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Seed Systems and Supply Chain of Rice in India

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Abstract

Rice accounts for 32.7% and 41.5%, respectively, of the acreage and production of food grains in India, during 2015-16. To meet the growing demand of 1.36 billion people, rice production needs to be increased by 20.8% by 2020 under declining and degrading land and water resources. Enhancing seed and varietal replacement rates coupled with integrating natural resource management is one of the important approaches to bridge the gap between potential and realized yields. Enabling the resource poor farmers with quality seed is still an imminent challenge. A strong and vibrant seed system is essential for food security of the country and accelerating growth in agriculture. This paper presents the various prevalent seed systems, seed chain, seed supply, quality seed status and its impact, issues and strategies to ensure continuous availability of quality seed of rice to farmers.

Introduction

Globally, India ranks first in acreage (26.6%) and 2nd in production (21.5%) of paddy. Its yield (3623 kg/ha) is only 80.8% of the world's average yield (Anonymous, 2016). Rice is an important food crop for the country accounting for 22.0% of the gross cropped area during 2012-13 (Anonymous, 2016). Further, it accounts for 32.7% and 41.5%, respectively, of the acreage and production of food grains during 2015-16 (Anonymous, 2017a). Green revolution was made possible by enabling public policies, good services (seed, water and fertilizers), hard working and innovative Indian farmers, besides input responsive dwarf varieties of wheat and rice. In the last 50 years of post green revolution, rice area, production and yield have increased by 1.24, 3.08 and 2.8 times, respectively (Anonymous, 2016). Quality seed played an important and critical role in bridging the yield gaps through improved productivity and it alone contributes about 15-20% to the crop yield. To meet the growing demand of 1.36 billion people, rice production needs to be increased by 20.8% by 2020 under declining and degrading land and water resources. This may be achieved by enhancing seed and varietal replacement rates coupled with integrating natural resource management, raising the ceiling to crop productivity; sustaining the gains achieved and also extending them to new niches. Enabling the resource poor farmers with quality seed is still an imminent challenge. A strong and vibrant seed system is essential for food security of the country and accelerating growth in agriculture. This paper presents various prevalent Indian seed systems, seed chain, seed supply, quality seed status and its impact and future strategies to ensure continuous availability of quality seed of rice to farmers.

Mile stones in the development of seed sector in India

Report of Royal Commission on Agriculture in 1928 was the beginning of the journey of seed sector development in India (Table 1). Presently, Indian seed sector comprises public sector institutions as well as private seed companies. Public seed sector includes various organizations, *viz.*, National Agriculture Research System (NARS) comprising 103 Indian Council of Agricultural Research (ICAR) Institutes/ Bureaux/National Research Centres, Project Directorates, 81 All India Coordinated & Network Projects and 11 Agricultural Technology Application Research Institutes, 3 Central Agricultural Universities and 5 Deemed Universities, 4 Universities having Faculty of Agriculture, 696 Krishi Vigyan Kendras (KVKs), National Seed Corporation Limited, New Delhi; 61 State Agricultural Universities, 15 State Seed Corporation and 24 State Seed Certification Agencies (Chauhan *et al.*, 2016a; ICAR Telephone Directory 2017; icar.org.in 26.7.2017). Private seed sector experienced rapid growth under liberalized government policy which resulted in establishment of around 500 seed companies across the country. Recently, Directorate of Seed Research Mau has been upgraded to Indian Institute of Seed Science (Table 1) highlights the important developments related to seed sector in the country.

