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A review: The Indian seed industry, its development, current status and future

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Abstract
The agricultural sector is highly dependent on the availability and quality of seeds for a productive harvest. The response of all other inputs depends on quality of seeds to a large extent and estimated 15 – 20% contribution of quality seed alone to the total production which is depending upon the crop and it can be further raised up to 45% with efficient management of other inputs. Today, the Indian seed industry is the fifth largest seed market in the world and valued at more than Rs 2500 crores. The seed industry has grown steadily in the last four decades. A number of transformations have taken place in this sector over the past few decades like rising a penetration of the organised sector, growth in contract farming, agriculture becoming more mechanized, easy loan facilities, rise of exports, use of agrochemicals and high yielding seeds and an increasing role of the private sector in processing, branding and marketing, etc. Government took many progressive and reformative steps in last three decades for the growth of seed sector in the country. In terms of global trade, India is almost self-sufficient in flower, fruits and vegetables and field crops seeds. Research also have related to quality enhancement technologies such as cereals with higher proteins, minerals and vitamin contents like Golden rice, QPM and Fe and Zn enriched millets. A single-window clearance is recommended for faster release of useful transgenic crops along with its public awareness on benefits and possible risk issues in future.

Keywords: Indian Seed Industry, Seed Production, Seed Certification, Seed policy.

Introduction

What is seed?

Seed is a basic agricultural input and it is an embryo, embedded in the food storage tissue. Seed is also defined as a matured ovule which consists of an embryonic plant with storage of food and surrounded by a protective seed coat.

Importance of seed

Seed is the basic and most critical input for sustainable agriculture. Therefore our major concern and focus is to produce quality seed to take more and more from less and less. The response of all other inputs depends on quality of seeds to a large extent and estimated that the direct contribution of quality seed alone to the total production is about 15 – 20% depending upon the crop and it can be further raised up to 45% with efficient management of other inputs. Today, the Indian seed industry is the fifth largest seed market in the world and valued at more than Rs 2500 crores ($ 500 million). Government took many progressive and reformative steps in last three decades for the growth of seed sector in the country.

The agriculture is the backbone of rural economy. Agriculture in India has made significant growth and we are on the path of second green revolution through modern agricultural technology. For sustainable agriculture, a good quality seed is the most basic and essential input. The Indian seed industry has played a very critical role in the growth of Indian agricultural. Indian seed industry is the fifth largest seed market in the world and valued around Rs 2500 crores ($ 500 million) with about 150 organized seed companies and is proposed to be around 3750 crores ($ 750 million) by 2002 (Gadwal, 2003) [6]. Indian seed industry is accounting for 4.4 % of global seed market after the U.S. (27%), China (20%), France (8%) and Brazil (6%). In terms of global trade, India is almost self-sufficient in flower, fruits and vegetables and field crops seeds. The seed industry has grown steadily in the last four decades. There is seed legislation in place and a Draft Seeds Act of 2001 is being finalized on the basis of the recommendations of Seed Policy Review Group. It will replace the existing Seeds Act of 1966 and Seed (Control) Order of 1983.

A number of transformations have taken place in this sector over the past few decades like rising a penetration of the organised sector, growth in contract farming, agriculture becoming more mechanized, easy loan facilities, rise of exports, use of agrochemicals and high yielding seeds and an increasing role of the private sector in processing, branding and marketing, etc. The agricultural sector is highly dependent on the availability and quality of seeds for a productive harvest. Therefore, in order to increase the quantity and quality of produce, efforts are made to introduce enhanced varieties of seeds with the help of advance technology and modern agricultural methods. In March 2002 the first transgenic hybrid cotton seed was allowed for commercial cultivation in the farmer's field.

Need for a second Green Revolution

The "Green Revolution" ushered during the late 60s and 70s is recognized to be a turning point in our Indian Agriculture. It is well known that the introduction of high yielding, semi-dwarf and fertilizer responsive varieties of wheat and rice led to a dramatic shift from "food scarce" to "food secure" status in the country. This success was the result of holy alliance between policy makers/administrators and the hard working farmers. In order to meet the growing demands for our increasing population, likely to be 1.7 billion by 2050, we shall need to double our food production (Paroda, 2013) [13]. This can only be possible by bridging the existing yield gaps through improved productivity and by integrated natural resource management. Hence, the second Green Revolution would demand much faster growth of seed sector especially to meet the demand of hybrid seeds and to replace old with new high yielding varieties. For this, a Mission on Seed Production is urgently needed.

