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Sustaining national food security and increasing farmers' income through quality seed

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ABSTRACT

Since independence, India achieved a distinction from ship-to-mouth status to self dependent, food surplus and net exporter of food grains in 69 years and recorded an all time high (285.2 million tonnes) production during 2018-19 from meagre 50.8 mt during 1950-51. In spite of spectacular success in food production over the years, it is a great challenge to sustain high production as well as enhance it further to meet the future requirement, as the population continues to grow steadily with an annual growth rate of 1.10% and expected to be 1.42 billion and 1.48 billion by 2025 and 2030, respectively, from 1.32 billion during 2017; coupled with enhanced consumption of food grains due to rising income, necessitating an increase of 4.5% and 15.7% by 2020 and 2030, respectively, over the present food production. It is a great challenge in view of climate change, diminishing and degrading land and water resources, increasing biotic and abiotic stresses and loss of bio-diversity. The present paper discusses the trend of production and productivity of food crops from 1950-51 to 2018-19; assess the contribution of seed to food production, seed chain, quality seed production and scope of quality seed for enhancing farmers' income and future strategies for seed research, production and development to sustain food production. Requisite assets such as a strong crop specific cultivar development programmes, 850 high yielding food crop varieties comprising 657 of cereals and 193 of pulses released during the last six years, robust and vibrant seed systems, quality regulatory mechanism, globally competitive seed sector and the largest arable land with 46 soil types across 15 agro-climatic zones favouring seed production of diverse crops are available for sustaining high food production and meet the future demand for seed and food. Ensuring availability of quality seed in adequate quantity though imperative, yet, itself is not enough to trigger the production if it is not coupled with achieving sufficient varietal diversity in seed chain preferably phasing out gradually the old and obsolete varieties and inducting recently developed high yielding and disease resistant varieties. The overall progress and outcome are largely dependent on Government policies and support, which require consistent and adequate financial resources for sustaining a vibrant seed production, farm power machinery, processing units, storage, seed testing, delivery systems and trained human resources besides remunerative prices to the farmers.

Key words: Breeder seed, Cereals, Food security, Participatory seed production, Pulses, Seed security, Seed systems, Seed chain, Seed replacement rate

Agriculture is the mainstay of India despite its gradual and consistent declining contribution to national Gross Domestic Product/ Gross Value Added (GDP/GVA) over the last 10 years and it stood at 17.1% during 2017-18, since 54.6% population is still directly or indirectly dependent on agriculture and associated activities. Of the 17.1% contribution of agriculture to GVA, crops contributed about 9.4% (Anonymous 20a). Since independence, India achieved a distinction from ship-to-mouth status to self dependent, food surplus and net exporter of food grains in about 69 years. This was made possible due to concerted and integrated efforts of research and development personnel, hard working innovative farmers backed by enabling government policies. India achieved an all time high food production of 285.2 million tonnes (mt) during 2018-19 (nttp://agri.coop.nic.in visited on september 27, 2020), which is higher by 20.2 mt over the highest ever achieved earlier during 2013-14 (265.0 mt). This spectacular success in food production enabled Indian policy makers to enact Food Security Act 2013 which enabled 67% of the then Indian population (1.2 billion) to get food grains at highly subsidized rates of ₹ 1 (coarse cereals), ₹ 2 (wheat) and ₹ 3 (rice) per kilo gram to nearly over 840 million people of the total 1324 million total population. Presently, India has

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the 2nd next to USA, during 2017 highest arable land (156.5 m ha) and globally accounts for 2.3% of the land; 4% water and 17.7% of the population (Anonymous 2019a; 2020a). The present paper discusses the trend of production and productivity of food crops during the last 69 years (1950-51 to 2018-19); assess the contribution of seed to food production, seed chain, quality seed production and scope of quality seed for enhancing farmers' income and future strategies for seed research, production and development to sustain food production.

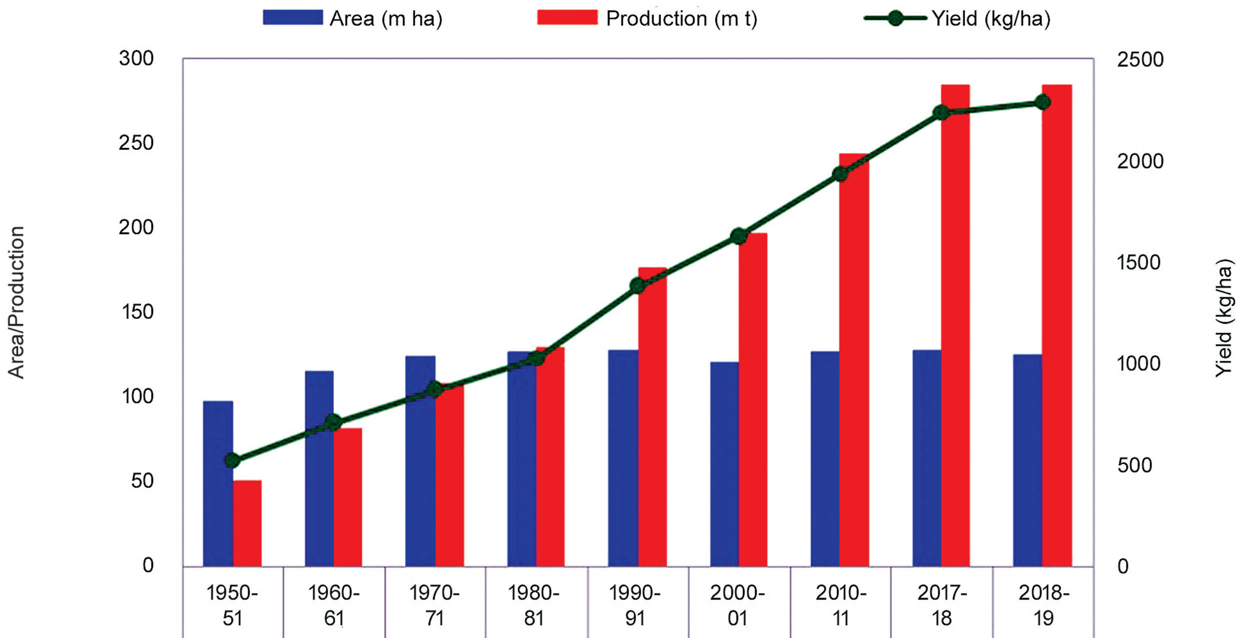
Food production scenario in India

Food crops comprise cereals and pulses. The contribution of pulses during the last seven years (2012-13 to 2018-19) to acreage and production of food grains varied between 19.0-23.9% and 6.5%-8.8%, respectively (Anonymous 2019a). The food production increased during the first 60 years consistently from meagre 50.8 m t during 1950-51 to 244.5 m t during 2010-11 showing an increase of 381.3% (Fig 1). During the corresponding period, the gross cropped and net sown area also rose considerably from 131.9 million hectares (m ha) in 1950-51 to 197.6 m ha in 2010-11 and 118.8 m ha to 141.6 m ha, an increase of 49.8% and 19.2%, respectively. The net sown area consistently increased and peaked during 1990-91 (142.9 m ha), an increase of 20.3% over that of 1950-51. It was fairly consistent ranging from 131.9 m ha (2002-03) to 141.9 m ha (2008-09) with an increase of only 7.5%. During the last decade (2005-06 to 2014-15), the net sown area showed very little change (1.7%) varying from 139.2 m ha during 2006-07 to 141.6 m ha during 2010-11 (Anonymous 2019a). However, during 2014-15, the gross cropped year increased up to 198.4 m ha from 189.0 m ha during 2009-10 but there was marginal decline in net sown area (140.1 m ha). The highest gross (200.9 m ha) and net sown area (141.9 m ha) was recorded during 2013-14 and 2008-09, respectively. The irrigated gross and net area increased from 17.3% (1950-51) to 48.1% (2015-16) and 17.6% (1950-51) to 49% (2015-16), respectively (Anonymous 2020a) and the cropping intensity has also increased to 1.41.

The irrigated area under food crops also gradually but consistently increased from 18.1% in 1950-51 to 52.6% in 2015-16 (Anonymous 2020a). It is inferred that area expansion coupled with technology (varieties, inputs, irrigation, etc.) ensured food grain enhancement since 1950-51 until 1990-91. Thereafter and in recent years, it was largely due to technological advances in cultivar development and crop management. Further, trend analysis of the last 12 years (2007-08 to 2018-19) revealed that food production varied from 218.1 mt (2009-10) to 285.2 mt (2018-19), registering an increase of about 30.8% (Anonymous 2019a, nttp://agri.coop.nic.in, visited on september 27, 2020). It showed an increase of 7.6% during 2018-19 over the earlier highest ever production during 2013-14. Overall, the area, production and yield during 2018-19 increased from 97.3 m ha (1950-51) to 124.8 m ha; 50.8 m t (1950-51) to 285.2 m t and 522 (1950-51) to 2285 kg/ha registering an increase of 28.3%, 461.4% and 337.7%, respectively.

Cereals

Of the cereals, rice (*Oryza sativa* L.), wheat (*Triticum*



	1950-51	1960-61	1970-71	1980-81	1990-91	2000-01	2010-11	2017-18	2018-19
Area (m ha)	97.3	115.6	124.3	126.7	127.8	121.0	126.7	127.6	124.8
Production (m t)	50.8	82.0	108.4	129.6	176.4	196.8	244.5	284.8	285.2
Yield (kg/ha)	522	710	872	1023	1380	1626	1930	2233	2285

Fig 1 Trends in area (m ha), production (mt) and yield (kg/ha) of food grains during 1950-51 to 2018-19.

aestivum L. / *Triticum dicoccum* Schuble / *Triticum durum* Desf.), maize (*Zea mays* L.), pearl-millet [*Pennisetum typhoides* (Burm.f.) S. & H.] and sorghum (*Sorghum vulgare* Pers.) accounted for about 97.6%-98.0% and 98.3%-99.3% of total acreage and production of cereals and other coarse grains (barley, minor and small millets) accounted for the rest during 2013-14 to 2018-19. Hence, only five crops were taken into account for presenting scenario of cereals in India.

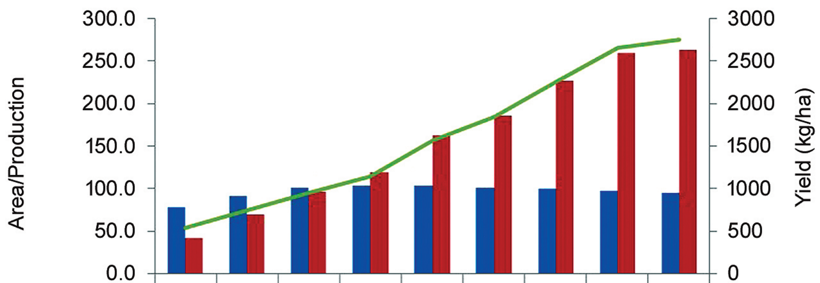
India ranked 3rd after China and USA contributing 10.5% to the global cereal production during 2017 (Anonymous 2020a). Cereal production in India showed spectacular progress since 1950-51 and increased by 520.5% with only 22.3% increase in cropped area, from 42.4 m t (1950-51) to 263.1 m t (2018-19) and 78.2 m ha (1950-51) to 95.6 m ha (2018-19), respectively. Yield (kg/ha) during this period increased by 407.7% from 542 to 2752 (Fig 2). During the last 12 years, production increased from 216.0 m t during 2007-08 to 263.1 m t during 2018-19 (Anonymous 2019a, 2020a) showing a surge of 21.8%. However, no consistent trend of increase/decrease was discernable. The lowest production was recorded during 2009-10, a drought year, and production declined by 5.8% over the base year. The production exhibited clear peaks during 2011-12, 2013-14 and 2018-19. This was made possible by increased production of wheat, rice and maize, the main contributors to the cereal production. The acreage of cereals ranged from 95.6 m ha (2018-19) to 100.7 m ha (2008-09) and the yield (kg/ha) except years 2009-10 and 2014-15, increased consistently until 2018-19 from 2150 (2007-08) to 2752 (2018-19).