Table 1. Milestones in the development of Indian seed sector

Year	Event	Objective/s
1928	Report of Royal Commission on Agriculture	First major milestone in the history of seed sector development.
1945	Famine Enquiry Commission	Emphasised need for multiplication and distribution of quality seed of improved varieties.
1952	Grow-More Food Program Committee	
During 50's	Seed Farms were established in Community Development Blocks	Department of Agriculture started Seed Farms to multiply foundation seed.
1961	First hybrid maize was released	Later hybrids of sorghum and pearl-millet were released.
1963	National Seeds Corporation Ltd was established	To develop a sound seed industry in the country.
1966	Enactment of Seed Act	To regulate quality of seed.
1967	Seed Review Team	Set-up to examine the seed situation in the country and to give suggestions.
1969	Tarai Development Corporation, Pantnagar	To develop 16,000 ha for seed production.
1969	State Farms Corporation of India	Production of certified seed having 38,325 ha in 14 farms.
1971	Report of National Commission on Agriculture	Stressed the need for maintaining purity of seed.
1974	Setting up of joint working party	To formulate National Seed program.
1976	National Seed Project	
1976	Phase I	Implementation in four states.
1978	Phase II	Five more states.
1990	Phase III	Four more states.
1987	Expert Group on Seed	To review the entire seed sector and to give suggestions.
1988	New Policy on Seed Development, Govt. of India.	To make available the best planting material in the world to the Indian farmers.
1983/ 1994	Seed Control Order under the Essential Commodity Act 1955	To regulate quality and pricing of seeds.
1991	New Industrial Policy	Opened doors for the foreign investors in the Indian seed industry.
2001/ 2003	PPV & FR Act / PPV & FR Act Rules	To protect plant breeder's and farmer's rights.
2002	National Seed Policy	To develop seed industry.
2004	Establishment of Directorate of Seed Research, Mau, UP	To undertake research and coordination on seed production.
2008	Joining of OECD seed schemes	To facilitate seed trade in international market.
2009-14	Export and Import Policy (New EXIM)	Liberalized export of seeds and planting materials with few exceptions.
2010	Seed Bill 2004 – pending in parliament	To produce quality seed and also protect Farmers' interests.
2011	Modified New policy on Seed Development / Modified policy on Seed Sector	Provision for import of wheat and rice.
2015	ISTA accreditation of first public sector laboratory	To produce quality seed matching international seed standards to promote seed export.
	Cotton Seed Price (Control) Order,2015	To provide an effective system for fixation of sale price for cotton seeds to ensure their availability to the farmers at fair, reasonable and affordable prices.

2016	Up gradation of Directorate of Seed Research, Mau to Indian Institute of Seed Science, Mau, UP	Conduct of basic, applied and strategic research on seed science, coordination of seed production and to capacity building in seed production, testing, quality assurance, certification and policy issues.
	Licensing and Formats for GM Technology Agreement Guidelines, 2016	To provide an effective system for fixation of sale price for cotton seeds to ensure their availability to the farmers at fair, reasonable and affordable prices.

Seed systems

Seed system can be defined as framework of institutions/ farmers group organized together by their involvement or influence on the seed multiplication, processing, quality assurance and marketing of seeds. There are three major seed systems: informal, formal and integrated.

Formal

Formal seed system is characterised by large scale production of seed of officially released varieties with strict quality assurance mechanism. The formal seed system is easier to characterize, as it is well organized and systematic involving a chain of activities leading to certified seed/ labelled seed of notified varieties. The chain usually starts with development of different types of varieties/ hybrids and formal variety release and maintenance. Guiding principles in the formal system are to maintain varietal identity and purity and to produce seed of optimal physical, physiological and sanitary quality (Reddy *et al*., 2007). There is a clear distinction between seed and grain.

Informal

Informal seed system is characterised by small scale supply of locally known varieties without any government interference in quality control. Activities tend to be integrated and locally organized, and the informal system embraces most of the other ways in which farmers themselves produce, disseminate and access seed: directly from their own harvest; through exchange / barter among friends, neighbours, relatives; and through local grain markets. Encompassing a wider range of seed system variations, flexibility characterizes the informal system most. Varieties may be landraces or mixed races and may be heterogeneous, modified through on farm breeding. In addition, the seed is of variable quality (diverse purity and physical/ physiological quality). The same general steps take place in the local system as in the formal sector (variety choice, variety testing, introduction, seed multiplication, selection, dissemination and storage) but they take place as integral parts of farmers' production systems rather than as discrete activities. There is not always necessarily a distinction between seed and grain. The steps do not flow in a linear sequence and they are not monitored or controlled by government policies and regulations. Rather, they are guided by local technical knowledge and standards and by local social structures and norms.