Development of seed industry in India (Policies and Regulations)

Seed industry's excellent growth story is reflective of India's own agriculture momentum. The National Seeds Corporation (NSC) were established in 1963 undertakes production, processing and marketing of agricultural seeds. The Seeds Act, 1966 provides for the legislative framework for regulation of quality control of seeds sold in the country. The Seeds Act was formulated in 1963 and came into force in 1966. Its important features are; seeds should contain specific seed standards, which include stipulated minimum physical and genetic purity, seed germination % and not exceeding the maximum permissible limit of off-types and weed seeds. The seeds should be tagged either by compulsory labelling or voluntary certification. Seed testing laboratories (STLs) are now 124 (till mid of 2016) which involved in checking the compatibility of different varieties of seeds, usually tested for germination and vigour, diseases, purity, genetic traits and general seed health for quality assurance. World Bank launched a funding project i.e. The National Seed Project (NSP) which was implemented in three phases viz., Phase I (1977-78), Phase II (1978-79) and Phase III (1990-91). Under these projects initially nine State Seed Corporations (15 at present), State Seed Certification Agencies (22 at present), State Seed Testing Laboratories were established and Breeder Seed Programme were also under taken.

New Seeds Policy of 1988 made a revolution in Indian seed industry by liberalizing the seed trade and made Indian farmers to access best quality seed or planting material from abroad the world. Seed Bank Scheme (2000) also set up seed banks in non-traditional areas to meet the demand for seeds during natural calamities, shortfall in seed production and other emergency situations. PPV & FRA (Protection of Plant Varieties and Farmers Rights Act) in 2001 provides farmers the right to save, use exchange, share and sell farm produce of protected variety except sale of branded seed. Farmer or group of farmers can claim compensation if it is failed to give specified performance under given conditions as specified by the breeder of the variety. The National Seeds Policy of 2002, stresses the importance of providing farmers enough superior quality seed on time to meet the country's food security needs. In 2005, National Seed Research and Training Centre (NSRTC) in Varanasi were initiated to have a separate Central Seed Testing Laboratory for seed quality control and act as a referral lab when disputes arise in a court of law with regard to quality of seed. The government has also launched a Central Sector Scheme namely, "Development and Strengthening of Infrastructure Facilities for Production and Distribution of Quality Seeds" from the year 2005-06.

Current status of the seed industry

The requirement of certified/quality seeds is assessed by State Governments on the basis of the area sown under different crop varieties, area covered by hybrid and self-pollinated varieties as well as the seed replacement rate achieved. The availability of seed is ascertained by the State Departments of Agriculture on the basis of the production of different public and private seed production agencies.

India's seed industry has grown in size and level of performance over the past four decades. Both private and public sector companies/corporations are involved with the production of seed. The success achieved with the introduction of high yielding varieties of wheat and rice and the hybrids of maize, millets and cotton could be sustained due to sound policy support provided through establishment of public sector organizations, such as the National Seeds Corporation (NSC), Tarai Development Corporation (TDC), State Farms Corporation of India (SFCI) and the State Seed Corporations (SSCs) during the Green Revolution period. The seed sector grew steadily in the subsequent period with the establishment of several private seed companies dealing with both field crops and vegetables.

The most dramatic change in the seed scenario was experienced in the first decade of current millennium. First, the introduction of PPV&FR Act, 2001 and the second release of Bt cotton in India in 2002. The rapid expansion of Bt cotton production area (reaching to ~90% in 10 years) has enhanced the demand for Bt cotton hybrid seed by 220% (Dravid, 2011) [4]. The adoption of Bt cotton technology increased production by 139%. India could turn into a net exporter of cotton from being an importer just a decade ago. In this case, the private sector took the lead in accessing the technology from the MNCs. All these factors led to higher growth of Indian seed industry (around US $ 2000 million), with a potential to grow by 60% in the next 5 years.