India ranked 2nd after China in paddy production sharing 21.9% of the global production during 2017 (Anonymous 2019a). Rice in India contributed 46.2% and 44.3%, respectively, to cereals acreage and production during 2018-19. Rice production in India during the last 12 years, varied between 96.7 m t (2007-08) from 43.9 m ha to 116.5 m t from 44.2 m ha cropped area during 2018-19 (Anonymous 2019a) showing an increase of 20.5% with almost no change in area suggesting a spectacular increase in yield from 2202 to 2638 kg/ha. In 69 years (1950-51 to 2018-19), it registered an increase of 468.3%, from 20.5 m t to 116.5 m t with concomitant increase in area by 43.5% from 30.8 m ha to 44.2 m ha. Of this, irrigated area also showed an increase from 31.7% to 60.1% (2015-16). The yield also increased gradually from 668 to 2638 kg/ha.

India's contribution to global wheat production was 12.8% during 2017 and it ranked 2nd after China (Anonymous 2020a). In India, contribution of wheat to total acreage and production of cereals was 30.6% and 39.4%, respectively, during 2018-19. Wheat production and cropped area also increased from meagre 6.5 m t to 103.6 m t and 9.8 m ha to 29.3 m ha, respectively, from 1950-51 to 2018-19, with an increase of 1493.8 % and 199.0%, respectively. The irrigated area also increased nearly 3 times from 34% to 94.2% (2015-16). The yield during this period showed spectacular gains from 663 to 3533 kg/ha, more than five times (Anonymous 2019).

Coarse cereals (maize, sorghum and pearl millet) contributed 21.1%-22,8% and 14.8%-16.6% to the total cereal cropped area and production, respectively, during 2013-14 to 2018-19. Since 1950-51 there has been a gradual decline in area under sorghum and pearl millet (Anonymous 2019a). Maize, though showed variable, yet, increasing trend for cropped area from 3.2 m ha (1950-51) to 9.5 m ha (2017-18) but declined to 9.0 m ha during 2018-19, a surge of 196.9% and 181.3%, respectively. Similar trends were recorded for production and yield (kg/ha) that increased from 1.7 m t to 27.7 m t during the corresponding period. The highest production was recorded during 2017-18. Over the last 69 years, production increased by 152.9% and yield by 463.3% during 2018-19. The maize area under irrigation was also more than doubled from 11.4 % (1950-51) to 26.7% (2015-16).

Sorghum cropped area was 15.6 m ha during 1950-51 and attained the highest (18.7 m ha) during 1968-69 (Anonymous 2019a). Thereafter, consistent gradual decline was observed until 1998-99 when it reached 9.8 m ha. Since 1999-2000, area remained below 10 m ha and continued to decline further and reached the lowest ever of 4.1 m ha (2018-19). Overall, the cropped area during 2018-19 reduced by 73.7% as comapred to that of 1950-51 and by 78.1% as compared to the highest ever. Sorghum production ranged from 5.5 m t during 1950-51 to 12.8 m t from 13.0 m ha during 1992-93. It was 3.5 m t from 4.1 m ha during 2018-19.The yield (kg/ha) increased continuously from 1950-51(353) to 2017-18 (998) and declined to 849 during 2018-19. The area, production and yield showed a net change of -73.7%, -11.6% and 140.5%, respectively, during 2018-19, as compared to that of 1950-51. During the last seven years, the lowest production was during 2018-19 and the highest yield and production was in



	1950-51	1960-61	1970-71	1980-81	1990-91	2000-01	2010-11	2017-18	2018-19
Area (mha)	78.2	92.0	101.8	104.2	103.2	100.7	100.3	90.6	95.0
Production (mt)	42.4	69.3	96.6	119.0	162.1	185.7	226.3	259.6	263.1
Yield (kg/ha)	542	753	949	1142	1571	1844	2256	2660	2752

Fig 2 Trends in area (m ha), production (m t) and yield (kg/ha) of cereals during 1950-51 to 2018-19.

2017-18. The irrigated area increased from 3.0% (1950-51) to 10.3% (2015-16).

The cropped area under pearl millet showed variable but increasing trend from 1950-51 and except for two years (1987-88 and 1993-94), remained well above 10 m ha. The highest ever (13.9 m ha) was attained during 1973-74 (Anonymous 2019a). From 1995-96 onwards, the area remained below 10.0 m ha except 2003-04 (10.6 m ha). It continued to decline, but no definite trend, and reached 7.1 m ha during 2015-16 and 2018-19. The production of pearl millet ranged from 2.6 m t (1950-51) to 8.7 m t (2018-19) and the highest (12.1 m t) was recorded during 2003-04. There was spectacular increase of 323.3% in yield from 1950-51 (288 kg/ha) to 2018-19 (1219 kg/ha) and the change in area and production was -21.1% and 234.6%, respectively.The irrigated area also enhanced from 3.4% to 10.5% during 2015-16 (Anonymous 2020). During the last 12 years (2007-08 to 2018-19) no definite trend was observed, the area, production and yield varied between 7.0 m ha (2015-16) -9.6 m ha (2007-08); 6.5 m t (2009-10)-10.0 m t (2007-08) and 731 kg/ha (2009-10)-1305 kg/ha (2016-17), respectively (Anonymous 2019a, 2020).

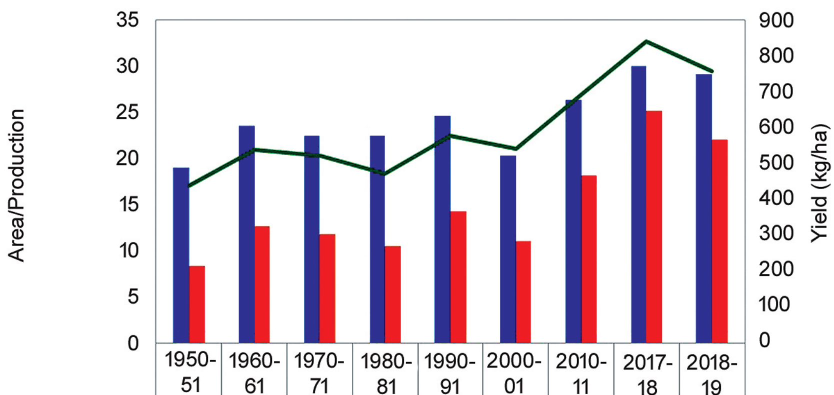
The country has been producing surplus rice, wheat and maize over the years and also a major exporter in the world market. India during 2019-20 exported wheat (0.22 m t), rice (9.49 m t) and maize (0.37 m t) and earned foreign exchange worth ₹ 4.4 billion, 453.8 billion and 10.2 billion, respectively. During the first seven months (April- October 2020) of the current financial year (2020-21), foreign exchange worth ₹ 10.02 billion has been achieved from the export of 0.51 m t of wheat and ₹ 356.44 billion from 8.87 m t of rice (http://agriexchange.aped.gov.in, visited on December 5, 2020) and ₹ 13.77 billion from export of 0.92 mt of maize during April-September 2020 (https://commerce-app.gov.in, visited on December 9, 2020).

Pulses

Pulses are unique for high protein content (20 to 25%), ability to fix atmospheric nitrogen (ca 30-150 kg/ha) and consistent source of income and employment to small and marginal farmers; and thus hold a premier position in the global agriculture (Ali and Gupta 2012). In India, pulses constitute a group of 12 crops that include mainly chickpea (*Cicer arietinum* L.), pigeonpea (*Cajanus cajan* L.), mungbean (*Vigna radiata* L. Wilczek), urdbean (*Vigna mungo* L. Hepper), lentil (*Lens culinaris* L.) and fieldpea (*Pisum sativum* L.). These six crops contributed about 90% to the total production of pulses. India is the largest producer of pulses and ranked first, contributing 22.2% to the global production (Anonymous 2020a) during 2017. It is also the biggest consumer with a domestic consumption of about 22.0 m t during 2016-17 and expected to be 25.0 m t by 2020-21(Anonymous 2018a). Because of annual deficit of more than 5.5 m t, India imported huge quantity of pulses 5.8 m t (about 26.6% of consumption) worth ₹ 256.2 billion during 2015-16 and the highest import was during 2016-17 (₹ 285.2 billion). Since then pulses production made a remarkable gain during 2016-17 (23.1 m t) and 2017-18 (25.2 mt) but decreased during 2018-19 (22.1 mt) resulting into considerable decline in import bill during 2017-18, 2018-19 and 2019-20. But import bill increased by 27.3% during 2019-20 over that of 2018-19. Nevertheless, pulses worth ₹ 12.2-18.0 billion were also exported annually during this period. During 2019-20, 0.24 m t of pulses has been exported, worth ₹ 15.3 billion. During the first seven months (April-October 2020) of the current financial year (2020-21), import and export of pulses have been 1.16 mt (worth ₹ 54.91 billion) and 0.18 mt (worth ₹ 12.83 billion), respectively (http://agriexchange.apeda.gov.in, visited on December, 2020).

India has made spectacular progress in pulses production during the past 69 years.The area and production has increased substantially from 19.1 m ha (1950-51) to 30.0 m ha (2017-18) and 8.4 m t (1950-51) to 25.2 m t (2017-18) registering an increase of 57.1% and 200.0%, respectively (Anonymous 2018 a, b, c).This increase was 52.9% and 163.1% in acreage and production during 2018-19 (Anonymous 2020a). The yield (kg/ha) showed variable and inconsistent trend during this period ranging from 441 (1950-51) to 757 (2018-19) and had an overall enhancement of 71.7%. Nevertheless, the increase in yield (841) was highest (90.7%) during 2017-18 (Fig 3).

Pulses area during the last 12 years also increased from 23.6 m ha during 2007-08 to nearly 30 m ha during 2017-18 and 29.2 m ha during 2018-19, a surge of 27.1% and 23.7%, respectively. Pulses are predominantly grown under rainfed environment as only 19.1% cropped area was irrigated until 2015-16 as compared to 9.4% during



	1950-51	1960-61	1970-71	1980-81	1990-91	2000-01	2010-11	2017-18	2018-19
Area (mha)	19.1	23.6	22.5	22.5	24.7	20.4	26.4	30.0	29.2
Production (mt)	8.4	12.7	11.8	10.6	14.3	11.1	18.2	25.2	22.1
Yield (kg/ha)	441	539	524	473	578	544	691	841	757

Area (mha) Production (mt) Yield (kg/ha)

Fig 3 Trends in area (m ha), production (m t) and yield (kg/ha) of pulses since 1950-51.

1950-51 (Anonymous 2020). During the last 12 years, due to the systematic sustained research and development efforts, pulses production showed a remarkable surge from 14.8 m t (2007- 08) to a record level of 25.2 m t (2017-18), an increase of 70.3% (Anonymous 2019a). The increase in total production of pulses has been on account of improvement in yield (kg/ha) which has increased from 625 kg in 2007-08 to 841 in 2017-18, an enhancement by 34.6% as well as surge of acreage by about 5.0 m ha since 2015-16 registering an increase of 20%.

