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Research Review Article

An overview of oilseeds and oil scenario, seed chain and strategy to energize seed production

J S CHAUHAN[1], P R CHOUDHURY[1], S PAL[1] and K H SINGH[2]*

Indian Council of Agricultural Research, Krishi Bhawan, New Delhi 110 001, India

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ABSTRACT

Oilseeds in India accounted for 15.7% of the total arable land during 2017–18. The present paper discusses oilseeds and vegetable oil scenario in India; seed chain, current status of quality seed and strategies for seed production & development to enhance oilseeds output through bridging the vast untapped potential of the available technologies to reduce heavy dependence on oil imports. Of the nine annual oilseeds, groundnut, soybean, rapeseed-mustard and sesame during the last seven years (2012–13 to 2018–19) contributed 89.2–94.4% to acreage and 90.4%-95.0% to production of oilseeds. The area, production and yield of oilseeds attained an overall increase of 131.1%, 510.9% and 164.2%, respectively, from 1950–51 to 2018–19. Of the several programmes initiated to harness the vast exploitable yield reservoir of oilseeds, National Mission on Agricultural Extension and Technology launched during XII plan and Mega seed project during 2005-06, had great impact on enhanced availability of quality seed of newly released varieties and thus production of oilseeds. Considering annual growth of demand for edible oil, population growth and the per capita consumption of about 102.3 m t of oilseeds would be required by 2030. To meet this formidable challenge, the assets such as vibrant crop specific improvement programmes, 187 newly released high yielding varieties, improved crop management technologies, robust and effective seed chain and climate favouring seed production of diverse oilseeds are available in the country.

Keywords: Breeder seed, Net availability of vegetable oils, Oilseeds, Participatory seed production, Seed chain, Variety replacement rate

India is the 4th largest vegetable oil economy in the world next to USA, China and Brazil, accounting for 6.5% of global oilseeds output; 3.7% of vegetable oil production; 5.4% of oil meal production; 2.5% of oil meal export; 18.8% of oil import and 11.3% of the world's edible oil consumption, during 2019–20 (Anonymous 2020a). In India, oilseeds contribute 0.74% and 4.49% to gross national products and agricultural sub-sector, respectively, during 2015-16 (Anonymous 2018a). The demand for edible oil is highly income and price elastic. There is a continuous surge in demand for edible oil even at the present level of consumption and it is expected to grow by about 3.5–6.0% annually over the next 10 years, which translates into a total of 29.0-34.0 million tonnes (m t) of oil by 2030 (DRMR 2011; NAAS 2017). Considering about 20% contribution from secondary sources like rice bran, cottonseed, palm oil, coconut and other tree borne oilseeds, the vegetable oil requirements from nine annual oilseeds to meet the domestic edible and industrial demands works out to be equivalent to 82 m t of oilseeds by 2030 from the present level of production of 33.22 m t during 2019-20 (DRMR 2011; Anonymous 2019a; 2nd advance estimates of production of oil seeds and commercial crops for 2020-21 as on February 24, 2021 https://*www.agricoop.nic.in*, visited on September 28, 2021). Of the several approaches to increase oilseed production such as vertical and horizontal expansion of the crop and bridging the vast gap between realizable and realized potential of the existing technologies, the latter is first and foremost short term goal. The frontline demonstrations in various oilseeds during 2018-19 have shown very high exploitable yield reservoir (EP II), viz. difference between mean yield of front line demonstration with improved technology and national average yield, varying from 42.6% (*rabi*)-51.5% (*kharif*) for groundnut; 39.2% for soybean; 57.2% for rapeseed-mustard; 90.3% (*rabi/spring*)-140% (*kharif*) for sunflower; 7.4% for sesame; 31% for safflower; 15.2% for niger; 52.6% for castor and 56.3% (rainfed)-149.9% (irrigated) for linseed with an overall average of 48.9% (Dr Reddy, IIOR, Hyderabad, 2019 *personal communication*). Seed is considered to be a low cost but an important agricultural input to realize the potential of high yielding varieties and may increase yield by 15-20% and if coupled with efficient crop management,

Present address: [1]ICAR, Krishi Bhawan, New Delhi; [2]ICAR-DRMR, Bharatpur, Rajasthan. *Corresponding author e-mail: kharendrasingh@gmail.com.

up to 40–45%.The present paper discusses the trend of production and productivity of oilseeds since 1950-51; domestic and net edible oil availability, seed chain and production and strategies for energizing seed chain, research and development to enhance oilseeds output to reduce heavy dependence on oil imports.

Oilseeds scenario in India

Oilseeds in India comprise nine annual crops, viz. groundnut (*Arachis hypogaea* L.), soybean (*Glycine max* L.), rapeseed (*Brassica rapa* L. var. yellow sarson/brown sarson/toria; *Brassica napus* L. ssp. *oleifera* DC var. annua L.; *Eruca sativa* Mill.) - mustard (*Brassica juncea* (L.) Czern.&Coss. ; *Brassica nigra* [L.] Koch; *Brassica carinata A*. Braun), sesame (*Sesamum indicum* L.), linseed (*Linum usitatissimum* L.), niger (*Guizotia abyssinica* L. f. *Cass.*), sunflower (*Helianthus annuus* L.), safflower (*Carthamus tinctorius* L.) and castor (*Ricinus communis* L.). Of these, groundnut, soybean, rapeseed-mustard and sesame during the last seven years (2012-13 to 2018-19) contributed 89.2-94.4% to acreage and 90.4-95.0% to production of oilseeds. Contribution of the rest of the crops (linseed, niger, sunflower, safflower and castor) was about 5.6-10.8% and 5.0-9.6%, respectively, to oilseed acreage and production. The oilseed production increased during the first six decades consistently from meagre 5.16 m t during 1950-51 to 32.48 m t during 2010-11 showing an increase of 529.5%. During the corresponding period, the cropped area also rose considerably from 10.73 million hectares (m ha) in 1950-51 to 27.22 m ha in 2010-11, an increase of 153.7%. Except four years (2000-01 to 2003-04), when the area under oilseed dipped by 2.0-11.0% as compared to that of 1990-91, the cropped area was always higher in the next 25 years. Recently (2018-19), it registered an increase of 13.3% and the highest increase (30.5%) in area was observed during 2013-14, over that of the lowest cropped area during 2002-03. Oilseed production since 1990-91 increased from 18.61 m t to 31.52 m t during 2018-19, showing an increase of 69.4%.