At present, a decelerating productivity growth rate, increasing prices and demand for food grains, shrinking natural resources, fragmented land holdings and the challenges of climate change have emerged as the major concerns for the governmental policy makers and scientists alike. For raising the agricultural productivity, seed is most appropriate and cheapest input. Only by the use of good quality seeds we can increase the yield about 15-20 percent and it may be up to 45 % with proper and efficient use of other inputs (Ali, 2016) [2]. Therefore, any attempt to turn around our agricultural productivity will largely depend on higher replacement rate of

quality seeds of high yielding varieties / hybrids. Unfortunately, in spite of several efforts to ensure availability of good quality seeds of high yielding varieties/hybrids, the replacement rates in most of the field crops are much below the optimum level (Singh and Chand, 2011) [19]. But, as per available data, the availability of quality seed is sufficient to meet our requirement (Table 1) and it is encouraging that both private and public sectors are contributing towards it (Table 2).

Table 1: Year-wise requirement and availability of quality/certified seeds (in lakh quintals)

Year	Requirement	Availability	Availability increased over last year (%)
2004-05	110.83	132.27	-
2005-06	107.08	140.51	6.23
2006-07	128.76	148.18	5.46
2007-08	180.74	194.31	31.13
2008-09	207.28	250.35	28.84
2009-10	249.12	279.72	11.73
2010-11	290.76	321.36	14.88
2011-12	330.41	353.62	10.04
2012-13	315.00	329.00	-6.96
2013-14	335.00	347.00	5.47
2014-15	344.00	352.00	1.44

Source: Directorate of Economics & Statistics, Ministry of Agriculture, GOI (http://docnet.nic.in/eands), Chauhan *et al.* (2016) [3]

The contribution of private sector seed companies in total seed production of the country is depicted in the following table:

Table 2: Total seed production by the public and private sectors

Year of Production	Total Seed Production (MT)	Seed produced by public sector (MT)	Seed produced by private sector (MT)	Share of private sector (%)
2003-04	1.32	0.70	0.63	47.48
2004-05	1.41	0.77	0.63	45.02
2005-06	1.48	0.79	0.69	46.80
2006-07	1.94	1.15	0.80	41.00
2007-08	1.94	1.12	0.83	42.59
2008-09	2.50	1.51	1.00	39.78
2009-10	2.80	1.71	1.09	38.93
2010-11	3.22	1.66	1.56	48.45
2011-12	3.54	1.81	1.73	48.87
2012-13	3.29	1.61	1.67	50.76
2013-14	3.47	1.68	1.79	51.59
2014-15	3.52	1.51	2.06	58.52

(Source: Singh and Chand (2011) [19] and Seeds Division, Department of Agriculture & Cooperation, Ministry of Agriculture, GOI)

In last two decades the ICAR institutes and SAUs have made significant progress in meeting fully the breeder seed requirement. In less than a decade, even the breeder seed production has been doubled from 62231 quintal (2005-06) to 122633 quintal (2010-11) (Paroda 2013) [13].

In real sense, growth of private sector began in early nineties when ICAR took a bold decision of providing breeder seed of parental lines of public bred hybrids and varieties freely to the private sector in order to ensure higher productivity of major crops. This enabled private seed companies to grow much faster even with limited R & D capacity. For this reason, we find today that some of the local seed companies are highly successful and building their capability further. The contribution of private research in terms of value is steadily increasing.

Though it is difficult to have an accurate estimation, it is presumed that private sector is currently spending on R&D about 10-15% of the total turnover. The top 5 MNCs account for ~44% of the total R&D investments, whereas the remaining 56% is contributed by nearly 30 Indian companies totaling about Rs. 200-300 crores per annum (Paroda 2013) [13] and an estimated Rs. 1200 crores have been invested by the industry in the recent years in quality assurance, seed testing, processing and storage infrastructure. The share of research hybrids in total turnover of crops like pearl millet, sorghum-sudan grass (SSG), sunflower, maize, sorghum and cotton was about 70% in 1997–98 compared to 46% in 1990–91. Private R&D's real investment in research has quadrupled between 1986 and 1998. Subsidiaries and joint ventures with multinational companies account for 30% of all private seed industry research (Kuldip, 2000) [10]. The private sector has also started to play an important role in the supply of quality seeds of vegetables and crops like hybrid maize, sorghum, bajra, cotton, castor, sunflower, paddy etc. In the case of vegetable seeds and planting materials of horticultural crops, the private sector is the dominant player (as given in table 3). The private sector's research focus is on Pest & disease resistance and most recently into developing varieties that can resist climatic extremities.