Quality seed production: Scenario

Seed sector, seed systems and supply chain

India has a strong seed sector comprising both public sector institutions as well as private seed companies. In our earlier publication (Chauhan *et al.* 2020) various milestones attained during its development since the report of Royal Commission of Agriculture in 1928, have been discussed. 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 $ 90.4 billion in 2024 with likely CAGR of 7.9% during 2020-24 (www.imarcgroup.com, visited on July 20, 2020). Indian seed market reached US$ 4.1 billion during 2018 with CAGR of 15.7% during 2011-18 and further expected to grow at a CAGR of 13.6% during 2019-24 to reach a value of US$ 9.1billion during 2024 (www.seedworld.in and www.ifca.org.in, visited on July 21, 2020). Thus share of India in global seed market is expected to enhance from 6.9% (2018) to 10.2% (2024). India, during 2018, imported 32716 tonnes of seeds of vegetables, flowers and field crops worth US$ 135 million of the total global import of 5.64 m t of seeds worth US$ 13.02 billion and also exported 38971 tonnes of seed worth US$ 137 million against global export of 5.69 m t worth US$ 13.81 billion, respectively, (worldseed.org, visited on November 5, 2020). Thus contribution of India, during 2018, to global seed import and export was only 0.58% and 0.69%, respectively, in terms of quantity and 1.04% and 0.99%, respectively, in terms of value. Chauhan *et al.* (2016; 2020) discussed at length the prevalent seed systems, supply chain and regulatory mechanisms for seed quality control in India. The seed chain involves multiple stakeholders both from public and private sectors also including NGOs and farmers. Quality of seed and pricing is regulated as per the Seeds Act (1966), Seed Rules (1968), Seed (Control) Order 1983 and other notifications from time to time.

Varietal diversity and varietal replacement rate in seed chain

Ensuring availability of quality seed in adequate quantity itself is not enough to trigger the production if it is not coupled with achieving sufficient varietal diversity in seed chain. Of the three seed systems prevalent in India, the present paper is based on analysis of formal system. 1259 varieties of field crops were released during the last six years (2014-19) and among them 850 belong to food crops consisting of cereals (657) and pulses (193). To assess the varietal replacement in seed chain, it is worthwhile to analyse the pattern of inclusion of recently released varieties in the seed chain. In the present paper, trend of seed indents for the last six years (2014-15 to 2019-20) was analysed to study the varietal diversity and varietal replacement rate 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. The number of varieties in the seed chain during the last six years increased from 1171 (2014-15) to 1375 (2017-18) but declined to 1275 (2018-19) and again increased to 1350 during 2019-20 (Table 1). Nevertheless, the number of varieties in the seed chain of food crops and oilseeds was fairly consistent during 2017-18 and 2018-19 but increased considerably during 2019-20 and there was sharp decline in varieties of the forages and fibres (Table 1). Only 22.4%-26.2% of the varieties qualified for formal seed production till date (5162) were in the seed chain during 2014-15 to 2019-20 and accounted for 41.4%-48.4% of the varieties released during 2002-19 (2790).

Breeder seed

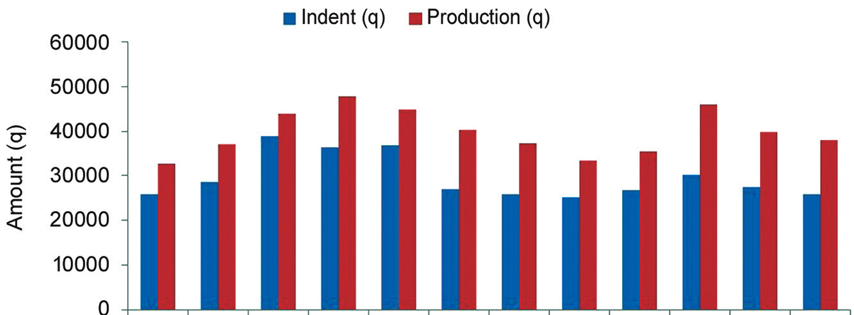
To initiate effective seed chain, the production of adequate quantity breeder seed is foremost and vital. The National Agriculture Research, Education and Extension System (NAREES) comprising ICAR institutes, State/ Central Agricultural Universities and other public sector organizations is mandated to produce breeder seed, which is demand driven and produced on the basis of indents received from private as well as public sector organizations, by Department of Agriculture, Cooperation and Farmers Welfare (DoAC&FW), Ministry of Agriculture & Farmers Welfare, Government of India, which in turn consolidates the indents and forward to the ICAR. The breeder seed thus produced is supplied by DoAC & FW to the indenting stakeholders both from public and private sectors for further multiplication in the form of foundation and certified seeds which is made available to the farmers.

Cereals

Contribution of cereals to the overall breeder seed indent ranged from 33.4% during 2012-13 to 45.2% during

Table 1 Varietal diversity in seed chain of field crops during the last six years

Crop	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Cereals	511	562	580	596	589	628
Pulses	281	263	308	329	329	349
Oilseeds	225	225	228	230	233	249
Forages	68	58	54	81	66	66
Fibres	86	46	46	139	58	58
Total	1171	1154	1216	1375	1275	1350



	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
Indent (q)	25903	28650	38954	36294	36831	27106	25836	25178	26703	30122	27507	25793
Production (q)	32759	37068	43985	47814	44889	40315	37194	33501	35490	45985	39751	38011

Fig 4 Breeder seed indent and production of cereals during 2007-08 to 2018-19.

2009-10 (Anonymous 2018b). During 2017-18, 2018-19 and 2019-20, cereals contributed 37.2%, 40.2% and 34.3%, respectively, to the total breeder seed indent. Analysis of indent and production of breeder seed for the last 12 years (2007-08 to 2018-19) showed inconsistent trend, breeder seed indent increased from 25903 q in 2007-08 to 38954 q in 2009-10 showing an increase of 50.4% and then consistently decreased to 25178 q in 2014-15 (Fig 4) showing a decline of 35.4% since 2009-10.

But it increased by 5.7% and 19.2%, respectively, in 2015-16 and 2016-17 (Anonymous 2018b). However, the seed indent declined by 8.9% during 2017-18 and 14.4% during 2018-19 as compared to that of 2016-17 (Fig 4). In the year 2007-08, indent for cereals was 43.5% of the total indent, it decreased during 2008-09 to 41.4% and reached the highest (45.2%) during 2009-10 and thereafter declined up to 33.4% until 2012-13. It again increased up to 37.0% (2013-14); 40.5% (2014-15); 43.1% (2015-16); reduced to 41.1%, 37.2% and 40.2% during 2016-17, 2017-18 and 2018-19, respectively. Among the cereals, wheat contributed the highest (74.4%-87.8%) followed by rice (10.0%-19.4%) to the total cereal indent during the last 12 years (Anonymous 2018b;2019b;2020b). Maize, sorghum and pearl millet together contributed less than 1% while contribution of other cereals (barley, small millets and other minor cereals) was 3.4%-7.4%. Wheat and rice with share of 78.8% and 17.4%, respectively, were the main contributors to the cereal indent during 2018-19 (25793 q). During 2019-20, wheat and rice contributed 74.1% and 22.7% to the breeder seed indent of cereals (21175.5 q), respectively. Chauhan *et al.* (2014) also reported predominant contribution of wheat and rice to total breeder seed indent of cereals. Breeder seed production followed the similar trends and always higher than the indents for all the 12 years (Fig 4) barring some varietal mismatches.

The analysis of varietal replacement rate revealed that in rice, the indented varieties increased gradually from 241 (2014-15) to 291 (2017-18 and 2018-19) and 310 varieties in 2019-20. Top 10 varieties contributed 37.1% in 2019-20 to 50.7% in 2014-15. 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 23.3% from 42 varieties (2014-15) to 30.8% from 49 varieties (2018-19) and from 3.4% from 17 varieties (2015-16) to 27.6% from 107 varieties (2019-20), respectively, for the varieties released between 2009-13 and 2014-18, respectively (Table 2). The predominant varieties in the seed chain were Cottondora Sannalu, Swarna Sub 1, Vijetha, Swarna, Sahbhagidhan, Pusa 1121 and Pratiksha. Of these, Swarna is the oldest and MTU 1121 latest released variety in the seed chain (Table 3). Cottondora Sannalu was the highest indented variety, with a contribution of 7.0%-11.5%. Of the 306 varieties released during 2014-19, only 107 were in seed chain during 2019-20.

In wheat, 138 to 165 wheat varieties were indented for production of breeder seed during 2014-15 to 2019-20 and the contribution of top 10 varieties to the total indent for the crop was 44.3 to 53.1% during the corresponding period (Table 3). The share of varieties released during the past 10 years, ranged from 28.2% in 2014-15 to 83.9% during 2019-20. HD 2967 was the leading variety in the seed chain with a contribution of 11.6%-15.7% followed by HD 3086 contributing 5.7%-11.0% to the total indent. Among the leading varieties in the seed chain, except GW 322 and DBW 17, the rest were released during the last 10 years.

The highest number of indented varieties/hybrids of maize were 44 during 2017-18 and 2018-19 which increased gradually from 26 in 2015-16 (Table 2). Nevertheless, number of varieties/hybrids was reduced to 40 during 2019-20. The share of top 10 leading varieties ranged from 61.6% (2014-15) to 85.3% (2018-19). The leading varieties in the seed chain were HQPM 4, Pratap Makka 3, Jawahar Makkai 216, DHM 117, Pratap maize hybrid 3, DHM 121, Pusa Composite 3, of these Jawahar Makkai 216 and Jawahar Makkai 218 was the oldest and latest release, respectively (Table 3). Jawahar Makkai 216 was the leading contributor to the seed indent with a share of 5.8 (2014-15) to 46.6% (2015-16). During 2019-20, DHM 117 followed by Pratap hybrid 3 and Jawahar Makkai 218 were the leading variety/hybrid with a contribution of 13.1%, 12.2% and 11.6%, respectively, to the total maize seed indent. Of the 108 varieties/hybrids released during 2014-19, only 17 were inducted into the seed chain until 2019-20.

Contribution of top 10 sorghum varieties/hybrids ranged from 69.5% in 2019-20 to 93.1% in 2018-19 and the number of indented varieties/hybrids was the lowest (8) during 2016-17 and the highest (36) during 2019-20 (Tables 2 and 3). Among the leading varieties, M 35-1 was released about 35 years ago. This variety was the highest contributor to the seed indent during 2014-15 (21.8%) and 2017-18 (22.0%), whereas CSV 20 (10.5%) in 2015-16; CSV 23 (80.2%) in

Table 2 Year-wise distribution of varieties of cereals in seed chain during the last five years (2014-15 to 2018-19) and their contribution to breeder seed indent of the crop