Further, trend analysis of the last 12 years (2007-08 to 2018-19) revealed that oilseed production varied from 24.88 m t (2009-10) to 32.75 m t (2013-14), registering an increase of about 31.6% (Anonymous 2019a, https://*www.agricoop.nic.in*, visited on September 27, 2020). It also peaked once earlier during 2010-11 (32.48 m t) and dipped for the next two years. During the last 69 years (1950-51 to 2018-19), the area, production and yield of oilseeds attained an overall increase of 131.1%; 510.9% and 164.2%, respectively. However, the highest increase in area, production and yield, respectively, was achieved, during 2013-14 (161.4%); 2013-14 (534.7%) and 2017-18 (166.9%) as compared to those of 1950-51. The irrigated area under oilseeds also gradually but consistently increased from 0.8% in 1952-53 to 28.4% in 2015-16 (Anonymous 2020b).

India's contribution to global groundnut (in shell) production was 13.7% during 2019-20 and it ranked 2nd after China (Anonymous 2020a). In India, groundnut accounted for 19.1% and 21.4%, respectively, of oilseed cropped area and production during 2018-19 (https://*www.agricoop.nic.in*, visited on September 27, 2020). Groundnut production, area and yield in India increased from meagre 3.48 m t to 6.73 m t, 4.49 m ha to 4.73 m ha and 775 kg/ha to 1422 kg/ha, respectively, from 1950-51 to 2018-19, with an increase of 93.1 %, 5.3% and 83.4%, respectively (Anonymous 2019a, 2020b). The irrigated area also increased considerably from 1.2% (1953-54) to 28.9% (2015-16). During the last 12 years (2007-08 to 2018-19), the cropped area dipped gradually and consistently from 6.29 m ha (2007- 08) to 4.60 m ha during 2015-16, a decline of 26.9%, but, again rose by 15.4% and 16.1%, respectively, during 2016-17, 2017-18 and again dipped marginally during 2018-19. India ranked 6th after Brazil, USA, Argentina, China and Paraguay; contributed about 2.8% to the global soybean production during 2019-20 (Anonnymous 2020a). In India, it contributed about 42.1% and 44.9% to total oilseed production and acreage, respectively, during 2018-19. Soybean production and area in India showed spectacular gains since 1970-71, when the crop was introduced from USA, and increased by several thousand folds, respectively, from 0.01 m t (1970-71) to 13.27 m t (2018-19) and from 0.03 m ha (1950-51) to 11.13 m ha (2018-19). Yield (kg/ha) during this period increased by 179.8% from 426 to 1192 (Anonnymous 2019a; 2020b). However, the highest production (14.67 m t), acreage (11.72 m ha) and yield (1353 kg /ha) were recorded during 2012-13; 2013-14 and 2012-13, respectively. Yield (kg/ha) except year 2010-11 and 2012-13, was lower as compared to that of 2007-08 and varied from 739 (2015-16) to 1353 (2012-13). The crop is largely grown as rainfed and only 0.9% area was under irrigation during 2015-16 (Anonymous 2020b).

India ranked 3rd after Canada and China in rapeseed-mustard production sharing about 11.3% of the global producion during 2019-20 (Anonymous 2020a). Its contribution to oilseed area and production in India was 24.7% and 29.4%, respectively, during 2018-19. Yield showed an enhancement from 1001 to 1511 kg/ha, an increase of 50.9%. The area under rapeseed-mustard peaked thrice during the last 12 years, highest (6.90 m ha) during 2010-11 but showed variable trend, 5.96 m ha and 6.12 m ha during 2017-18 and 2018-19. Production increased over the base year during 2008-09 by 23.5% then declined during 2009-10, peaked during 2010-11 and continuously declined thereafter until 2016-17 but again peaked during 2018-19 and higher by 10.8% over the highest ever achieved during 2012-13. Nevertheless, the production during this period was always higher by 7.7%-58.8% over the base year. In 69 years (1950-51 to 2018-19), rapeseed-mustard production registered an increase of 1118.4% from 0.76 m t to 9.26 m t with concomittant increase in area by 195.7% from 2.07 m ha to 6.12 m ha. Of this, irrigated area also showed an increase from almost 0% (1952-53) to 79.9% (2015-16). The yield also increased gradually from 368 to 1511 kg/ha, an increase of 310.6% (Anonymous 2019a, 2020b).

Among sesame, linseed, niger, sunflower, safflower and castor, sesame was only predominant crop, contributing about 5.7%-7.5% and 2.2%-3.4%, respectively, to oilseed acreage and production in India during 2012-13 to 2018-19. The area and production under this crop peaked during 2015-16 and declined thereafter by 14.6% and 12.1%, respectively, during 2016-17; 19.0% and 11.2% during 2017-18 and 27.2% and 18.9% during 2018-19 (Anonymous 2019a, 2020b). Area, production and yield of sesame was altered by -16.8%; < 1% and 20.6% during 2018-19 over the base year. Linseed accounted for only 0.7%-1.3% and 0.4%-3.1% of the oilseed acreage and production, respectively, from 2012-13 to 2018-19. Yield/ha ranged from 477 kg during 2015-16 to 574 kg during 2018-19. The cropped area under linseed marginally increased (2.4%) from 2.86 lakh ha during 2012-13 to 2.93 lakh ha during 2013-14 but consitently decreased up to 2.63 lakh ha by 2015-16, showing a decline of 8.7% over the base year. Nevertheless, since then it registered an increase of 13.6% and 14.0%, respectively, during 2016-17 and 2017-18 but declined by 39.5% during 2018-19. Production decreased by 33.6% but yield increased by 14.1% during 2018-19 over the base year (Anonymous 2019a, 2020b). The area under niger was fairly low and consistently declined by 49.7% up to 1.56 lakh ha (2018-19) from 2.86 lakh ha (2012-13) and production by 55.4% from 1.01 lakh t (2012-13) to 0.45 lakh t (2018-19). The yield/ha ranged from 290-332 kg. Its contribution was low to oilseed acreage (up to 1.2%) and production (up to 1.4%).