Integrated

In many cases, however, a farmer will use the formal system for some crops and informal system for others. He may buy seed from the formal system once in order to obtain a particular variety and produce own seed from there onwards and share the new variety with neighbours and relatives. Farmers, particularly, smallholding farmers, are involved in multiple seed systems, which help them to obtain the seed they need. Community based seed production of the varieties preferred by the farmers by themselves in their own locality by organizing themselves into small groups. These groups cultivate the same variety avoiding cross pollination and follow the recommended cultivation practices particularly seed selection procedures. These farmers are given the appropriate training, and supplied with good quality foundation seed for multiplication, so that they become the source of improved seed for the entire village (Figure 1). Each season the farmers are supplied with foundation seed of different crops.

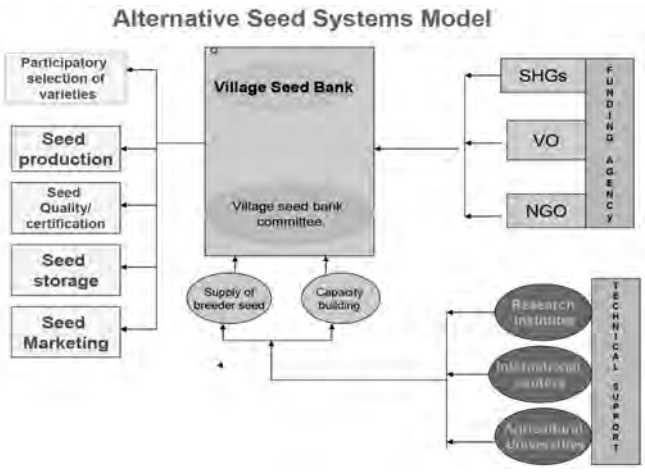

Figure 1. Integrated seed system

Seed supply chain

The ICAR is mandated to produce nucleus and breeder seed as per the indent received from Department of the Agriculture, Cooperation & Farmers Welfare (DAC & FW), Ministry of Agriculture and Farmers Welfare, Government of India. The production of breeder seed is demand driven and produced on the basis of indents received from private

as well as public sector organizations, by DAC which in turn consolidates the indents and forward to the ICAR. Crop Science Division of the ICAR coordinates the breeder seed production of field crops in the country with the cooperation of various SAUs and public sector crop based institutes. The breeder seed thus produced is supplied to indenting States Department of Agriculture as well as other public and private sector organizations for further multiplication in the form of foundation and certified seeds which is made available to the farmers (Figure 2). Production of quality seed (foundation and certified) of crops is primarily the responsibility of the States although ICAR institutes also produce limited quantity of certified/truthfully labelled (TL) seed. Each producing institute/agency fixes the price of foundation/certified/TL seed while price of breeder seed is fixed by the ICAR in consultation with DAC.

Figure 2. Stakeholders in the seed supply chain

Development of Varieties

The NARS as well as certain private seed companies have been continuously developing climate resilient varieties of seeds suitable for different agro-climatic regions and also engage in production of breeder/ basic seed, foundation, certified and TL seeds. This continuous variety improvement, led to release and notification of 4,615 varieties of field crops since 1969 till 75th meeting of Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops on August 12, 2016. Of these, 250 have also been de-notified (Chauhan *et al.,* 2016 b). These varieties are input-responsive, high yielding and show tolerance to major biotic and abiotic stresses. During the last 15 years, 1994 varieties were released and notified (Chauhan *et al.,* 2016 b), of which 986 were state releases (Figure 3) and a total of 231 rice varieties were released during 2009-16 (Figure 4) and maximum (63) were released during 2016.