Crop	Year	Indent (q)	Varieties/hybrids (no.)	Up to 1993	1994-98	1999- 2003	2004-08	2009-13	2014-18
Rice	2014-15	4837.5	241 (V-229; H-12)	62 (30.5%)*	20 (11.6%)	30 (18.6%)	87 (26.9%)	42 (23.3%)	-
	2015-16	5026.0	247 (V- 239; H-8)	65 (22.3%)	18 (12.0%)	29 (14.0%)	75 (28.7%)	43 (19.6%)	17 (3.4%)
	2016-17	5350.7	290 (V-282; H-8)	54 (16.1%)	14 (4.9%)	24 (9.9%)	77 (26.9%)	50 (29.6%)	71 (12.6%)
	2017-18**	4375.3	291 (V- 284; H-7)	69 (19.6%)	15 (6.0%)	24 (14.7%)	66 (23.3%)	68 (25.1%)	49 (11.5%)
	2018-19**	4674.0		68 (16.7%)	14 (5.1%)	22 (11.3%)	65 (19.1%)	49 (30.8%)	73 (17.0%)
	2019-20**	4805.6	310 (V-304; H-6)	62 (18.3%)	15 (7.6%)	23 (12.8%)	53 (13.3%)	50 (20.3%)	107 (27.6%)
Wheat	2014-15	20929.9	165	31 (12.8%)	20 (9.5%)	24 (15.3%)	44 (34.4%)	46 (28.2%)	-
	2015-16	20365.0	138	17 (11.0%)	10 (5.0%)	16 (10.5%)	41 (24.2%)	42 (46.7%)	12 (2.6%)
	2016-17	22185.7	142	14 (9.9%)	11 (7.0%)	15 (2.9%)	30 (16.8%)	47 (48.3%)	25 (15.1%)
	2017-18*	22112.7	148	17 (10.8%)	8 (3.7%)	13 (4.4%)	25 (10.7%)	46 (33.9%)	39 (36.6%)
	2018-19**	20321.8	141	20 (9.0%)	8 (3.1%)	12 (3.8%)	23 (10.0%)	41 (37.7%)	37 (36.4%)
	2019-20**	15700.6	144	9 (3.2%)	7 (0.9%)	5 (1.6%)	21 (10.4%)	39 (33.4%)	63 (50.5%)
Maize	2014-15	60.3	35 (V-17; H-18)	9 (23.9%	1 (3.8%)	4 (23.7%)	16 (35.1%)	5 (13.5%)	-
	2015-16	82.6	26 (V- 11; H-15)	-	2 (0.8%)	2 (55.1%)	15 (23.8%)	4 (20.0%)	3 (0.3%)
	2016-17	94.6	35 (V-15; H-20)	3 (0.9%)	2 (1.7%)	-	16 (53.4%)	8 (21.7%)	6 (22.4%)
	2017-18**	83.9	44 (V- 10; H- 44)	25 (19.5%)	-	-	14 (58.3%)	3 (8.2%)	2 (14.2%)
	2018-19**	85.7	44 (V-13; H-31)	20 (27.7%)	-	-	16 (39.1%)	4 (13.3%)	4 (19.9%)
	2019-20**	73.54	40 (V-14; H-26)	9 (9.7%)	-	-	10 (24.1%)	4 (17.8%)	17 (48.4%)
Sorghum	2014-15	51.9	26 (V-21; H-5)	6 (44.6%)	2 (4.2%)	2 (0.4%)	6 (20.1%)	10 (30.8%)	-
	2015-16	50.6	29 (V- 22; H-7)	16 (19.0%)	2 (4.6%)	-	8 (25.9%)	13 (50.6%)	-
	2016-17	6.7	8 (V-4; H-4)	1 (3.6%)	-	3 (11.3%)	2 (81.2%)	2 (3.6%)	-
	2017-18**	26.3	24 (V- 13; H- 11)	11 (38.0%)	-	-	4 (13.1%)	5 (30.2%)	4 (18.7%)
	2018-19**	50.6	30 (V-21; H-9)	6 (17.5%)	3 (41.6%)	-	5 (6.3%)	10 (30.3%)	6 (4.2%)
	2019-20**	17.64	36 (V-22; H-14)	11 (20.9%)	1 (1.3%)	-	5 (12.2%)	9 (27.9%)	10 (37.7%)
Pearl millet	2014-15	8.3	16 (V-9; H-7)	5 (35.9%)	-	2 (1.3%)	4 (33.3%)	5 (29.4%)	-
	2015-16	8.4	19 (V-10; H-9)	2 (5.1%)	-	2 (5.0%)	3 (11.1%)	12 (78.5%)	-
	2016-17	8.5	22 (V-9; H-13)	1 (2.4%)	-	3 (6.7%)	4 (18.1%)	11 (56.6%)	3 (15.7%)
	2017-18**	6.9	19 (V-7; H-12)	4 (9.9%)	-	2 (9.1%)	3 (12.0%)	7 (36.5%)	3 (32.5%)
	2018-19**	8.8	24 (V-12; H-12)	8 (24.0%)	-	1 (2.3%)	3 (14.8%)	7 (21.5%)	5 (37.8%)
	2019-20**	6.1	16 (V-5; H-11)	1 (1.6%)	-	-	1 (4.1%)	4 (10.5%)	10 (83.4%)

V: Variety (Also includes composite(s) of maize, sorghum and pearl millet); H: hybrid and * : Within parenthesis is the contribution to the crop indent.** (Source : https://seednet.gov.in/readyrecknor/Seed_III_VI.aspx visited on December 13, 2018/November 22, 2019).

Table 3 Share of top 10 varieties in breeder seed indent of major cereals and promising varieties in seed chain during the last six years (2014-15 to 2019-20)

Crop	Share (%)	Prominent varieties (among top five in a year) in seed chain**
Rice	37.1 (2019-20) - 50.7 (2014-15)	Cottondora Sannalu (2000)[a], Swarna Sub 1 (2009), Vijetha (1997), Swarna (1985), Sahbhagidhan (2011), Pusa 1121 (2005), Pratiksha (2006), MTU 1121 (2016),IR 64 Drt. (2015), Pusa Basmati 1509 (2013), Pusa 44(1994)
Wheat	44.3 (2016-17) - 53.1 (2019-20)	HD 2967 (2011), GW 322 (2002), DBW 17 (2007), RAJ 4079 (2011), HD 3086 (2014), WH 1105 (2013), RAJ 4328 (2013), PBW 723 (2016), PBW 725(2015), WB 2 (2017), HD 8759 (2017), HD 3226 (2018)
Maize	61.6 (2014-15) - 85.3 (2018-19)	HQPM 4(2010), Pratap Makka 3 (2005), Jawahar Makkai 216 (2004), DHM 117 (2010), Pratap Maize Hybrid 3 (2016), DHM 121 (2014), Pusa Composite 3 (2005), Jawahar Maize 218 (2018)
Sorghum	69.5 (2019-20) - 93.1 (2018-19)	M 35-1 (1984), CSV 20 (2009), CSV 23 (2008), CSV 17 (2009), CSV 27 (2012), CSV 24SS (2011), CSH 14 (1992), Phule Revati (2012), Phule Suchitra (2015), PKV Ashwin (2013), Vasudha (2008), HJ 541 (2014), CSH 9 (1982)
Pearl millet	(2018-19) - 91.1 (2014-15*)	Dhanshakti (2013), Mandore Bajra Composite 2 (2011), RAJ 171(1992), ABPC 4-3 (2012).FBC 16 (2007), HHB272 (2015), JBV4 (2007), JBV 2 (1999), Pusa Composite 701(2016), MPMH 21 (2016)

*Based on 8 varieties /hybrids; ** Varieties indented at least twice or in 2017-18 &/or 2018-19, 2019-20; a:Year of release within parenthesis

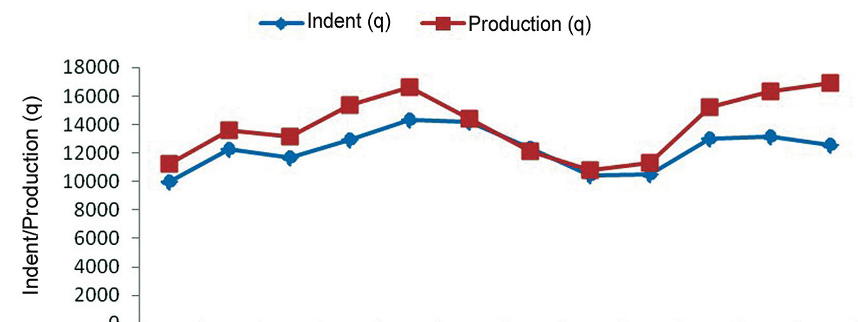
2016-17, CSV 15 (40.8%) in 2018-19 and HJ 541 (19.8%) ranked first among the indented varieties/hybrids. Varieties/ hybrids released during the last 10 years contributed about 65.6% from 19 varieties/hybrids during 2019-20 (Table 2). Of the 42 varieties/hybrids released during 2014-19 only 4, 6 and 10 were in the seed chain, respectively, during 2017-18, 2018-19 and 2019-20.

In pearl millet, inconsistent trend of number of indented varieties/hybrids was observed, ranging from 16 (2014-15) to 24 (2018-19). Sixty-five varieties/hybrids were released during 2014-19 and only 10 were in the seed chain during 2019-20. The highest (91.1%) and lowest (69.1%) contribution of leading 8 varieties/hybrids was recorded during the year 2014-15 and 2018-19, respectively (Table 3). The highest contribution (22.7%-49.1%) to the total breeder seed indent was from Dhanshakti from 2014-15 to 2019-20.

Pulses

Share of pulses in the total seed indent ranged from 8.4% (2015-16) to 17.7% (2008-09 and 2013-14). No definite pattern was discernible about the contribution of pulses to the total seed indent during the decade (2007-08 to 2016-17) since it was quite variable. Except 20014-15 and 2015-16, the contribution was always more than 15%. During the last three years, they contributed 17.9% (2017-18), 19.5% (2018-19) and 21.8% (2019-20) to the total indent. Breeder seed indent for pulses consistently increased from 9 948 q (2007-08) to 14303 q (2011-12) except the year 2009-10 (Anonymous 2018b). The increase was 43.6% over the base year, 2007-08. Since 2012-13, indent declined by 44.7% and was 10488 q during 2015-16. Thereafter, it showed increasing trend, 13008 q, 13160 q and 12525 q during the year 2016-17, 2017-18 and 2018-19, respectively, registering an increase of 24.0%, 25.5% and 19.4%, respectively (Anonymous 2019b;2020b). The indents peaked thrice in 2008-09, 2011-12 and 2017-18 during the last 12 years (Fig 5).

In pulses, chickpea is the main crop with contribution of 68.5% (2015-16) - 80.2% (2009-10) to the total breeder seed indent. Mungbean is the next highest contributing crop to breeder seed indent of pulses (5.2%-10%). The pigeonpea, fieldpea, urdbean and lentil each contributed around 5% to the total breeder seed indent of pulses during 2007-08 to 2018-19.The chickpea, pigeonpea, mungbean, urdbean, lentil and fieldpea together account for 97.3%-98.8% of the total pulses indent during 2012-13 to 2018-19. During the last seven years, among these crops, the share of chickpea in the total seed indent ranged from



	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
Indent (q)	9948	12268	11700	12944	14303	14155	12341	10427	10488	13008	13160	12525
Production (q)	11234	13585	13155	15360	16656	14430	12128	10817	11312	15252	16321	16920

Fig 5 Breeder seed indent and production of pulses from 2007-08 to 2018-19.

68.5% (2015-16)-78.2% (2018-19). The contribution of mungbean was next highest, varying from 6.1% (2018-19) to 10.1% (2014-15). Urdbean, pigeonpea and lentil contributed 3.5% (2018-19)-5.6% (2012-13); 2.2% (2018-19)-4.7% (2014-15) and 2.7% (2014-15)-4.4% (2012-13), respectively. The indent for fieldpea showed a remarkable enhancement and its share was 11.8% to the total seed indent for pulses during 2015-16 otherwise its contribution showed a range of 4.1% (2017-18)-5.5% (2012-13). During 2019-20 chickpea, pigeonpea, mungbean, urdbean, lentil and fieldpea contributed, 80.3%,1.9%, 4.0%,2.9%,3.6% and 4.5 %, respectively, to the total pulses seed indent (13519 q). Chauhan *et al.* (2014) also reported predominant contribution of chickpea to total breeder seed indent of pulses. Breeder seed production followed the similar trends and, in general, always higher than the indent for all the 12 years (Fig 5) barring some varietal mismatches. Nevertheless, during the last seven years, the production of breeder seed was less than the indent by 1.4%-39.0% (Anonymous 2018b; 2019b; 2020b) for mungbean except 2015-16 and 2016-17; by 6.9%-24.1% for urdbean except 2013-14. Short fall in breeder seed production (38.6%) against the indent was also recorded during 2015-16 for field pea.

Since pulses are grown in diverse agro-climatic conditions, it is imperative to produce quality seeds of agro-climatic condition-specific-variety (ies). In chickpea, the highest number of varieties (75) in the year 2014-15 and the lowest (63) in the year 2016-17 were indented (Table 4). Top 10 varieties contributed from 57.8% (2017-18) to 72.8% (2016-17). JAKI 9218 which was the leading variety with a contribution ranging from 9% to 16% during different years under study was released in 2007 and also contributed 8.5% and 5.8 % to the seed indent during 2018-19 and 2019-20, respectively. Of the 46 varieties released during 2014-19, 28 were inducted into the seed chain during 2019-20.