Sunflower was introduced to India during 1970-71 with about 12 lakh ha area and gradually increased up to 26.7 lakh ha during 1993-94, since then it showed gradual declining trend up to 2001-02. It again improved and registered an increase until 2005-06 (23.4 lakh ha). Thereafter, the area showed consistent decline and reached to the lowest level of 2.62 lakh ha during 2018-19. It contributed 1.0-3.1% and 0.7-1.7%, respectively, to the oilseed acreage and production during 2012-13 to 2018-19. The highest area (26.7 lakh ha), production (14.6 lakh t) and yield (826 kg/ha) was observed during 1993-94; 2007-08 and 2018-19, respectively (Anonymous 2019a, 2020b). Further, during the last seven years, sunflower cropped area and production declined by 68.5% and 58.5%, respectively, but yield increased by 26.1% and being the highest during 2018-19 as compared to those of 2012-13.

Contribution of safflower to oilseed production and acreage was extremely low, about up to 0.4% and 0.7%, respectively, during 2012-13 to 2018-19. Since 2012-13, the safflower acreage consistently declined up to 2018-19 by 3.3% (2013-14); 4.9% (2014-15); 28.9% (2015-16); 21.7% (2016-17); 55.4% (2017-18) and 75.0% (2018-19). Its production showed an increase of 3.7% during 2013-14 and decreased thereafter by 20.4% (2014-15) to 77.1% (2018-19). Nevertheless, yield/ha though did not follow a definite pattern ranging from 416 kg (2015-16) – 673 (2017-18) and declined by 20.2% to 537 kg during 2018-19. Production of castor varied from 13.76 lakh t from 8.08 lakh ha during 2016-17 to 19.64 lakh t from 12.34 lakh ha during 2012-13. Its contribution was 3.0%-4.8% to acreage and 3.8%-6.9% to production of oilseeds from 2012-13 to 2018-19. The acreage and production of castor has been continuously declining since 2012-13 and reduction was as high as 39.1% and 39.0% , respectively, during 2018-19. But yield/ha consistently increased during the last seven years from 1592 kg in 2012-13 to 1902 kg in 2017-18, registering a spectacular increase of 19.5%, but declined by 16.2% during 2018-19 and almost similar to that of 2012-13.

Domestic oil production, net oil availability, import and export

Net domestic vegetable oils production ranged from 7.37 m t in 2006-07 to 10.35 m t in 2018-19, registering an increase of 40.4% (Anonymous 2020b). Nevertheless, it was highest during 2013-14 (Table 1). The contribution of annual oil seeds ranged between 67.2% (2018-19) – 80.0% (2006-07; 2007-08) during this period (Table 1). The continuous widening gap between demand and domestic supply due to ever increasing population and improved living standard has resulted into large imports during the last 14 years, which has gone from 4.72 m t in 2006-07 to 15.36 m t in 2017-18, 15.02 m t in 2018-19 and 14.72 m t in 2019-20, an increase of 225.4%, 218.2% and 211.9%, respectively. Vegetable oil/fat intake varied from 5.8 kg (2004-05)-8.2 kg (2011-12) in rural and 8.0 kg (2004-05)-10.4 kg (2011-12)/person/annum in urban areas, respectively, depending on the purchasing power (Anonymous 2020b). The per capita edible oil consumption gradually and consistently increased from 11.1 kg/year (2006-07) to 18.1 kg/year (2018-19) with an overall increase of 63.1%, but peaked during 2017-18 (19.5 kg/year), an increase of 75.7% with about 40% self-sufficiency (Anonymous 2020b).

Besides vegetable oils, India also imported oilseeds (niger, sesame, groundnut, others), oilmeals and castor oil to the tune of 1.28 lakh t (2011-12)–14.25 lakh t (2019-20) worth ₹ 194 crores (2011-12) – ₹4541 crores (2019-20). During 2019-20, the quantity and value of import has increased by 1013.3% and 2245.8%, respectively, over that of 2011-12 (Table 2). The vegetable oils imports are valued to an extent of foreign exchange worth over ₹ 74996 crores during 2017-18 (Table 1), a heavy burden on exchequer. Nevertheless, import of vegetable oils reduced marginally by 2.2%, valued at ₹ 69023 crores, a decrease of about 8.0% during 2018-19 and by 4.2%, valued at ₹ 68558 crores and a decrease of 8.6% during 2019-20. Vegetable oils and total (oilseeds and vegetable oils) imports accounted for about 50.4% and 52.2%, respectively, of the agricultural imports and their contributions to the total national imports were 1.92% and 1.99%, respectively, during 2018-19 (Anonymous 2020b). During the first ten months (April 2020-January 2021) of the current financial year (2020-21), India's import was 9.47 lakh t valued at ₹ 3503 crores. Further, 11.75 m t of vegetable oils has also been imported worth ₹ 67846 crores.

Nevertheless, the country has also been exporting oilseeds, oilmeals, vegetable and castor oils. The highest

Table 1 Domestic production, net availability, import and per capita availability of vegetable oils during 2006-07 to 2018-19