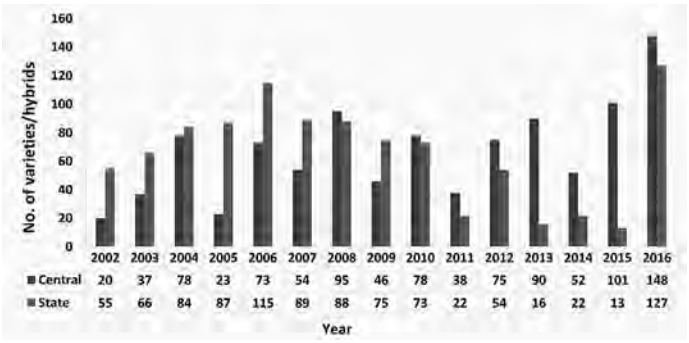

Figure 3. Central and state varieties of field crops released in India during 2002-2016 (Source: Chauhan *et al.,* 2016b)

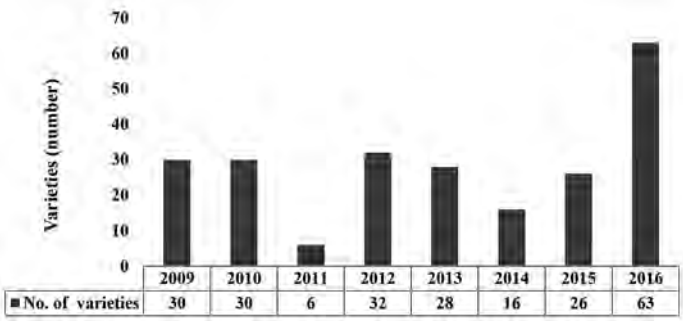

Figure 4. Rice varieties released during 2009-2016

Rice varieties in seed chain

Breeder seed is the first step of effective formal seed chain and only notified varieties as per section 5 of Seed Act, 1966 qualify for production of certified seed. Of the 900 varieties / hybrids of rice qualifying for such seed production, more than 300 were in the seed chain during 2016-17 (Table 2). The number of hybrids varied from 8-12 and their contribution to total breeder seed production of the crop was very low. Of the 4 years, Cottondora Sannalu (MTU1010) was the leading top most variety in three years while Swarnasub1 was the topmost leading variety during 2016-17. Only seven varieties occupied the first five positions in the seed chain and contributed from 28.6-34.8%.

Certified seed/Truthfully labelled seed marketing and distribution take place through a limited number of officially recognized seed outlets. There are adequate provisions under existing seed legislations to regulate the quality of seeds and the mechanisms for such regulations are in keeping with the federal structure of the country. The powers of enforcement and implementations of Seed Act, 1966 are appropriately vested in the State Governments. Besides, the provisions of Seeds Act 1966 and Seed Rules 1968, the Seeds (Control) Order 1983 are applicable to both notified and non-notified seeds. Seed certification is voluntary but labelling is mandatory. The business of selling, exporting and importing seeds can be carried out only under a license issued by the State government. Seed dealers are required to maintain books, accounts and

Table 2. Varieties (V) and hybrids (H) of rice in seed chain and their contributions to breeder seed indent (Anonymous, 2017b)