In pigeonpea, contribution of top 10 varieties/hybrids to the breeder seed indent ranged from 57.8% in 2017-18 to 71.6% in 2016-17 (Table 5) and the number of indented varieties/hybrids was the lowest (35) during 2015-16 and the highest (60) during 2017-18. Among the leading varieties, UPAS 120 is the oldest, released more than 40 years ago and still contributed (3.7%-4.7%) to the seed indent during 2017-18, 2018-19 and 2019-20. The highest contributor to the seed indent was BSMR 736 (12.0%) in 2014-15, TJT (8.2%) in 2015-16, UPAS 120 (11.9%) in 2016-17, Narendra Arhar 1(8.6%) in 2017-18, Rajiv Lochan (11.7%) in 2018-19 and 2019-20 (12.4%). Varieties released prior to 1993 still contributed significantly, 24.4% during 2019-20 (Table 4). Of the 31 varieties released during 2014-19, 16 were in the seed chain during 2019-20.

Number of mungbean indented varieties showed variable trend from 54 during 2014-15 to 64 during 2019-20. Top 10 varieties contributed 62.2% in 2019-20 to 86.2% in 2017-18 (Table 5) to the total breeder seed indent. The highest indent, in general, was for the varieties released during 2009-13, ranging from 20.6% (2014-15) to 53.9% (2015-16). Nevertheless, varieties developed during 2014-18 had the major share, 47.2% from 20 varieties during 2019-20 (Table 4). The predominant varieties in the seed chain released within 10 years were IPM 02-3, IPM 2-14, Pant Mung 5, MH 421, SML 832 and IPM 205-7, whereas those released within 15 years were SML 668 (2004), HUM 16 (2006) and Meha (2005). IPM 2-3 was the highest indented variety, with a contribution of 7.4%, 27.1%, 25.8%, 18.1% and 16.2%, respectively during 2014-15, 2015-16, 2016-17, 2017-18 and 2018-19. Of the 30 varieties released during 2014-19, 6, 11and 20 were in seed chain during 2017-18, 2018-19 and 2019-20 contributing 22.1%, 28.0% and 47.2% to the breeder seed indent, respectively.

The indented urdbean varieties for breeder seed production ranged from 33 (2015-16) 37,45, 47 and 50 during 2014-15, 2015-16, 2016-17, 2017-18, 2018-19 and 2019-20, respectively, and the contribution of top 10 varieties to the total indent for the crop was 82.2% during 2015-16 (Table 4 and 5). Variety Type 9 was released nearly 37 years ago still persisted in the seed chain during 2019-20 with a share of 4.7% in the seed indent (Table 5). The share of varieties released during the past 10 years (2009-18), to breeder seed indent varied from 25.0% in 2015-16 to 45.5% during 2019-20. Of the 22 varieties released during 2014-19, 11 were indented for breeder seed production during 2019-20. Pant Urd 31 followed by IPU 02-43 were the leading varieties in the seed chain with a contribution of 15.1-32.2% and 6.4%-11.6% to the total indent, respectively. Contribution of varieties released during 2014-18 increased gradually and consistently from 1.8% during 2015-16 to 17.2% during 2019-20 (Table 4).

From 40 indented varieties of lentil for breeder seed production during 2014-15, the number went down to 31 during 2015-16 (Table 4) but consistently increased thereafter to 42 (2018-19) but reduced to only 31 during 2019-20. Eighteen varieties were released during 2014-19, of that 15 were in the seed chain during 2019-20 contributing 70.2% to the total indent (Table 4). Varieties developed during 2009-18 contributed 30.5% from 11 varieties during 2014-15 and 98.9% from 25 varieties in 2019-20. Among the predominant varieties in the seed chain, Pant Lentil 8, Pant Lentil 7, Pant Lentil 6, IPL 316, Raj Vijay Lentil 3, Shekhar 5, IPL 220, KLS 09-3 (Krish), KLB 2008-4 (Krati) and L 4717 were released during the last 10 years and JL 3 was the oldest, released in 1999 (Table 5). The top three leading varieties with significant contributions from 2014-15 to 2018-19 were Pant L 8 (8.2%-15.6%), HUL 57 (5%-17.7%) and Moitree (3.1%-13.4%).

In fieldpea, 21(2015-16) to 26 (2019-20) varieties were indented for seed production. Share of top 10 leading varieties was 86.8%, 90.8%, 80.3%, 74.9%, 87.1% and 77.7% during 2014-15, 2015-16, 2016-17, 2017-18, 2018-19 and 2019-20, respectively. The leading varieties in the seed chain, released within the last 10 years were Aman, IFP 4-9, HFP 529, Dantiwada field pea 1 and IPDF 10-12 (Table 5). Variety HUDP 15 and Central Field Pea IPDF 12-2 was the oldest (1999) and latest (2017) released variety, respectively. HUDP 15 was the leading contributor to the

Table 4 Year-wise distribution of varieties of pulses 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/ hybrids (no.)	Up to 1993	1994-98	1999- 2003	2004-08	2009-13	2014-18	2019-23
Chickpea	2014-15	8284.4	75	6 (9.9%)*	8 (11.8%)	13 (22.0%)	33 (43.9%)	15 (12.3%)	-	-
	2015-16	7184.3	67	7 (5.9%)	6 (4.9%)	13 (21.9%)	20 (41.9%)	18 (23.9%)	3 (1.6%)	-
	2016-17	10119.4	63	9 (5.8%)	7 (6.1%)	9 (27.5%)	17 (38.8%)	16 (18.6%)	5 (3.2%)	-
	2017-18**	10226.4	70	5 (0.7%)	5 (3.5%)	12 (15.6%)	15 (27.7%)	18 (19.0%)	15 (33.6%)	-
	2018-19**	9790.2	72	9 (1.4%)	5 (1.7%)	8 (13.2%)	16 (13.5%)	17 (35.7%)	17 (34.5%)	-
	2019-20**	10678.6	72	4 (0.8%)	4 (0.6%)	9 (8.6%)	7 (8.3%)	20 (31.4%)	27 (50.1%)	1 (0.2%)
Pigeonpea	2014-15	392.7	48	15 (36.5%)	6 (17.4%)	5 (10.7%)	15 (18.8%)	7 (16.5%)	-	-
	2015-16	267.4	35	6 (30.0%)	4 (13.7%)	2 (5.9%)	1 (27.3%)	8 (19.5%)	2 (3.9%)	-
	2016-17	308.3	43 (V-41; H-2)	9 (28.3%)	2 (8.8%)	2 (3.1%)	14 (22.1%)	10 (34.6%)	6 (3.2%)	-
	2017-18**	359.8	60 (V-58; H-2)	16 (27.9%)	3 (11.7%)	4 (1.1%)	16 (22.2%)	11 (33.2%)	10 (3.9%)	-
	2018-19**	265.5	45 (V-44; H-1)	11 (21.2%)	3 (10.0%)	2 (1.3%)	13 (23.2%)	8 (39.6%)	8 (4.6%)	-
	2019-20**	250.9	57 (V-57; H-0)	16 (24.4%)	2 (6.9%)	2 (0.06%)	12 (15.2%)	9 (31.4%)	16 (22.1%)	-
Mungbean	2014-15	802.7	54	5 (3.8%	6 (3.3%)	14 (25.1%)	17 (47.2%)	12 (20.6%)	-	-
	2015-16	701.8	38	1 (0.1)	2 (2.6%)	9 (12.8%)	13 (30.5%)	13 (53.9%)	-	-
	2016-17	811.0	43	3 (11.5%)	-	10 (13.9%)	15 (33.4%)	14 (50.6%)	1 (0.6%)	-
	2017-18**	972.1	59	12 (1.3%)	5 (1.8%)	11 (8.5%)	13 (18.7%)	12 (47.7%)	6 (22.1%)	-
	2018-19**	759.7	54	5 (0.7%)	2 (0.9%)	11 (20.5%)	11 (6.6%)	14 (43.2%)	11 (28.0%)	-
	2019-20**	536.8	64	8 (0.8%)	3 (0.5%)	8 (3.1%)	9 (15.7%)	16 (32.7%)	20 (47.2%)	-
Urdbean	2014-15	520.8	47	11 (20.9%)	5 (5.1%)	10 (18.9%)	13 (39.2%)	8 (15.9%)	-	-
	2015-16	423.6	33	2 (7.8%)	4 (2.7%)	6 (8.5%)	10 (56.7%)	10 (23.2%)	1 (1.8%)	-
	2016-17	454.1	37	4 (7.3%)	3 (0.6%)	6 (16.5%)	12 (43.2%)	10 (29.7%)	2 (2.6%)	-
	2017-18**	478.1	45	15 (21.8%)	3 (2.3%)	4 (12.5%)	10 (30.6%)	9 (26.6%)	4 (6.3%)	-
	2018-19**	471.6	47	9 (14.7%)	3 (2.6%)	6 (7.5%)	11 (33.8%)	11 (31.5%)	7 (9.9%)	-
	2019-20**	384.6	50	11 (13.4%)	4 (6.2%)	3 (6.7%)	10 (28.3%)	11 (28.3%)	10 (17.2%)	1 (0.03%)
Lentil	2014-15	380.5	40	11 (21.5%)	6 (23.6%)	4 (4.5%)	8 (19.9%)	11 (30.5%)	-	-
	2015-16	449.1	31	5 (2.3%)	5 (4.5%)	3 (13.5%)	10 (48.8%)	8 (31.0%)	-	-
	2016-17	467.0	39	15 (10.1%)	5 (5.5%)	3 (11.0%)	8 (43.6%)	8 (30.4%)	-	-
	2017-18**	450.5	41	8 (7.7%)	4 (7.9%)	2 (8.3%)	7 (20.1%)	12 (22.3%)	8 (20.4%)	-
	2018-19**	484.5	42	7 (6.8%)	4 (3.4%)	2 (1.9%)	6 (18.4%)	10 (45.0%)	13 (24.6%)	-
	2019-20**	480.7	31	2 (0.3%)	2 (0.2%)	1 (0.03%)	1 (0.6%)	10 (28.7%)	15 (70.2%)	-
Fieldpea	2014-15	718.7	27	6 (36.5%)	1 (1.7%)	1 (0.03%)	1 (0.6%)	10 (28.7%)	15 (70.2%)	-
	2015-16	1237.2	21	3 (3.2%)	-	5 (47.1%)	7 (27.5%)	5 (19.0%)	1 (3.4%)	-
	2016-17	610.7	25	8 (9.9%)	-	4 (14.2%)	6 (32.5%)	5 (37.4%)	2 (6.1%)-	-
	2017-18**	551.0	23	2 (3.0%)	-	3 (9.0%)	7 (26.0%)	4 (37.8%)	7 (24.1%)	-
	2018-19**	532.6	24	1 (0.9%)	-	4 (8.7%)	7 (25.8%)	6 (37.7%)	6 (26.9%)	-
	2019-20**	600.6	26	-	-	1 (9.3%)	3 (5.2%)	7 (30.7%)	15 (54.8%)	-

V: Variety; H: hybrid and * : Within parenthesis is the contribution to the crop indent. ** (Source : https://seednet.gov.in/readyrecknor/Seed_III_VI.aspx visited on December 13, 2018/November 22, 2019).