Year	Net availability (million tonnes)							Imort value (₹ in crores)	Self sufficiency (%)	Per capita availaibility (kg/year)
	Domestic					Import	Total			
	[A]*	[B]**	Total [A+B]	Export & industrial use	Net					
2006-07	5.90	2.25	8.15	0.78	7.37	4.72	12.09	9540	61.0	11.1
2007-08	6.96	2.49	9.45	0.80	8.65	5.61	14.26	10301	60.6	11.4
2008-09	6.66	2.52	9.16	0.70	8.46	8.18	16.64	15837	50.8	12.7
2009-10	5.89	2.51	8.40	0.45	7.95	8.82	16.77	22317	47.4	13.3
2010-11	7.63	2.75	10.38	0.59	9.78	7.24	17.02	25920	57.5	13.6
2011-12	7.06	2.84	9.90	0.95	8.96	9.94	18.90	38909	47.4	13.8
2012-13	7.20	2.86	10.06	0.84	9.22	10.60	19.82	53562	46.5	15.8
2013-14	7.75	3.01	10.76	0.71	10.19	10.98	21.17	44038	48.1	16.8
2014-15	6.55	3.08	9.63	0.59	9.04	13.85	22.89	64890	39.9	18.3
2015-16	6.06	2.93	8.99	0.55	8.44	14.82	23.26	68677	36.8	17.7
2016-17	7.31	3.44	10.75	0.65	10.10	15.31	25.41	73039	39.7	18.2
2017-18	7.36	3.65	11.01	0.63	10.38	15.36	25.74	74996	40.3	19.5
2018-19	7.43	3.52	10.95	0.60	10.35	15.02	25.55	69023	40.5	18.1

*Primary source: groundnut, rapeseed-mustard, soybean, sunflower, sesame, niger seed, safflower, castor and linseed. ** Secondary source: coconut, palm oil, cottonseed, rice bran, solvent extracted oil and tree & forest origin

export (92.39 lakh tonnes) was during 2011-12 worth ₹ 24844 crore, whereas highest foreign exchange worth ₹ 29589 crores was achieved during 2013-14 with export of 81.25 lakh tonnes (Table 2). Since 2013-14, export earnings were substantially reduced by 3.2%, 31.8% and 20.2%, respectively, during 2014-15, 2015-16 and 2016-17 (Table 2). Exports have also been reduced by 51.0% during 2016-17 as compared to that of 2011-12. Nevertheless, the export earnings have substantially increased since 2016-17 by 10.7%, 28.3% and 14.8% during 2017-18, 2018-19 and 2019-20, respectively. Export of 61.22 lakh tonnes of oilseed and products during 2018-19 fetched India foreign exchange worth ₹ 25433 crores equivalent to 9.26% and 1.10%, respectively, of agricultural and total national exports (Anonymous 2020b). During the first ten months (April 2020-January 2021) of the current financial year (2020-21), India exported 50.48 lakh t of oils seeds, oil meals and vegetable oils worth ₹ 26251 crores.

Seed Systems and supply chain

Seed system, a framework of institutions/farmers group organized together by their involvement or influence on the seed multiplication, processing, quality assurance and marketing, could be formal, informal or integrated. Chauhan *et al.* (2020) discussed in detail the three seed systems interlinking various stakeholders in formal and integrated system and supply chain. Of the three seed systems prevalent in India, the present paper is based on analysis of formal system.

Varietal diversity in seed chain

The number of varieties in the seed chain during the last six years increased from 217 during 2014-15 to 238 during 2017-18 and highest number of indented varieties in the seed chain was for rapeseed-mustard followed by groundnut (Table 3).

In the present paper, trend of seed indents for the last six years (2014-15 to 2019-20) was analyzed to study the varietal diversity, induction of recently released varieties and exclusion of old obsolete varieties in the seed chain. The varieties were also grouped according to their release and notification years to assess their contribution to indent of breeder seed. Oilseeds are predominantly grown in diverse agro-climatic conditions under stressed environment; therefore, it is imperative to produce quality seeds of agro-climatic condition-specific-variety (ies). The indented groundnut varieties for breeder seed production ranged from 40 to 56 during 2014-15 to 2019-20 (Table 4) and the contribution of top 10 varieties to the total indent varied from 81.5% (2015-16) to 88.3% (2014-15). Among the leading varieties in the seed chain, except Dharani, G 2-52, ICGV 00350, KCG 6, GVKV 5, Kadiri Harithandhra, the rest were released prior to 10 years period. TMV 2 released in 1976 and KCG 6 (released in 2016) were the earliest and latest released varieties (Table 5). Contribution of varieties released during the last 10 years (2009-18), as per the guidelines of National Food Security Mission (NFSM), DAC&FW, to promote recently released high yielding varieties, varied from 14.8% from 17 varieties (2014-15) to 44.2% from 30 varieties (2019-20). The contribution of varieties released up to 1993 declined gradually from 15.4% to 2.4% during 2017-18 but slightly increased during 2018-19 (3.8%) and 2019-20 (5.6%). Of the 33 varieties released during 2014-19, 15 were indented for breeder seed

Table 2 Trends in import and export of oilseeds, oil meals and oils during 2011-12 to 2019-20*

Year	Oil meals		Oilseeds (sesame, niger, groundnut, others)		Oil other than vegetable oil**		Total	
	Quantity (lakh tonnes)	Value (₹ in crores)	Quantity (lakh tonnes)	Value (₹ in crores)	Quantity (tonnes)	Value (₹ in crores)	Quantity (lakh tonnes)	Value (₹ in crores)
Import								
2011-12	0.86	98.7	0.42	93.6	60	1.3	1.28	194
2012-13	1.48	210.4	0.82	406.1	140	2.2	2.30	619
2013-14	1.27	200.0	1.28	979.5	70	2.0	2.55	1182
2014-15	1.65	272.7	0.87	547.5	50	1.8	2.52	822
2015-16	2.55	429.9	0.92	442.7	30	1.1	3.47	838
2016-17	5.50	974.5	1.97	918.7	110	1.5	7.47	1895
2017-18	4.86	746.7	1.61	583.4	39	2.5	6.47	1334
2018-19	5.04	869.2	3.18	1669.1	224	5.3	8.22	2544
2019-20	8.60	1519.5	5.65	3013.9	138	8.0	14.25	4541
Export								
2011-12	74.05	11796	13.11	8207	0.30 (4.93)**	269 (4572)**	92.39	24844
2012-13	65.78	16519	9.40	7451	0.36 (5.66)	469 (4310)	81.20	28749
2013-14	65.76	17070	9.82	7830	0.23 (5.44)	325 (4364)	81.25	29589
2014-15	39.04	8129	14.30	10637	0.42 (5.66)	580 (4710)	59.42	24056
2015-16	20.56	3600	10.89	8176	0.30 (5.87)	518 (4616)	37.62	16910
2016-17	26.32	5410	12.40	9104	0.61 (5.99)	786 (4521)	45.32	19821
2017-18	35.27	6969	11.44	7668	0.37 (6.97)	570 (6730)	54.05	21937
2018-19	44.25	10438	10.28	8080	0.50 (6.19)	745 (6170)	61.22	25433
2019-20	26.55	5859	10.50	9363	0.85 (5.93)	1202 (6324)	43.83	22748