Year	Varieties / hybrids	Five top most varieties having highest indent	Indent (q)	Contribution (%)	Contribution of top most 5 varieties to total indent (%)
2013-14	V - 229 (99.87%) H- 12 (0.13%)	Cottondora Sannalu (MTU 1010)	485.0	10.2	30.9
		Swarna (MTU 7029)	443.1	9.3	
		Vijetha (MTU 1001)	193.6	4.1	
		Sahbhagi Dhan	181.4	3.8	
		IR 64	161.4	3.4	
		Total indent	**4745.0**		
2014-15	V - 219 (99.85%) H - 11 (0.15%)	Cottondora Sannalu (MTU 1010)	498.6	11.5	34.8
		Swarna-sub1	388.0	9.0	
		Vijetha (MTU 1001)	230.6	5.3	
		Swarna (MTU 7029)	202.0	4.7	
		Sahbhagi Dhan	188.3	4.4	
		Total indent	**4328.0**		
2015-16	V - 248 (99.69%) H - 11 (0.31%)	Cottondora Sannalu (MTU 1010)	427.1	8.5	28.6
		Swarna (MTU 7029)	359.4	7.2	
		Swarnasub1	232.9	4.6	
		Vijetha (MTU 1001)	210.1	4.2	
		Sahbhagi Dhan	206.1	4.1	
		Total indent	**5026.0**		
2016-17	V - 310 (99.94%) H - 8 (0.06%)	Swarnasub1	553.2	10.8	31.2
		Cottondora Sannalu (MTU 1010)	342.0	6.7	
		Sahbhagi Dhan	339.8	6.6	
		IR 64	183.3	3.6	
		Naveen (CR-749-20-2)	178.9	3.5	
		Total indent	**5119.0**		

display the stock position and sale price. State governments have powers in pursuance of section 13 of Seed Act, 1966 to appoint inspectors to regulate the seed trade. Seed Inspectors are vested with adequate powers for quality control, *viz.*, to draw the sample; enter and search; examine records, registers, and documents; seize the stock and issue 'Stop Sale' order in case the commodities under reference contravene provisions of law. Inspectors are also authorized to take punitive action / launch proceedings against dealers found to be selling sub-standard seeds. A dealer's license is liable to be suspended/cancelled for contravention of the Seed Act 1966. The seed in respect of which the contravention has been committed can be forfeited under Section 20 of the Seeds Act. The penalties are provided under Essential commodities Act, 1955 (Trivedi and Gunasekaran, 2014). The dealers can also be directed to distribute seeds in specified manner in public interest

Quality seed production of rice

Breeder seed: Breeder seed indent was highest (5,772 q) during 2011-12 and declined thereafter until 2014-15 (4,328 q) which was 8.7%, 16.2% and 25.7% during 2012-13, 2013-14 and 2014-15, respectively (Table 3). Since 2014-15, the breeder seed indent consistently increased to 5119 q during 2016-17. The increase was 17.3% in 2015-16 and 19.4% in 2016-17 (Table 3). The production of breeder seed was always higher than the indented quantity, nevertheless, varietal mismatch was invariably observed. The production was higher by 8.4% during 2015-16, a drought year, to 118.9% during 2013-14.

Table 3. Trends in indent and production of breeder seed of rice*

Year	Indent (q)	Production (q)
2011-12	5,772	6,828
2012-13	5,267	11,455
2013-14	4,837	10,586
2014-15	4,286	7,757
2015-16	5,026	5,449
2016-17	5, 119	8,765**

*Anonymous (2017b) and ** IIRR- AICRP on Rice Annual Report (2017)

Certified / quality seeds

It is the certified/quality seeds made available to the farmers/growers that could raise crop productivity by

enhancing seed replacement rate. In paddy, maximum dissemination of quality seeds was during 2011-12 (74.41 lakh q) showing an increase of 22.1% over that of 2009-10 and remained almost stagnant for the next two years. However, the quantity of paddy quality seed declined by 10.2% during 2014-15 over that of 2011-12. Nevertheless, it was higher by 9.7% over the base year, 2009-10 (Table 4). The reduction in dissemination of quality seed could be partly due to drought in 2014-15.