Table 5 Share of top 10 varieties in breeder seed indent of major pulses and promising varieties in seed chain during the last six years (2014-15 to 2019-20)

Crop	Share (%)	Prominent varieties (among top five in a year) in seed chain*
Chickpea	57.8 (2017-18) - 72.8 (2018-19)	JAKI 9218 (2007)[a], Gangaur (2008), JG 11 (1999), Digvijay (2007), JG 315 (1984), RSG 974 (2010), JG 14 (2009),GNG 2171 (2017), GNG 1958 (2013), RVG 203 (2013), RGV 202(2015), RGV 201(2012), GNG 2144 (2015)
Pigeonpea	57.8 (2017-18) - 71.6 (2016-17)	Maruti (1986), Narendra Arhar 1(1997), Asha (1993), TJT 501 (2009),UPAS 120 (1976), Rajiv Lochan (2011), BDN 711(2012), LAM 41(2007), Rajendra Arhar 1 (2018),
Mungbean	62.7(2019-20) - 86.2 ((2017-18)	SML 668 (2004), IPM 02-3 (2009), HUM 16 (2006), IPM 2-14 (2011), PDM 139 (2001), Pant Mung 5 (2010), MH 421 (2012), Meha (2005), SML 832 (2013), IPM 205-7(2016)
Urdbean	63.5 (2017-18) - 82.2 (2015-16)	Pant U 31 (2008), IPU 02-43 (2009), Azad Urd 3 (2006), Lam Minumu 752 (2010), Pratap Urd 1 (2013), Vishwas (2012), Type 9 (1982), Uttara (2000), Indira Urd 1 (2015), Mash 479 (2011)
Lentil	67.4 (2018-19) - 84.6 (2014-15)	HUL 57 (2005), Pant L 8 (2010), Pant L7 (2009), JL 3 (1999), Pant L 6 (2009) , Azad Masoor 1 (2005), IPL 316 (2013), Moitree (2008), Raj Vijay Lentil 3 (2014), L 4717 (2017), Shekhar 5 (2017), IPL 220 (2018), KLS 09-3 (Krish) (2015), KLB 2008-4 (Krati) (2015)
Fieldpea	74.9(2017-18) - 90.8 (2015-16)	HUDP 15 (1999), Prakash (2006), KPMR 400 (2001), Shubra (2001), KPMR 522 (2001), Aman (2009), Vikas (2005), IFP 4-9 (2011), HFP 529 (2012), Dantiwada field pea 1 (2011), IPDF 10-12 (2014), Punjab 89(2015),Central Field pea IPDF 12-2 (2017)

*Varieties indented at least twice or in 2017-18 &/or 2018-19, 2019-20; a Year of release within parenthesis

seed indent, 5.6%, 22.2%, 8.0%, 5.5%, 9.6% and 9.3%, respectively, during 2014-15, 2015-16, 2016-17, 2017-18, 2018-19 and 2019-20. Prakash (9.8%-19.6%) until 2016-17, KPMR 400 (11.6%-14.6%) and Shubra (11.7%-12.8%) until 2015-16 contributed notably. Of the 16 varieties released during 2014-19, 15 were inducted into the seed chain during 2019-20.

Foundation seed

Merely producing adequate breeder seed may not be enough to increase crop production unless it is systematically converted in downward stream to other classes such as foundation and certified/labelled seed as it is the latter which is made available to the end users (farmers).Total foundation seed production (for cereals, pulses. oilseeds, forages and fibres) during the last 12 years ranged from 8.5 lakh q during 2007-08 to 18.0 lakh q during 2018-19, registering an increase of 111.8% (Anonymous 2019c). However, it showed continuous increase from 8.5 lakh q during 2007-08 to 22.3 lakh q during 2011-12; the highest ever achieved with an increase of 162.4% but, thereafter, showed an inconsistent trend of decrease in the next seven years until 2018-19. This decrease was 27.4% (2012-13); 22.0% (2013-14); 41.4% (2014-15); 32.7% (2015-16); 0.9% (2016-17), 12.6% (2017-18) and 19.3% (2018-19). Foundation seed produced during 2017-18 and 2018-19 was less by 11.8% and 18.6%, respectively, than that of 2016-17. And, foundation seed produced during 2018-19 had been reduced by 7.5% over that of 2017-18. Despite declining production of foundation seed, the enhanced quality seed production would probably be achieved by increasing seed multiplication ratio through efficient crop management.

Certified/quality seed

Production of certified/quality seed since 2007- 08 has increased by 105.3% in 2018-19. It increased from 2007-08 (1.94 m t) up to 2011-12 (3.54 m t), having an overall increase of about 82.5%. Thereafter it exhibited a variable but declining trend until 2015-16, and reduction ranged from 0.6%-7.0% over that of 2011-12 (Anonymous 2019c). During 2016-17, 2017-18 and 2018-19, an increase of 7.3%, 18.4% and 12.7%, respectively, was recorded over the highest ever quality seed production achieved earlier during 2011-12 (Table 6).

The quality seed production during 2017-18 was 4.19 m t, which was higher by 10.3% as compared to that of 2016-17. However, quality seed produced during 2018-19 had been reduced by 4.8% over that of 2017-18 (Table 6). Although, the declining trends of certified/quality seed production, a matter of serious concern, yet, it was higher than the highest ever demand of quality seed that was 3.71 m t during 2017-18. Nevertheless, the gap between availability and demand reduced from 12.9 % during 2017-18 to 12.7% during 2018-19 considering the same level of demand as that of 2017-18. However, the actual demand for seed was only 3.54 m t instead of 3.71 m t during 2018-19. There has been a continuous surge in the demand for seed during the last 11 years varying from 2.07 m t (2008-09) to 3.54 m t (2018-19) registering an increase of 71.0%. The highest demand for seed was recorded during 2017-18 with an increase of 79.2% over that of 2008-09 (Table 6). The demand for seed was declined by 2.0% during 2015-16 as compared to that of 2014-15. But it again showed an increase of 4.7%, 10.1% and 5.0%, respectively, during 2016-17, 2017-18 and 2018-19 over that of 2015-16. The

Table 6 Demand and availability of quality seed in India and share of public and private sector in seed production during 2008-09 to 2018-19

Year	Seed (million tonnes)		Surplus availability (%)	Production/ availability (million tonnes)		Share (%)	
	Availability [A]	Demand [D]		Public	Private	Public	Private
2008-09	2.51	2.07	20.8	1.51	1.00	60.2	39.8
2009-10	2.80	2.49	12.4	1.71	1.09	61.1	38.9
2010-11	3.22	2.90	11.0	1.66	1.56	51.6	48.4
2011-12	3.54	3.30	7.3	1.81	1.73	51.1	48.9
2012-13	3.29	3.15	4.4	1.62	1.67	49.1	50.9
2013-14	3.47	3.35	3.7	1.68	1.79	48.4	51.6
2014-15	3.52	3.44	2.3	1.51	2.01	43.0	57.0
2015-16	3.44	3.37	2.1	1.47	1.97	42.9	57.1
2016-17	3.80	3.53	7.6	1.84	1.96	48.4	51.6
2017-18	4.19	3.71	12.9	1.79	2.40	42.8	57.2
2018-19	3.99	3.54	12.7	1.71	2.28	42.8	57.2

availability of quality seed during the period was, invariably, always higher than the demand by 2.1% during 2015-16 and 20.8% during 2008-09. The gap between availability and demand was 12.9% and 12.7% during 2017-18 and 2018-19, respectively (Table 6). Contribution of private sector to total seed production in the country gradually increased and ranged between 39.8%-57.2% during the last 11 years.

Certified/quality seed distributed to stakeholders

Cereals

It is the certified/quality seed made available to the farmers/growers that could raise crop productivity by enhancing seed replacement rate. The quality seed of cereals, distributed to the stakeholders during the last eight years showed an upward trend and increased from 190.0 lakh q (2011-12) to 238.0 lakh q (2017-18) with an increase of 25.3% but decreased to 206.9 lakh q during 2018-19 showing an overall increase of about 8.9% (Anonymous 2019a, Dr. Chander Mohan, Assistant Commissioner (Seed), personal communication). A decrease of 3.7% in seed supply, however, was observed during 2013-14 over that of 2011-12 (Table 7).

Quality seed distribution of wheat was the highest during 2017-18 (139.3 lakh q) with an increase 42.7% over that of 2011-12. In rice also, maximum dissemination of quality seeds was during 2016-17 (84.6 lakh q) showing an increase of 26.7% over the lowest quantity (66.8 lakh q) during 2014-15 (Table 7). Nevertheless, rice seed distribution was reduced by 2.2% and 16.4% during 2017-18 and 2018-19, respectively, over that of 2016-17. In maize, quality seed distribution has increased consistently since 2012-13 and reached maximum during 2015-16 but declined by 27.1%, 37.9% and 36.7%, respectively, during 2016-17, 2017-18 and 2018-19. The seed distribution during 2015-16 was higher by 89.4% over that of the base year, 2011-12. But, no consistency was observed in the pattern of quality seed distribution for sorghum and pearl millet. However, during 2017-18, the seed distributed for pearl millet was the lowest and reduced by 21.7% as compared with 2011-12. Further, sorghum seed distribution was reduced by 13.0% during 2017-18 over the highest seed distributed (2.3 lakh q) during 2012-13 (Table 7). Overall changes during 2018-19 over that of 2011-12 in the dissemination of quality was -2.7% for rice; 20.9% for wheat; 19.1% for maize; -30.0% for sorghum; -17.4% for pearl millet and -53.7% for barley and small millets. Wheat (51.3%-58.5%) followed by rice (32.9%-39.6%) were the main contributors to the total certified /quality seed distributed and the rest of the crops (maize, sorghum, pear millet, barley and small millets)

Table 7 Distribution of certified/quality seeds (lakh q) of cereals

Crop	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
Rice	74.4	72.1	72.5	66.8	74.6	84.6	82.7	72.4
Wheat	97.6	116.5	93.8	117.8	95.8	124.9	139.3	118.0
Maize	9.4	9.1	11.0	11.7	17.7	12.9	11.0	11.2
Sorghum	2.0	2.3	2.1	1.7	2.0	2.0	2.0	1.4
Pearl millet	2.3	2.1	2.2	1.9	3.6	2.2	1.8	1.9
Barley/small millets	4.1	2.3	1.4	3.1	1.2	2.6	1.2	1.9
Total	190.0	204.4	183.0	203.2	195.0	229.1	238.0	206.9

contributed around 8.0%-10.0% during the last eight years (Anonymous 2019a).

Pulses

During 2011-12 to 2018-19, in pulses, the quantity of quality seed distributed increased from 22.26 lakh q during 2011-12 to 29.47 lakh q during 2016-17 (Table 8) but declined to 23.54 lakh q during 2017-18 as compared with that of 2016-17(Anonymous 2019a) but again increased to 31.80 lakh q during 2018-19 with an increase of 7.9% over the highest ever attained during 2016-17. The overall increase was 10.1% (2012-13); 24.9% (2013-14); 11.3% (2014-15); 2.0% (2015-16), 32.4% (2016-17), 5.8% (2017-18) and 42.9% (2018-19) over that of the base year (2011-12). Chickpea, pigeonpea, mungbean, urdbean, lentil and fieldpea contributed, 50.8%-62.9%; 6.2%-10.2%, 6.9%-9.0%; 5.9%-13.4%; 2.9-%-4.8% and 6.1%-11.4%, respectively, to the total quality seed of pulses distributed during the last eight years (Anonymous 2019a). The share of other pulses (cowpea, rajmash, mothbean, horsegram, lathyrus, ricebean) was only 2.0%-5.3% (Table 8). No specific trend was discernible from the distribution of quality seed of pulses during the last eight years (Anonymous 2019a).