*http://agriexchange.apeda.gov.in/indexp/18headgenReportmonth_combine.aspx 18.08.2019/25.06.2020; **Castor oil

Table 3 Varietal diversity in seed chain of oilseeds during the last six years

Crop	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Groundnut	56	40	42	49	46	49
Soybean	27	30	31	39	36	44
Rapeseed-mustard	60	75	73	64	61	55
Sesame	29	27	29	28	29	32
Linseed	23	18	19	25	28	31
Niger	6	10	8	8	8	11
Sunflower	5	5	6	8	10	7
Safflower	6	8	9	12	12	15
Castor	5	3	5	5	4	5
Total	217	216	222	238	234	249

production during 2019-20 (Table 4). Kadiri 6 (released in 2005), ICGV 9114 (released in 2017) and Kadiri 9 (released in 2016) were the leading varieties in the seed chain with a contribution of 27.5%-38.5%; 7.0%-13.7% and 7.0%-10.2% to the total indent, respectively.

In soybean, the indent of varieties for breeder seed increased gradually from 27 (2014-15) to 44 varieties (2019-20). Top 10 varieties contributed 80.6% (2017-18) - 98.6% (2014-15). Contribution of varieties released during the last 10 years (2009-18), varied from 1.7% from 5 varieties in 2014-15 to 66.8% from 29 varieties in 2019-20 (Table 4). Varieties released during 2014-18 were predominantly indented during 2016-17, 2017-18, 2018-19 and 2019-20 with consistent rise in contribution to 27.2%, 42.9%, 50.1% and 64.0%, respectively (Table 4). Old varieties released up to 1993 contributed only 1% and 0.1% to the total seed

Table 4 Year-wise distribution of varieties of selected oilseeds in seed chain during the last six years (2014-15 to 2019-20) and their contribution to breeder seed indent of the crop

Crop	Year	Indent (q)	Varieties	Up to 1993	1994-98	1999- 2003	2004-08	2009-13	2014-18	2019-23
Groundnut	2014-15	10546.0	56	13(15.4%)	3 (0.7%)	4(0.3%)	19(68.8%)	17(14.8%)	-	
	2015-16	7128.8	40	3 (7.5%)	1 (0.2%)	1(0.08%)	16(61.5%)	18 30.6%)	1(0.02%)	
	2016-17	11318.2	42	5(7.9%)	1 (0.1%)	2(8.6%)	12(59.7%)	17(22.2%)	5(1.4%)	
	2017-18*	10168.4	49	5 (2.4%)	2 (0.1%)	1 (0.001%)	17(57.6%)	202(28.7%)	4 (10.2%)	
	2018-19*	10458.9	46	6(3.8%)	2 (0.6%)	0	12(56.4%)	18 30.4%)	8(8.8%)	
	2019-20*	9343.3	49	6(5.4%)	1(1.0%)	0	12(49.4%)	15(26.8%)	15(17.4%)	
Soybean	2014-15	15210.8	27	2 (0.3%	5 (27.8%)	6(29.1%)	9 (41.0%)	5 (1.7%)	-	
	2015-16	16832.0	30	0	3 (23.7%)	5(21.5%)	7 (35.1%)	8 (5.8%)	7(13.9%)	
	2016-17	17766.5	31	2(0.3%)	3 (22.0%)	5(17.1%)	6 (26.6%)	6 (7.1%)	9(27.2%)	
	2017-18*	21950.5	34	0	4 (12.9%)	5(17.0%)	6(19.2%)	7(8.0%)	12 42.9%)	
	2018-19*	14800.5	36	2(1.0%	2 (17.8%)	4(13.5%)	6(13.8%)	6 (4.8%)	16(50.1%)	
	2019-20*	16901.3	44	4 (0.1%	1 (14.4%)	4(10.4%)	6 (8.2%)	7 (2.8%)	22(64.0%)	
Rapeseed-mustard	2014-15	127.3	60	22(74.5%)	5 (7.9%)	5(2.9%)	9 (5.7%)	19 (8.6%)	-	
	2015-16	107.1	75	15(27.2%)	4 (5.1%)	12(4.1%)	12(24.3%)	27(37.6%)	5(1.3%)	
	2016-17	100.8	73	20 (44.4%)	5 (3.4%)	8(6.3%)	11(10.3%)	26 32.0%)	3 (3.3%)	
	2017-18*	81.9	64	17(28.5%)	4 (4.5%)	2(0.7%)	10(13.4%)	22 50.5%)	9 (2.4%)	
	2018-19*	84.8	61	14(25.6%)	6 (3.8%)	2(0.9%)	7(9.0%)	20(55.4%)	11(5.4%)	
	2019-20*	76.1	55	7 (5.9%)	0	0	4(7.8%)	19(55.1%)	24(31.3%)	1(0.06%)
Sesame	2014-15	23.2	29	7 (7.8%)	3 (19.9%)	7(22.2%)	6 (35.6%)	6 (14.5%)	-	
	2015-16	25.8	27	5(7.7%)	2 (15.1%)	5(13.7%)	8 (53.0%)	6 (10.5%)	1(0.08%)	
	2016-17	29.3	29	7(11.1%)	2 (13.4%)	2(3.6%)	8 (56.4%)	10(15.5%)	-	
	2017-18*	18.1	28	7(20.7%)	2 (16.2%)	2(1.7%)	7 (39.9%)	9 (22.3%)	1(0.1%)	
	2018-19*	44.0	29	9(6.7%)	2 (12.5%)	3(1.8%)	6 (38.5%)	18(30.6%)	1(0.04%)	
	2019-20*	29.6	32	8(17.6%)	2 (2.5%)	2(3.7%)	5 (21.5%)	9 (43.8%)	6(10.9%)	
Linseed	2014-15	60.7	23	1(3.6%)	2 (2.6%)	6(14.9%)	9(55.9%)	5(22.9%)	-	
	2015-16	46.5	18	1 (5.4%)	-	6(17.6%)	8 (62.3%)	3 (14.7%)	-	
	2016-17	48.8	19	1 (1.4%)	1 (1.8%)	3(24.8%)	7 (50.3%)	4 (16.2%)	3(5.4%)	
	2017-18*	73.0	25	3(5.4%)	1 (2.5%)	2(2.6%)	6 (42.3%)	7 (36.2%)	6(11.0%)	
	2018-19*	75.4	28	-	-	3(3.4%)	7 (23.1%)	6(30.2%)	12(43.2%)	
	2019-20*	72.4	31	-	-	-	5 (19.8%)	5 (28.3%)	21(51.6%)	1(0.3%)