Table 4. Distribution of certified/ quality seeds of paddy (Anonymous, 2016)

Year	Quantity (lakh quintals)
2009-10	60.95
2010-11	69.34
2011-12	74.41
2012-13	72.14
2013-14	72.45
2014-15	66.84

Impact of quality seed use

Enhanced seed replacement rate leads to increased yields: During the last six years, availability of certified/ quality seed showed an inconsistent increase ranging from 9.7-22.1% over that of 2009-10. The increase in seed availability resulted into high seed replacement rates (SRR) in paddy until 2013-14 (57.6%). Due to severe drought during 2014-15, area and production coupled with SRR declined. Probably, there was less availability as well as demand for seed due to continuous drought since 2013-14 and about 0.55 million ha area was reduced during 2014-15 as compared to 2013-14 and the SRR was 32.8% (Chauhan *et al.*, 2016a). However, the increased SRR was, in general, associated with increased yield. The area under rice remained fairly consistent during the last five years, ranging from 42.75 (2012-13) to 44.14 million ha (2013-14) with about 2.95-1.50% decline during 2012-13 and 2015-16 as compared to that of 2011-12 (Anonymous, 2016).The rice cropped area was 43.39 million ha during 2015-16 (Figure 5). Similar was the trend for production which increased by about 1.28% during 2013-14 and decreased by 0.93% during 2015-16.Yield (kg/ha) during this period varied from 2391 (2014-15) to 2461 (2012-13) and it was 2404 during 2015-16 (Figure 5).

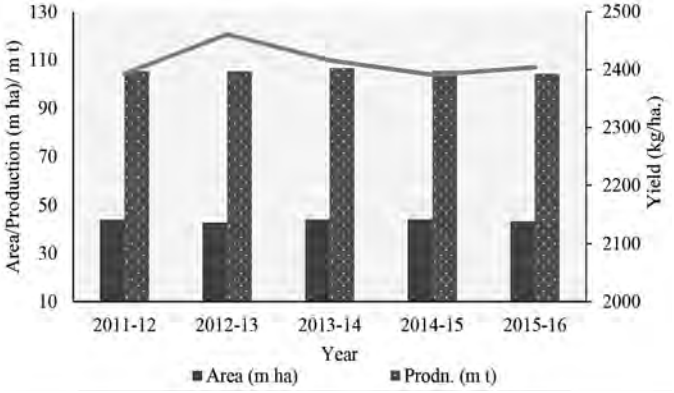

Figure 5. Recent trends in area, production and yield of rice

Increased rice export: India became food surplus country from food scarce as a result of green revolution in 70's, which enabled policy makers to enact Food Security Act in 2013 which ensures availability of food (rice, wheat, coarse cereals) to about 64% of the population at much reduced price. The increased seed replacement rate as a consequence of enhanced availability of quality seed could be one of the major reasons for high rice production despite two consecutive drought years (2014-15 and 2015-16) and sustaining continuous export of rice over 10 million tonnes (Table 5). India earned a sizeable amount of foreign exchange by exporting basmati and non-basmati rice. During the last six years, the export of basmati rice increased from 3.17 million tonnes in 2011-12 to 4.0 million tonnes in 2016-17, registering an increase of 26.2% (Table 5). Export of non-basmati rice during the corresponding period registered an increase of 105.8%

Table 5. Export of rice from India during the last six years

Year	Quantity (Million Tonnes)			Value (Billion US $)		
	Basmati	Non Basmati	Total	Basmati	Non Basmati	Total
2011-12	3.17	4.00	7.17	3.22	1.72	4.94
2012-13	3.46	6.69	10.15	3.56	2.65	6.21
2013-14	3.75	7.15	10.90	4.86	2.93	7.79
2014-15	3.70	8.23	11.93	4.52	3.32	7.84
2015-16	4.04	6.37	10.41	3.48	2.31	5.79
2016-17	4.0	6.81	10.81	3.22	2.55	5.77

Source: India export of principal commodities. http:// agriexchange. apeda. gov. in/ indexp /18 headgen report month_combine.aspx (24.7.2017)

until 2014-15 (8.23 million tonnes) over that of 2011-12 (4.0 million tonnes). Presently (2016-17), India exported 6.81 million tonnes of non-basmati rice which is 70.3% higher than that of 2011-12. Total (basmati + non-basmati) rice export increased consistently from 7.17 million tonnes during 2011-12 to 10.81 million tonnes during 2016-17, registering an increase of 50.8%. The foreign exchange earnings were 3.22-4.86 billion US $ and 1.72-3.32 billion US $ from basmati and non-basmati rice, respectively, during 2011-12 -2016-17 (Table 5).