Quality seed of chickpea consistently accounted for 50.8%-62.9% of the total pulse seed and the highest quality seed supply was during 2018-19 which was higher by 11.6% and 17.6%, respectively, over the highest ever achieved during 2013-14 and that of 2011-12 . Pigeonpea quality seed distribution declined gradually by 12% over that of 2011-12 until 2014-15 and increased by 11.2%, 47.9%,41.4% and 43.2%, respectively, during 2015-16, 2016-17, 2017-18 and 2018-19 over that of 2014-15 (Table 8).The highest seed supply was recorded during 2016-17 for mungbean, higher by 8% over the highest ever achieved earlier during 2012-13 (Table 8). During 2017-18 and 2018-19, mungbean seed distribution decreased by 7.4% and 4.3%, respectively, over that of 2016-17. The quality seed distribution for urdbean was lowest during 2013-14 with decrease of 29% over the base year but consistently increased thereafter until 2017-18 (3.16 lakh q) an increase of 92.7% but declined by 29.4% and 3.5% during 2018-19 as compared to 2017-18 and 2011-12, respectively (Table 8). For lentil, the highest quality seed distribution was during 2016-17, which declined by 29.0% and 8% during 2017-18 and 2018-19. But overall, the seed supply was higher by 92.4% during 2018-19 as compared to the one during 2011-12. The fieldpea seed supply was the highest during 2013-14 (3.17 lakh q) higher by 133.1% as compared with that of 2011-12 but thereafter continuously declined by to the extent of 36.0%, 45.4%, 40.4%, 47.0% and 12.6%, respectively, during 2014-15; 2015-16; 2016-17; 2017-18 and 2018-19.

Seed: a driver for enhancing farmers' income

Government of India launched a programme during 2017 for doubling farmers' income by 2022. This could be achieved by enhancing production with low cost by developing and adopting low cost production technologies. Seed is a low cost agricultural input and quality seed can contribute 15-20% to yield. Quality seed produced by farmers will be an added advantage if marketed properly. The seed production chain has very well defined role for all the stakeholders. Farmers have been the integral part of the seed chain since the concept of formal seed production initiated in early 70's. Farmers either individually or in growers/farmers association have been involved in foundation and certified seed production for public sector organization in central (National Seed Corporation) or States Seed Production Corporation. Even a large number of farmers actively participate in seed production programmes of national and multinational private seed companies throughout India especially seed hubs in Telengana, Andhra Pradesh and Karnataka for hybrids of corn, pearl millet, rice and sunflower. But formalization of participatory or farmers participatory seed production is a recent initiative such as ICAR-Mega seed project envisioning this as one of the major activities and National Mission on Agricultural Extension and Technology, the DoAC & FW, Ministry of Agriculture & Farmers Welfare, Government of India conceptualized and supported Seed Village programme. All these programmes have been mainly structured as source of livelihood. Several ICAR institutes and State Agriculture Universities have developed their own models for farmers' participatory seed production by incentivizing it. In this

Table 8 Distribution of certified/quality seeds (lakh q) of pulses

Year	Crop							
	Chickpea	Pigeonpea	Mungbean	Urdbean	Lentil	Fieldpea	Other pulses	Total
2011-12	13.16	1.92	2.00	2.31	0.66	1.36	0.85	22.26
2012-13	14.83	1.80	2.13	2.33	0.70	1.79	0.93	24.51
2013-14	17.48	1.73	1.95	1.64	1.28	3.17	0.55	27.80
2014-15	14.73	1.69	2.00	1.84	1.19	2.03	1.30	24.77
2015-16	13.58	1.88	1.83	2.23	0.98	1.73	0.47	22.71
2016-17	17.17	2.50	2.30	2.69	1.38	1.89	1.54	29.47
2017-18	11.95	2.39	2.13	3.16	0.98	1.68	1.25	23.54
2018-19	19.50	2.42	2.20	2.23	1.27	2.77	1.40	31.80

context, University of Agricultural Sciences, Dharwad (Karnataka) launched systematic and very well organized programme during 2004-05 which transformed the seed programme of the university and augmented the university revenue, it was an ideal programme for some time and set tone for others. But later it could not be sustained as it was due to personal missionary zeal of some of the staff, owned by the university but limited efforts were made to make it viable at farmers' end. It should have been up scaled and institutionalized as Seed Industry. A scientific Seed production is vital and essential for quality seed production. Entrepreneurship development among the farmers should be aimed at. Along with formulation of sustainable seed plan for contingency under natural calamities focus should also be on capacity building of farmers especially women and rural youth for quality seed production as a means of additional livelihood. Unemployed youths can be trained in the field of seed quality assurance and with financial support and seed quality assurance laboratories, *"Seed clinic"* may be established in major seed growing areas. Farmers should form farmer's producer organization or club together to make a company. Recently, in 23 villages of Telangana, farmers made their own company to avoid middle man and sale their farm produce at premium price (Anonymous 2019d). The company has also been getting technical back stopping at no cost from a non-governmental organization to facilitate marketing and made substantial gains in terms of financial resources as well as living standard of farmers in the villages. JNKVV, Jabalpur has developed excellent seed systems, seed village system, model systems, rice-fallow–chickpea system by distributing small quantities of breeder/foundation seed of recently released varieties for dissemination of seed production management technologies involving participation of farmers and thus facilitated local diffusion mechanisms in the rural area (Rao 2013 ; 2014). Farmers' participatory rice hybrid seed production systems were also developed in new niches, Balaghat and Seoni in Madhya Pradesh. The University imparted technical back stopping including capacity building of the stakeholders. Similarly, IGKVV, Raipur established rice hybrid seed production hub with the participation of farmers in Dhamtari in Chhatisgarh. Such activities of seed production especially of hybrids in rice, corn, sorghum and pearl millet may be extended to other parts of the country by the Agriculture Skill Council of India involving rural youth through KVKs and CAU/SAUs for ensuring livelihood security and also enhancing income.

Madhya Pradesh Government initiated a concept of seed cooperatives in 2001 to increase seed availability of desired, demanded and recommended varieties, timely availability with reduced price to the farmers and 83 societies were created which rose to 2283 (Bhatnagar and Chouhan 2014). Thereafter, a large number of them were merged to form a separate seed cooperative sector and about 700 have become members of seed federation which were working in 50 districts dealing with about 123 varieties of 18 crops. Registered seed societies under cooperative act are independent unit but adhere to the rules and regulations of the act. Bhatnagar and Chouhan (2014) also critically analyzed the challenges, threats and concluded that formation of effective seed supply network at village level needs farmers' better understanding and cooperative approach which is not possible for successful implementation of seed plan. Further, they opined that societies require short and long term finance policy for purchase of inputs and creating infrastructure, convergence of efforts of cooperatives and government agencies in seed distribution pogramme keeping in view state seed rolling plan and to offset/compensate carry over losses, a great risk. Being decentralized system of seed production and marketing, cooperative played and would continue to play a significant role in enhancing farmers' income, improving their livelihoods, seed and variety replacement rates, consequently increasing production and ensuring/sustaining food security.

Challenges and strategy

India has been self-sufficient in cereals as the projected demand for 2020-21 is assessed to be 253 m t and projected supply during 2016-17 was 240-251 m t. Production of cereals has already reached 252 m t by 2016-17 and 263.1 m t during 2018-19 (Anonymous 2018a; 2019a). The projected supply of pulses during 2016-17 was 22 m t against production of 23.1 m t and the demand for 2020-21 is estimated to be 25.0 m t whereas, 25.2 m t were produced during 2017-18 but declined to 22.1 m t during 2018-19. The expected average annual growth of production for the next decade (2015-24) would be 2.74%-3.21% (pulses); 1.76% (rice); 1.4% (wheat) and 2.7% (nutri-cereals), well above the annual population growth rate (1.10%). Presently, the country is self sufficient for food grains due to high food production of 284.8 m t (2017-18) and 285.2 m t (2018-19). This record food production was substantially because of good South-West monsoon coupled with technological advances and new research programmes by NAREES. In fact, the annual compound growth rate in pulse production (3.19%) during 2004-15 (Anonymous 2018a) was even higher than that of rice (1.52%), and comparable with wheat (3.21%). But demand of pulses is also increasing at 2.8% per annum. In spite of spectacular success in food production over the years, there is no room for complacency since it is a great challenge to sustain such high production as well as enhance it further to meet the future requirement, as the population continues to grow steadily with an annual growth rate of 1.10% (2017) and expected to be 1.42 billion and 1.48 billion by 2025 and 2030, respectively, from 1.32 billion during 2017 (Anonymous 2019a); coupled with enhanced consumption of food grains due to rising income, necessitating an increase of 4.5% and 15.7% in food production over the present production of 285.2 m t by 2020 (298 m t) and 2030 (330 m t), respectively. Of this, pulses should increase at a pace of 9.5% (24.3 m t) and 44.8% (32.0 m t) while cereals at 4.0% (273.7 m t) and 13.3% (298.0 m t), respectively, by 2020 and 2030. Although technological advances have shown time and again that national food security could be ensured till date yet it has been a formidable challenge in view of climate change, diminishing and degrading land and water resources, increasing biotic and abiotic stresses, loss of bio-diversity. There could be multi-pronged strategy for enhancing food production in the country, *viz.* vertical growth in yield through genetic enhancement raising yield ceiling; productivity enhancement and horizontal expansion of the crop to new niches. There is very little scope of horizontal expansion of food crops as it would be at the cost of other crops. First and foremost approach could be bridging the existing gaps between potential and realized yields through improved productivity and by integrated natural resource management. Therefore, there is a need for developing climate resilient technologies including varieties for sustainable high production of food crops to meet the demand. Food security would be insured through seed security as it is the key input for realizing potential productivity of varieties &/or other technologies and alone contributes about 15-20 % to the crop productivity. Seed is life, a tag line; used by International Seed Federation (worldseed.org visited Feb. 5, 2019*)* truly reflects the importance of seed. Seed, although a low cost input, yet very critical and important for productive agriculture, a lifeline of more than 50% of the Indian population. The importance of quality seed has been recognized since time immemorial as '*Subeejam Sukshetre Jayate Sampada yate'* (Manu Smiriti) meaning- Good Seed on Good Soil Yields Abundantly. Timely availability of quality seed to the end users, farming community, is of great importance. Low availability of quality seeds has been one of the major constraints in improving productivity of pulses. Ali *et al.* (2016) assessed the total seed requirement of pulses as 33 lakh q at 30% seed replacement rate.

New initiatives for development, especially for pulses, such as creation of 150 seed hubs since 2016-17 and strengthening 12 centres in major pulse growing states under NFSM, DoAC & FW, Ministry of Agriculture & Farmers Welfare, Government of India (Chauhan *et al.* 2017; Prasad *et al.* 2017) led to enhanced breeder seed production and maintenance of seed chain of newly released varieties and had great impact on enhanced availability of quality seed and thus production of pulses. Significant progress has been made in the production of breeder and certified/quality seed of food crops as a consequence of ICAR-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 covering entire gamut of seed chain from nucleus seed to supply to farmers. During the last five years (2014-15 to 2018-19) seed availability enhanced from 230.7 lakh q to 258.5 lakh q for cereals and 28.9 lakh q to 43.6 lakh q for pulses, an increase of 12.0% and 50.9%, respectively. During 2017-18, the seed availability (35.6 lakh q) has surpassed the actual assessed requirement of 33.0 lakh q for pulses (*https://seednet.gov.in/readyrecknor/Seed_III_VI.aspx,* visited on December 13*,* 2018; Selvraj 2013) and it has resulted in record production of 25.2 million tonnes during 2017-18, attaining self sufficiency. Therefore, such target oriented programmes/initiative should not only continue but further expanded and strengthened in terms of financial and well qualified and trained human resources. The increased seed availability resulted into high seed replacement rate (SRR) in major cereals and pulses. The SRR during the last 12 years (2007- 08 to 2018-19) increased from 25.2% to 39.6% (wheat); 25.9% to 33.1% (paddy); 44.2% to 68.8% (maize); 48.5% to 58.2% (pearl millet); 19.9% to 27.9% (sorghum); 21.8% to 28.7% (mungbean); 23.9% to 30.8% (urdbean) and 11.9% to 34.8% (chickpea); 16.1% to 51.5% (pigeonpea); 15.9% to 30.7% (lentil) and 16.3% to 37.5% (fieldpea) in 2018-19 as compared to that of 2007-08. Among the cereals, the highest SRR was achieved for wheat (40.3%, during 2016-17); paddy (57.6%, during 2013-14); maize (71.8%, during 2014-15); pearl millet (62.9%, during 2008-09) and sorghum (50.0%, during 2015-16). In pulses, the highest SRR was 49.6% for mungbean and urdbean; 34.1% for lentil; 37.5% for fieldpea; 34.8% for chickpea and 51.5% for pigeonpea during 2018-19. The enhanced SRR was one of the main factors in increasing food production (Chauhan *et al.* 2016a). Despite best efforts, the SRR was less than the ideal SRR of at least 33% for self pollinated crops (wheat, rice, and pulses except pigeonpea); 50% for cross pollinated varieties (maize, sorghum, pearl millet and pigeonpea) and 100% for hybrids; for maize, pearl millet and sorghum in cereals and mungbean, urdbean and lentil during 2018-19. The inconsistency in the SRR is a matter of concern and needs focussed approach in order to maintain desirable SRR.