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

indent during 2018-19 and 2019-20, respectively. The predominant varieties in the seed chain were JS 335, JS 95-60, JS 93-5, JS 20-34, MAUS 71 and JS 97-52 contributing, respectively, 12.8%-29%; 7.4%-35.8%; 9.9%-21.5%; 5.6%-15%; 2.8%-5.0% and 2.6%-4.0%, to the seed indent. Of the 40 varieties released during 2014-19, 22 were in seed chain during 2019-20.

In rapeseed-mustard, the highest number of indented varieties (75) in the year 2015-16 and the lowest (55) in the year 2019-20 (Table 4). Top 10 varieties contributed from 39.0% (2016-17) to 76.0% (2014-15). Among the predominant high yielding varieties in the seed chain during the last six years, except NRCHB 101, Pusa mustard 25, Raj Vijay Mustard 2, Pusa mustard 28, Giriraj (DRMR IJ 31), Pusa Mustard 30, Pusa Mustard 26, Pusa mustard 27, Chhatisgarh Sarson, Pant Pili Sarson 1 and Uttara, the rest were released before 10 years. RH 761, released during 2019 was also indented during 2019-20. Pusa Bold and Benoy were the leading varieties with a contribution ranging from 3.0–23.7% and 3.8–5.2%, respectively. The contribution of varieties released up to 1993, declined from 74.5% in 2014-15 to 5.9% in 2019-20 (Table 4). Of the 44 varieties released during 2014-19, only 24 were indented for seed production during 2019-20.

The highest number of indented varieties of sesame was 32 during 2019-20 (Table 4). The share of varieties released during 2014-18 also increased from 0.08% from one variety (2015-16) to 10.9% from six varieties (2019-20). The share of top 10 leading varieties varied from 68.6% to 84.9% during 2018-19. The leading varieties in the seed chain were Punjab Til No.1, Suprava, Gujarat Til 2, Jawahar Til [Venkat], TKG 306, Gujarat Til 10 and Rajasthan Til 351. Of these, Punjab Til No.1 and Suprava was the oldest and latest released variety, respectively (Table 5). TKG 306 was the leading variety in the seed chain, contributing 5.8%-17.8%, to the total indent up to 2018-19. Gujarat Til 3 followed by Rajasthan Til 351 were the leading varieties with contribution of 14.6% and 9.7%, respectively, to the seed indent during 2019-20 and only six out of 10 varieties released during 2014-19 were inducted in the seed chain.

In linseed, from 23 indented varieties for breeder seed production during 2014-15, the number went down to 18 during 2015-16 (Table 4) but consistently increased thereafter to 31 (2019-20). Twenty-two varieties were released during 2014-19 and 21 were in the seed chain during 2019-20, contribution to the total indent was 51.6% for varieties released during 2014-18 (Table 4). The highest (97.3%) and lowest (68.7%) contribution of leading 10 varieties was observed during the year 2014-15 and 2019-20, respectively. Of the 24 varieties developed during the 2014-2019, 21 contributed the highest during 2019-20. The top three leading varieties with significant contributions during the last six years were Indira Alsi 32 (6.9-21.9%), Kartika (2.8-15.6%) and JLS 73 (4.8-7.6%) released during 2005, 2005 and 2011, respectively.

In niger, 4-11 varieties were indented for breeder seed production during 2014-15 to 2019-20. The predominant varieties in the seed chain were Birsa Niger 3 (released in 2010), JNS 9 (released in 2006), Uttakal Niger 150 (released in 2002) and Deomali (released in 1992) with share of 8.3-34.1%; 9.9-29.5%; 14.5-31.6% and 10.4-16.7%, respectively. JNC 6, released in 2002, was another leading variety indented during 2019-20 and contributed 29% to the breeder seed. Of the five varieties released during the last six years, only JNS 28, a variety released in 2017 was inducted in the seed chain until 2019-20. In sunflower, mostly hybrids from private sector dominate and do not form the part of formal seed system. Very low quantity of breeder seed (0.97-2.78 q) was indented for 5-10 hybrids/varieties during the last six years. Kanthi (released in 2012), DRSF 113 (released in 2007), RHA 95C-1 (released in 2009) contributed 54.6-65.5% to the total indent during 2015-16, 2016-17 and 2017-18 whereas; LFSH 17 (released in 2018), KBSH 41(released in 2005) and KBSH 53 (released in 2009) accounted for 75.8% of the breeder seed indent during 2019-20.

Safflower indented varieties ranged from 6 (2014-15) to 15 (2019-20). The predominant varieties in the seed chain were AKS 207 (released in 2007), PBNS 40 (released in 2007), Prabhni Kusum (released in 2007) accounted for 13-32.9%; 9.9-21.7% and 7-16.1%, respectively, of the indents. Of the 8 varieties released during 2014-19, only NARI 96, a release of 2018 was inducted in the seed chain during 2018-19 and accounted for 7% and 6.3% during 2018-19 and 2019-20, respectively, of the seed indent. IF 764 (released in 2016) was another leading variety with contribution of 32.9% to the breeder seed indent during 2019-20.