Issues

- **Unrealistic demand for breeder seed:** Sudden big fluctuations in varietal demands in quick spans poses challenge to availability of breeder seed as nucleus seed for such unexpected unusual high demands may not be available. For example, to achieve a target SRR of 50.5% by 2019-20 even for all time high rice cropped area (45.5 million ha), only 919.1 q breeder seed is required while an indent of 5119.2 q for breeder seed production was received during 2016-17.
- **Varietal mismatch:** Although breeder seed production is invariably higher than the indented quantity, however, many a times seed of indented quantity of several rice varieties is not produced in sufficient quantity.
- **Non-lifting of breeder seed and weak seed chain:** The agencies such as States Department of Agriculture, States Seed Corporation, private seed producers and others responsible for conversion of breeder seed to foundation and certified seed do not lift the allotted quantity of breeder seed to take up effective conversion of indented breeder seed. Further, some agencies lift the breeder seed but sometime go for direct multiplication of certified seed which is not advisable.Traceability of breeder seed source in rice multiplication chain, thus, is a serious concern for quality seed production.
- **Over dependence on private-sector without any formal agreement:** Tendency of several states for not placing timely indents for requisite quantity of breeder seed. In fact, there is declining trend in many states for indents even for major rice varieties and procuring seed through tendering process, thus, quality of seed cannot be ensured.
- **Intellectual Property Rights:** In view of National/ International treaties such as CBD, ITPGRFA, Nagoya Protocol, PPVFRA and NBA restricting the easy access of quality seed of newly released hybrids and varieties and also restrict the free and easy exchange of germplam among the stakeholders from public as well as private sector involved in genetic enhancement and development of new rice varieties.
- **Climate change:** Deteriorating effects of climate change that has already affected the seed production programmes in many states.

Strategies

Inherent strengths of India are being the 2nd largest arable land with 46 soil types across 15 agro climatic zones favour seed production backed by strong national genetic enhancement and development programmes for new rice varieties, wide network of agriculture extension services. Growing demand for quality seed as SRRs in rice is consistently increasing and focus is on enhancing Varietal Replacement Rate, supportive public policies are the growth drivers for a vibrant seed systems and supply. Strategy development with focus on following issues would further strengthen the seed systems and rice seed supply chain in the country to address the demanding needs of ever increasing population of the country:

- Realistic assessment of breeder seed vis-à-vis strengthening of state seed rolling plan and seed chain.
- Need for development of rapid tests such molecular markers to replace grow out test, to establish genetic purity and seed health. Development of molecular markers to enable genetic purity testing and management of nucleus seed and its further maintenance.
- Focus should be on enhancing Varietal Replacement Rate with target Seed Replacement Rate, *viz.*, 35% for rice.
- To mitigate the adverse effects of climate change, search for identification of suitable alternate areas for seed production in non-traditional area/ season should be systematically pursued.
- Capacity building of various stake-holders in seed chain with focus on enhancing farmers' participation in seed production, development of seed villages and seed banks and main streaming of farmers protected varieties.
- Establishing seed hubs and National Seed Bank especially for meeting urgent demands of contingency planning.
- Marketing intelligence for increasing seed trade and encourage the export of seed by providing incentives to the exporters
- Introduction of bar code/ QR code for traceability of breeder seed source in multiplication chain.
- Establishment of rice advisory body/ referral lab for implementation of quality control system.

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