6.3%, during 2012-13; 2013-14; 2014-15; 2015-16 and 2016-17, respectively (Table 6). However, during 2017-18 seed distribution was 10.9% higher but declined during 2018-19 by 26.6% compared to that of 2011-12.'



	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Indent (q)	76.30	75.32	49.28	109.67	95.20	127.32	107.06	101.07	81.90	84.76	76.02
Production (q)	142.21	152.41	123.80	211.23	213.30	290.43	304.32	249.40	303.06	256.32	258.64

Fig. 6. Trend of breeder seed indent and production of rapeseed-mustard during the last 11years (2009-10 to 2019-20)

Implication

Enhanced seed replacement rate and yield: Seed replacement rate (SRR) is considered as an important intervention for yield enhancement in all crops as it has proven time and again that use of quality seed alone could increase yield by 20%. The ideal SRR is considered as 33% for Indian mustard, Ethiopian mustard, gobhi sarson and yellow sarson and 50% for brown sarson, toria and taramira. The SRR of rapeseed-mustard was quite variable during the last 10 years but always well above the threshold. The SRR during 2013-14 was 51.3% and during 2018-19 was 52.4% in comparison to 74.8% during 2009-10. The highest SRR (78.9%) was achieved during 2011-12 (Table 6). Concerted efforts of researchers and development personnel involved in rapeseed-mustard seed production programme have resulted in higher availability of quality seed of recently released varieties to achieve spectacular gains in SRR and VRR during the last six years. Besides high SRR, the VRR is also high as contribution of old and obsolete varieties (released up to 1993) has substantially reduced from 49.4% (2014-15) to 1.7% (2019-20) for Indian mustard, 81.1% (2014-15) to 25.1% (2019-20) for toria and 64.0% (2014-15) to 18.9% (2019-20) for yellow sarson. These two factors (SRR and VRR) contributed to increased productivity (yield) and thereby enhanced production of rapeseed-mustard during the last 11 years.

Issues and strategy

Seed chain involves several stakeholders with definite responsibility. It has mainly two activities: breeder seed production and conversion of breeder seed into downstream classes to achieve higher seed production and delivery system to the end users. All these components of seed chain need to be energised (Prasad *et al*., 2017; NAAS, 2018). The following are the issues and strategy exclusively pertaining to rapeseed-mustard seed production.

Non-notified and old varieties in the seed chain: Several pre-released varieties [three advanced breeding lines of toria, *viz.,* TS 36, TS 38 and TS 46 and two of Indian mustard

(RGN 303 and Rajendra Suphalam)] have repeatedly been indented for breeder seed production and production figures were also reported. It was inappropriate as breeder seed can only be produced for notified varieties as per Seed Act 1966. How the breeder seed production was monitored and downstream conversion has taken place for these pre-released varieties is the question that has remained unanswered. Therefore, there is an urgent need to release and notify them if their performance is acceptable as per the standards for release and notification of varieties or exclude from the formal system of seed production to maintain quality of seed. Organizations/institutes concerned should take up appropriate steps in this direction. Further, very old varieties of yellow sarson such as Jhumka and Benoy from West Bengal were observed in the seed chain with considerably higher indents despite four better varieties having been released for the region during the last five years. Therefore, there is an urgent need to have extensive efforts in showcasing, popularizing new and improved yellow sarson varieties in West Bengal to create demand for seed.

Table 6 Requirement, availability, distribution of certified/quality seed (lakh quintals) and seed replacement rate (SRR) of rapeseed-mustard during the last 10 years

Year	Requirement [R]	Availability [A]	[A-R] / R (%)	Certified/quality seed distributed	SRR (%)
2009-10	2.20	2.48	12.7	-	74.8
2010-11	2.45	2.80	14.3	-	63.6
2011-12	2.37	2.66	12.2	2.56	78.9
2012-13	2.44	2.65	8.6	1.88	57.3
2013-14	2.21	2.34	5.9	1.63	51.3
2014-15	2.64	2.70	2.3	2.13	54.6
2015-16	2.52	2.65	5.2	1.15	62.2
2016-17	2.49	2.47	-0.8	2.40	68.0
2017-18	2.31	2.55	10.4	2.84	54.9
2018-19	2.34	2.99	27.8	1.88	52.4

Quality of breeder seed: Breeder seed is the back bone of quality seed production programme. Therefore, its genetic and physical purity is of paramount importance. In view of the several cases of rejection of foundation seed plots due to questionable quality of breeder seed having been reported frequently, there is a greater concern for quality as huge cost and efforts are involved in seed production. Several stakeholders demand for having seed certification standards for breeder seed also. Therefore, there is a strong need for strengthening the maintenance breeding and nucleus seed production. It should be an effective and regular activity of the research/production centres with timely technical back stopping, capacity building programmes for stakeholder concerned and rigorous monitoring to ensure quality of breeder seed.