In castor, only hybrids GCH 4, GCH 7, GCH 8, a variety Kranti were indented for breeder seed production during 2014-15 to 2018-19 and together account for more than 90% of the seed indent. GCH 7 which was released during 2007 was the major contributor with 7.0% (2014-15) - 86.5% (2015-16) share in the breeder seed indent. GCH 8 released during 2018 and inducted to the seed chain during 2018-19 accounted for 48.8% of the indent. Of the seven hybrids/varieties indented during 2019-20, GCH 7, GCH 8 and Aruna (released in 1976) together contributed 58.2% of the indent and each had a share of 20.9%, 14% and 23.3%, respectively.

Breeder seed

The effective seed chain commences with the production of adequate quantity of breeder seed. The National Agriculture Research, Education and Extension System is mandated to produce breeder seed and supply through Department of Agriculture, Cooperation and Farmers Welfare (DoAC&FW), Ministry of Agriculture & Farmers Welfare, Government of India to the indenting stakeholders both from public and private sectors for downstream multiplication. Analysis of indent and production of breeder seed for the last 12 years (2007-08 to 2018-19) showed inconsistent trend, breeder seed indent gradually increased from 22577 q in 2007-08 to 41404 q in 2011-12 showing an increase of 83.4%. Then the indent consistently decreased for the next four years and reached the lowest during 2015-16 (23953q), showing a decrease of 42.1% over that of 2011-12. Though, breeder seed indent showed upward trend since 2015-16 yet remained lower than the highest ever recorded in 2011-12. However, it increased by 24.9%, 35.0% and 3.6%, respectively, (Anonymous 2020b) in 2016-17 (29294q), 2017-18 and 2018-19 (25153q) in comparison to that of 2015-16. In the year 2007-08, indent for oilseeds were 37.9% of the total indent, it decreased during 2008-09 and increased thereafter until 2012-13 and reached the highest (46.8%). It showed declining trend since then up to 2015-16 (38.7%). Thereafter, it again increased up during 2016-17 (40.0%) and 2017-18 (43.6%). Contribution of oilseeds to total indent was 39.0% and 42.8%, respectively, during 2018-19 and 2019-20. Among the oilseeds, soybean was the main contributor to the oilseeds indent (Anonymous 2018b; 2019c; 2020b,c) with a share ranging from 33.5% (2009-10) to 67.9% (2017-18) followed by groundnut, contribution ranging from 29.8% (2015-16)-66.0% (2009-10). Among the remaining seven crops, only rapeseed-mustard with a share of 0.25%-0.71% was the third highest followed by linseed (0.13%-0.34%) are worth mentioning ((Anonymous 2018b; 2019b; 2020b, c). Soybean, groundnut and rest of the crops contributed 63.9%, 35.3% and 0.8%, respectively, to the total breeder seed indent for oilseeds (26458 q) during 2019-20 (Anonymous 2018b; 2019b, 2020c). Chauhan *et al.*

(2014) also reported predominant contribution of soybean and groundnut to total breeder seed indent of oilseeds.

Among the 12 years, breeder seed production followed the similar trends and lower than the indents for 8 years except 2007-08, 2010-11, 2011-12 and 2018-19 (Anonymous 2020c).

Seed requirement and availability

Analysis of data of seed requirement and availability during the last 11 years (2008-09-2018-19) revealed that there has been a continuous surge in the requirement for seed of oilseeds, varying from 48.14 lakh q (2008-09) to 58.56 lakh q during 2018-19 with an overall increase of 21.6% (Anonymous 2019a; 2020b). The highest ever requirement (67.13 lakh q), higher by 39.4% than that of 2008-09, was recorded during 2014-15. The availability of quality seed of oilseeds during the last 11 years, except for two years, viz. 2014-15 and 2015-16, was invariably, higher than the requirement by 4.7% (2016-17)–21.0% (2009-10). Contribution of public sector to total seed availability in the country gradually decreased from 62.0 to 46.4%.

Seed replacement rate

During the last 12 years (2007-08 to 2018-19), there has been tremendous enhancement in seed requirement and availability. In general, barring a few years, seed availability was always higher than the requirement for most of the crops. This was amply demonstrated in the increased seed replacement rates (SRR) during this period for almost all the oilseeds except sunflower and rapeseed-mustard, viz. groundnut from 14.3–22.4%; soybean from 29.5–39.5%; sesame from 25% to 39.5%; safflower from 15.7–36.7% and castor from 31.3% to 54.0%. However, SRR for sunflower and rapeseed-mustard decreased from 62.9% (2007-08) to 30.3% (2018-19) and from 58.6% (2007- 08) to 52.4% (2018-19), respectively. The SRR reached highest, 25.4% for groundnut during 2013-14; 52.8% for soybean during 2011-12; 78.9% for rapeseed-mustard during 2011-12; 42.4% for sesame during 2016-17; 96.3% for sunflower during 2014-15; 36.7% for safflower during 2018-19 and 95.4% for castor during 2017-18 (https://seednet.gov.in/readyrecknor/Seed_III_VI.aspx, visited on October 20, 2019). Considering the ideal SRR of at least 33% for self-pollinated crops; 50% for cross pollinated crops and 100% for hybrids, the analysis revealed that despite spectacular success in seed production, ideal SRR is lower than the requisite one during 2018-19 for groundnut, sunflower and castor. Further, there is a need for consistently maintaining the requisite SRR for each crop. The increased SRR could be one of the reasons for increase in yield by 14.0% of oilseeds during the period under study.