Ensuring availability of quality seed in adequate quantity itself is not enough to trigger the production if it is not coupled with achieving sufficient varietal diversity in seed chain preferably phasing out gradually the old and obsolete varieties and inducting recently developed high yielding and disease resistant varieties. Seed chain of cereals and pulses during 2019-20 was maintained with 310 varieties/hybrids of rice, 144 of wheat, 40 of maize, 36 of sorghum and 16 of pearl millet; 72 varieties of chickpea, 57 of pigeonpea, 64 of mungbean, 50 of urdbean, 31 of lentil and 26 of fieldpea. Overall, 657 (including 65 varieties of barley and small millets) and 193 (including 22 varieties of arid legumes and other minor pulses) varieties/hybrids of cereals and pulses were released and notified during 2014-19, respectively. Of these, only 207 of cereals and 105 of pulses could be inducted in the seed chain until 2019-20. And, still substantial contribution during 2019-20, especially in cereals (rice and sorghum), was from varieties released prior to 1993 (also included such varieties for which release year is not known), *viz.* rice (18.3%); wheat (3.2%); maize (9.7%); sorghum (20.9%) and pearl millet (1.6%) whereas; in pulses, such contribution was high for pigeonpea (24.4%) and urdbean (13.4%). It is understandable as the newly released potential varieties may take 2/3 years before picking up indents. Therefore, there is need to have extensive efforts in showcasing, popularizing new and improved varieties and increase their seed multiplication for increased availability of quality seed in the country.

Efforts should be made by the concerned competent agency to regularly review and update seed rolling plan at least for five years, considering ideal SRR, the plan should clearly identify region wise varieties and assess the yearly seed requirement. Seed chain involves several stakeholders with definite responsibility. It has broadly 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). Various state seed producing agencies are the major indenters for breeder seed, hence states should come up with holistic planning of seed production programmes with desired targets for realizing seed security and timely place indents accordingly with either DoAC & FW (for centrally released varieties)/SAUs (for state release varieties)/or any other agency legally assigned the responsibility for production of breeder seed and also ensure lifting of such seeds. Unrealistic indents of breeder seeds for some of the varieties coupled with sudden substantial fluctuations in varietal demands in quick span is one of the reasons for inadequate or skewed availability of quality seed (Prasad *et al.* 2017).

The climate changes had adversely affected the breeder seed production programme in many crops especially chickpea during the last five years. Therefore, there is an urgent need to identify alternate areas or new niches in non-traditional season/areas for compensatory seed production and vast available rice-fallows offers an excellent opportunity for seed production of short duration and drought escaping varieties of *rabi* pulses. For contingent planning, seed production of stress tolerant varieties, even if there is no or low requirement should be a regular feature in the seed production programme to address last minute urgent need for such varieties in the event of monsoon failure or scanty and erratic rainfall.

Participatory seed production should be further refined to make it responsive, qualitative, financially viable and sustainable in transparent manner to complement the efforts of formal seed production. It could be either farmers or community based for demand driven varieties of that locality/district/zone. Such seed production will definitely result in timely availability of seed to the farmers and also huge savings in transportation cost. Such seed production should also evaluate options of value addition to seed such as palleting, coating and priming (Gaur 2013).

Development of seed quality testing laboratories and strengthening them into seed quality assurance hubs will play an important role for energizing the quality seed production in the country. ISTA accreditated laboratories are authorised to issue orange and blue international seed analysis certificate which is indispensable for global seed trade. India has 134 seed testing laboratories only one public sector laboratory is accreditated to ISTA, building capacity and establishment of more ISTA accreditated laboratories for seed quality assurance will create an enabling environment for seed export. Besides creation of state-of-the-art infrastructure for seed production, processing and seed testing, lack of qualified and well trained human resource is the major impediment in public seed sector that needs to be suitably addressed. There is a strong need for convergence of public and private seed sectors for enhancing quality seed production and rapid delivery to the end users by complementing efforts of each. In most of the food crops, either ideal seed replacement rates have been achieved or surpassed; therefore, focus should be now on enhancing varietal replacement rate.

In conclusion, all the assets such as a strong crop specific cultivar development programmes, 850 newly released high yielding varieties (2014-19), robust and vibrant seed systems, seed quality regulatory mechanism, globally competitive seed sector and largest arable land with 46 soil types across 15 agro-climatic zones favouring seed production of diverse crops are available for sustaining high food production and meet the future demand for seed and food. Nevertheless, the progress and outcome are largely depend on Government policies and support, which require consistent and adequate financial resources for sustaining a vibrant seed production, farm power machinery, processing units, storage, delivery systems and trained human resources. Besides these, seed research and development in the country should be strengthened in terms of infrastructure and human resources with prioritization of thrust areas such as seed health, seed quality enhancement and testing. The success would also depend on remunerative price to the farmers for their produce, which is the main driver for selection of crops by the farmers. Minimum support price (MSP), though remunerative but it is the market forces that are decisive in purchasing farm produce. It has been an open secret that farmers are compelled, due to economic reasons, to sell the produce at much lower price than MSP. This trend is particularly very common at the time of harvest especially observed in case of pulses during the last two years when bumper crops were harvested. Establishing storage facilities, seed banks, seed villages and seed hubs in various zones of the country, seed producing farmers' organizations/companies, could enable farmers to avoid distress sale and ensure remunerative prices of farm produce. It is therefore imperative that government policy/ies should ensure remunerative price to the farmers for their produce through market intervention in addition to enhance MSP, which is so vital for the food security of the nation.

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REFERENCES

Ali M, Gupta Sanjeev and Singh B B. 2016. Quality seeds to trigger high pulse production. *Indian Farming* **65**(10): 2–6.

Anonymous. 2018a. Pocket Book of Agricultural Statistics 2017. Directorate of Economics & Statistics. Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India, New Delhi, p 115.

Anonymous. 2018b. Breeder seed review report 2016-17. XXI Breeder Seed Review Meeting. ICAR-NBPGR, New Delhi. March 26, 2018. p 118.

Anonymous. 2019a. Agricultural Statistics at a Glance 2018. Directorate of Economics & Statistics. Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India, New Delhi, p 468.

Anonymous. 2019b. Breeder seed review report 2017-18. XXII Breeder Seed Review Meeting. CCS-Haryana Agricultural University, Hisar, Haryana. April 7, 2019, p 136.

Anonymous. 2019c. Annual Report 2018-19. Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India, New Delhi, p 220.

Anonymous. 2019d. Telangana : Bichaulion Se Bachane Ke Liye Kisano Ne Kampani Banaei, Isse Kamareddy Zile Ke 23 Gaon Main panch Salon Mai Ek Bhi Atama Hataya Nanhi Huei. Dainik Bhaskar, Jan 28 (Monday), 2019. Jaipur, pp 15 (Daily Hindi News paper).

Anonymous. 2020a. Agricultural Statistics at a Glance 2019. Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, New Delhi, p 315.

Anonymous. 2020a. Fourth advance estimates of production of food grains and commercial crops for 2019-20 as on September 22, 2020. Agricultural Statistics Division. Directorate of Economics & Statistics. Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, New Delhi. (*htpp://agri.coop.nic.in*, visited on September 27, 2020)

Anonymous. 2020b. Breeder seed review report 2018-19.Virtual XXIII Breeder Seed Review Meeting. Crop Science Division, Indian Council of Agricultural Research, New Delhi and Indian Institute of Seed Science, Mau, Uttar Pradesh, May 14-15, 2020. p 124.

Bhatnagar S S and Chouhan B L. 2014. Seed cooperatives in M P a successful approach. *(In) 7th National Seed Congress on Quality seeds for Successful Agriculture,* Bhopal, 25-27 Sept. 2014, pp 114–16.

Chauhan J S, S Pal and S Rajendra Prasad.2014. Recent trends in breeder seed production of selected food and oilseed crops. *(In) 7th National Seed Congress on Quality Seeds for Successful Agriculture*, Bhopal, 25-27 Sept. 2014, pp 103–05.

Chauhan J S, Prasad S Rajendra, Pal Satinder, Choudhury P R and Udayabhaskar. K. 2016a. Seed production of field crops in India: Quality assurance, status, impact and way forward. *Indian Journal Agricultural Sciences* **86**(5): 563–79.

Chauhan J S, Pal Satinder, Choudhury P R and Singh B B. 2016b. All India coordinated research projects and value for cultivation and use in field crops in India: Genesis, outputs and outcomes. *Indian Journal of Agricultural Research* **50**(6): 501–10.

Chauhan J S, Singh B B and Gupta Sanjeev. 2016c. Enhancing pulses production in India through improving seed and variety replacement rates. *Indian Journal of Genetics and Plant Breeding* **76**(4): 410–19.

Chauhan J S, Prasad S Rajendra, Pal Satinder and Choudhury P R. 2017. Seed systems and supply chain of rice in India. *Journal of Rice Research* **10**(1): 9–16.

Chauhan J S, Choudhury P R, Pal Satinder and Singh K H. 2020. Analysis of seed chain and its implication in rapeseed-mustard (*Brassica spp*.) production in India. *Journal of Oilseeds Research* **37**(2): 71–84.

Gaur V K. 2013. Farmer's participation in seed production. (*In*) *6th National Seed Congress on Advancement in agriculture through quality seeds*, Lucknow, 12-14, Sept. 2013, pp 86–09.

NAAS. 2018. Accelerating seed delivery systems for priming Indian farm productivity enhancement: A strategic view point. Strategy paper no.9, National Academy of Agricultural Sciences. New Delhi, p 22.

Prasad S Rajendra, Chauhan J S and Sripathy K V. 2017. An overview of national and international seed quality assurance systems and strategies for energizing seed production chain of field crops in India. *Indian Journal Agricultural Sciences* **87**(3): 287–300.

Rao S K. 2013. Role of agriculture universities in farmer's participatory seed production. (*In*) *6th National Seed Congress on Advancement in agriculture through quality seeds*, Lucknow, 12-14, Sept. 2013, pp 90–100.

Rao S K.2014. Success of participatory seed production through farmer's involvement. *(In) 7th National Seed Congress on Quality seeds for successful agriculture,* Bhopal, 25-27, Sept. 2014, pp 62–77.

Selvaraj S. 2013. Preparation of state seed rolling plan and strategy to tie up seed production with different seed agencies. (*In*) *6th National Seed Congress on Advancement in agriculture through quality seeds*, Lucknow, 12-14, Sept. 2013, pp 37–48.