Irrational breeder seed indenting: Rapeseed-mustard are small seeded crops with high seed multiplication ratio (SMR) and low seed rate but very high indents were placed in all the six years. Moreover, surplus (two to three folds higher) rapeseed-mustard breeder seed have been produced than the indents. Production of such quantities of breeder seed every year is a sheer wastage of resources. Chauhan *et al*. (2016) assessed the requirement of rapeseed-mustard breeder seed for the year 2019-20 for the highest ever cropped area (7.30 m ha) and target SRR (90.9%) considering seed multiplication ratio of 1:200 and seed rate @ 5kg/ha to be 8.30 q. But area during the last five years has been hovering around 6.0 m ha. In this scenario, with this quantity of breeder seed there could be 100% SRR. Similarly, crop-wise analysis revealed that proportion of the crops in the breeder seed indent were skewed to 47.68% during 2013-14 and 34.84% during 2016-17 for toria and 16.11% for yellow sarson during 2011-12 at the expense of Indian mustard but without any contingency. Even there is no targeted SRR; it was variable to an appreciable extent. Thus, there is a need for consistently maintaining the requisite SRR. Therefore, there is an urgent need to relook into the formulation of seed rolling plan for rapeseed-mustard. Careful planning is required considering actual area, SRR and varieties while developing seed rolling plan otherwise non-notified varieties of toria/Indian mustard and obsolete varieties like Jhumka and Benoy of yellow sarson could be indented even during 2019-20.

Varietal mismatches: Despite the fact that overall breeder seed production of field crops including rapeseed-mustard, in general, was always higher than the indents, there were some varietal mismatches. Greater efforts were made in the National Seed Project during the last five years that resulted in considerable reduction in varietal mismatches from 34% to 17%. It is envisioned to further bring down the varietal

mismatches to 5% in the next couple of years (Anonymous, 2020b). Further, analysis of seed chain of rapeseed-mustard revealed that varietal mismatches were reduced to 3.1% in 2017-18 in comparison to 16.7% in 2014-15 though this mismatch again increased to 6.6% during 2018-19 and reduced to 5.6% during 2019-20. During the last six years (2014-15 to 2019-20), the mismatches accounted for 3.6% to 27.9% of the total seed indent. It reduced considerably from 27.9% during 2014-15 to 3.8% during 2019-20. Such varietal mismatches caused deficit of breeder seed to the tune of 51%, 45.9%, 71.0%, 100.0%, 43.0% and 70.7%, respectively, during 2014-15, 2015-16, 2016-17, 2017-18, 2018-19 and 2019-20, for some of the indented varieties. Therefore, various breeder seed producing (BSP) centres should address this issue by proper planning, systematic and concerted efforts.

Tracking of breeder seed: Tracking of the breeder seed in the seed chain is an important issue to know its downstream conversion to foundation/certified seed or it is going directly for commercial utilization. Breeder seed production is a highly specialized and resource intensive activity. Further, non-lifting of breeder seed is also a matter of concern in almost all crops and rapeseed-mustard is not an exception. Hence liquidating such high quantity of breeder seed could also be a problem. There is a need to think of 'cooling period' for breeder seed production, in general, except for variety indented for the first time. Studies should be planned for seed quality enhancement for long term storage of breeder seed. Crop specific breeder seed banks may be created, be it in area of predominant cultivation or zone wise and, resources, thus saved, should be utilized for breeder seed production of other high volume oilseeds like groundnut and soybean.

Disparity in seed distributed and SRR: During the last decade, there has been a surge in seed requirement and abundant seed was produced. In general, barring 2016-17, seed availability was always higher than the requirement. But it is intriguing that quality seed distribution among the end use stakeholders in the seed chain, i.e to farmers, decreased. It might be due to production of seed of such varieties which were less preferred by the farmers or overproduction. Therefore, there is a need to carefully plan for demand driven seed production programme. Accordingly, breeder seed indents for such varieties should be placed with organization concerned well in advance. This necessitates that seed rolling plan should be developed in consultation with farmers / farmers producer organizations to avoid this anomaly and also offset the liquidity problem. Further, the seed distribution was also not directly linked to seed replacement rate (SRR), it was 78.9% when seed distribution was 2.56lakh q during 2011-12 while only 54.9% during 2017-18 with 2.84 lakh q quality seed was distributed. It was probably that seed was provided to the marketing agencies but could not reach the farmers, the ultimate users. In depth analysis should be carried out to sort out such anomalies.

Overall, there are no major issues with seed production chain of rapeseed-mustard. On the contrary, there is a serious concern for irrational seed indenting, over production of breeder seed and its quality and anomaly in SRR *vis-à-vis* distribution of certified/quality seed to the famers.

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