Challenges and strategy

Indian Council of Medical Research prescribed minimum nutritional norm of 14 kg/person/year visible oil/fat intake (Rai 1987). During 2018-19, total per capita availability was 18.7 kg/year, *viz.* 18.1 kg vegetable oil and 0.6 kg *vanaspati.* The per capita availability of edible oil and *vanaspati* surpassed the ICMR norms since 2008-09 (Anonymous 2020 b). India has ever increasing population which is expected to grow at average annual exponential growth rate of 1.10% and would be 1.42 billion and 1.48 billion by 2025 and 2030, respectively, from current population of 1.34 billion (DRMR 2011; Anonymous 2019a; 2020b), with increasing purchasing power of the people resulting in enhanced per capita edible oil consumption. It is expected that annual growth of demand for edible oil would be 3.54% during 2011-30 (DRMR 2011). Accordingly, it is estimated that the per capita edible oil consumption would be around 23 kg/year from the present level of 18.1kg/year. This necessitates the production of nearly 34 m t of edible oil which translates to 102.3 m t of oilseeds and annual oilseeds production should be around 82 m t to meet the requirement of edible oil by 2030 (DRMR 2011). The projected demand for oilseeds/edible oil was 59 m t and projected supply was only 33-41 m t during 2016-17. The projected demand for oilseeds/edible oil would be 61.5 m t/17.2 m t during 2021-22 and the projected supply be only 39.2 m t (Anonymous 2020b) against the highest ever production of oilseeds in India, 33.42 m t, during 2019-20. A daunting and very challenging task considering there is little scope of area expansion and the crops are grown under stressed agro ecosystem. The average annual growth rate of oilseeds production is expected to be 3.47%-4.29% during 2016-24 according to NCAER (Anonymous 2019c). Although, existing technological advances have shown time and again that oilseed production could be increased considerably yet it is a formidable challenge.

To further increase oilseed production, realizing the vast untapped exploitable yield reservoir (48.9%) of the oilseeds is essentially critical. This could be insured through seed security as it is the key input for realizing potential productivity of varieties &/or other technologies. In addition to ensuring timely availability of quality seed, sufficient varietal diversity in seed chain preferably inducting recently developed high yielding, stress tolerant varieties and replacing old and obsolete varieties, is imperative to enhance production of oilseeds. Greater efforts should be made in showcasing and popularizing newly released varieties and enhancing their seed multiplication for increased availability of quality seed. Therefore, there is an urgent need for increasing varietal replacement rate (VRR) as sufficient SRR, even more than the ideal one has been achieved already in 2017-18 in most of the oilseeds except groundnut and safflower. In all the oilseeds, enough of breeder seed is produced except soybean. In fact, several times more than the required quantity, this could be sufficient for more than 100% SRR in the entire cropped area. Hence, their downstream conversion chain from breeder to foundation/certified seeds need to be strengthened (Prasad *et al.* 2017).

Non-lifting/partial lifting of breeder seed by indenters is a serious concern in most of the crops including oilseeds as huge resources was infused for producing breeder seeds of highest quality. Therefore, reinforce rigorously policy of payment of 25% advance of the cost of breeder seed from the indenters to at least off-shoot the monetary losses in the likely event of non-lifting of seed. Similarly, the price of breeder seed should be regularly revised matching the premium activity. Keeping in view the critical gap between potential yield and state/national average, the Department of Agriculture, Cooperation and Farmers Welfare (DoAC& FW), Ministry of Agriculture & Farmers Welfare, Government of India and ICAR, New Delhi took several initiatives for oilseed research and development, such as inception of technology mission on oilseeds (TMO) during 1986 and later in 1990's broadening its scope by including pulses and rechristening it as technology mission on oilseeds and pulses (TMOP).The production and area during TMOP jumped from 10.83 m t from 19.02 m ha during 1985-86 to 20.11 m t from 25.24 m ha during 1992-93. During this period, area, production and yield increased by 32.7%, 85.7% and 39.8%, respectively. In fact, TMOP was credited to bring *yellow revolution* by 1992-93 when edible oil import was the lowest (1.0 lakh tonne) due to concerted and systematic efforts in mission mode by integrating production, processing and marketing. The level of self-sufficiency was all time high (98%) during 1992-93 and 1993-94. However, the per capita availability was only 6.8-7.1 kg/year during this period. Such initiatives should not only continue but also further strengthened in terms of human and financial resources and extend to currently non-covered areas and crops. Mega seed project launched during 2005-06 and National Mission on Agricultural Extension and Technology initiated during XII plan (Chauhan *et al.* 2016a; 2017; Prasad *et al.* 2017) included sub-mission on seed and planting material enhanced breeder seed production and had great impact on enhanced availability of quality seed of newly released varieties and thus production of oilseeds.

Regular review and updating seed rolling plan by the concerned authorities in consultation with SAU/ICAR institutes, considering ideal SRR with more emphasis on VRR would play an important role in further increasing oilseed production. Seed chain has broadly two activities: breeder seed production and its conversion into downstream classes to achieve higher seed production and delivery system to the end users. Various state seed producing agencies are the major indenters for breeder seed, hence states should come up with holistic planning of seed production programmes and timely place indents with appropriate agency. Since groundnut and soybean are the large volume crops with low seed multiplication ratio, therefore, greater emphasis need to be placed on seed production of these crops in seed hubs.

Chauhan *et al*. (2020b) elaborated and discussed various programmes of ICAR, New Delhi and the DoAC& FW and various models being adopted by different SAUs/ICAR institutes and state governments for farmer participatory seed production. It should be further refined to make it responsive, qualitative, financially viable and sustainable in transparent manner to complement the efforts of formal seed production. Focus should also be on capacity building of farmers especially women and rural youth for quality seed production and regular technical back-stopping by the research and development institutes (SAUs/KVKs/ICAR institutes) in the target areas.

Conclusion

Vibrant crop specific improvement programmes, 187 newly released high yielding varieties, robust and effective seed chain, climate favouring seed production of diverse oilseeds are available but coordinated and concerted efforts to derive synergy is essential to meet the challenges for further enhancing oilseed production. Further, private seed sector has a strong presence in India and playing an appreciable dominant role in meeting seed requirement. Therefore, there is an urgent need for public sector to work in tandem and develop partnerships and complement efforts of each other with the budge word, easy access to quality seed at affordable prices. Nevertheless, the progress and outcome are largely dependent on Government policies and support such as need based imports of edible oil, remunerative price to the farmers for their produce through minimum support price (MSP) and effective market interventions to ensure MSP and avoid distress sale, establishing storage facilities, seed banks, seed villages and oilseed hubs in various zones of the country.

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