Table 3: New vegetable hybrids in India (1998-2005)

Crop	Public Sector	Private Sector
Tomato	3	160
Brinjal	8	218
Chilli	2	73
Capsicum	1	31
Cauliflower	1	35
Cabbage	0	20
Okra	2	32
Watermelon	2	25
Cucumber	2	10
Gourds	6	80

Source: NSAI (2005)

The major share of investments in agriculture by the private sector pertains to Seed and Biotechnology Research, which is about 33% of the total (Pray & Nagarajan, 2012) [15]. The private sector comprises around 150 seed companies, which include national and multinational companies and other seed producing/selling companies. The quantum of seed produced and sold has gone up by five times from 14 lakh quintals to 70 lakh quintals from 1962-63 to 1995-96 period (DAC, Ministry of Agriculture, GOI). This seed component in 1990–91 comprised of proprietary hybrids, public-bred hybrids and open-pollinated varieties. The proprietary hybrids formed a significant portion of the total seed market. In terms of quantity, although proprietary hybrids had only 32.34% share of the market, in terms of value the share was 76% (Gadwal, 2003) [6]. The total market for purchased seed was 8.64 lakh tons valued at Rs 2249 crores. The component of proprietary hybrid seed was estimated to be around 51,314 tonnes in 1998–99 as against 19,300 tons in 1990– 91 and valued at Rs 636 crores as against Rs 95 crores respectively. The volume of seed of open pollinated varieties (OPV) increased by 51% to 774,881 tonnes In case of vegetables and pulses, the bought seeds were 1981.11 tonnes and 41,900 tonnes respectively in 1998–99 compared to nil in 1990–91 (Francis Kanoi survey report, 1991[5] and Mahyco report, 1999 [11]).

Seed production system in India

The Indian seed programme largely adheres to the limited generations' system for seed multiplication in a phased manner. The system recognizes three generations namely breeder, foundation and certified seeds and provides adequate safeguards for quality assurance in the seed multiplication chain to maintain the purity of the variety as it flows from the breeder to the farmer.

Breeder Seed

Breeder seed is the progeny of nucleus seed of a variety and is produced by the originating breeder or by a sponsored breeder. Breeder seed production is the mandate of the Indian Council of Agricultural Research (ICAR) and is being undertaken with the help of ICAR Research Institutions, National Research Centres and All India Coordinated Research Project of different crops, State Agricultural Universities (SAUs). There has been a steady increase in the production of breeder seed over the years.

Foundation Seed

Foundation seed is the progeny of breeder seed and is required to be produced from breeder seed or from foundation seed which can be clearly traced to breeder seed. The responsibility for production of foundation seed has been entrusted to the NSC, SFCI, State Seeds Corporations, State departments of Agriculture and private seed producers, who have the necessary infrastructure facilities. Foundation seed is required to meet the standards of seed certification prescribed in the IMSCS, 2013 both at the field and laboratory level.

Certified Seed

Certified seed is the progeny of foundation seed and must meet the standards of seed certification prescribed in the IMSCS, 2013. In case of self pollinated crops, certified seeds can also be produced from certified seeds provided it does not go beyond three generations from foundation seed stage-I. Certified seed production is organized by State Seeds Corporation, NSC, SFCI, other public, cooperatives & private companies etc. on it's own farms, governmental farms and progressive famer's field.

Seed Certification System in India

Seed certification is a legally sanctioned system for quality control of seed multiplication and production. In India, seed certification is voluntary and labelling is compulsory. The main objective of the Seed Certification is to ensure the acceptable standards of seed viability, vigour, purity and seed health. Any variety to become eligible for seed certification should meet the field and seed standards. General requirements includes variety should be a notified under Section-5 of the Indian Seed Act, 1966 and should be in the production chain and its pedigree should be traceable also. Field standards include the selection of site, isolation requirements, spacing, planting ratio, border rows etc. Specific requirements like presence of off-types in any seed crop, pollen-shedders in Sorghum, Bajra, Sunflower etc., Shedding tassels in maize, disease affected plants, objectionable weed plants etc., should be within the maximum permissible levels for certification. In India, Seed Certification Agencies in each States are establishment under Section 8 of the Seeds Act, 1966.

Maintenance seed quality

Seed quality is maintained through seed certification, seed testing, seed labelling and seed law enforcement by the State Seed Certification Agencies, which are 24 at present in different states in the country. Other states have maintains the seed quality by seed certification through State department of Agriculture. Seeds being sold in the market are compulsorily required to be labelled as prescribed under the Seeds Act, 1966. Seed quality standards are prescribed under the IMSCS, 2013 [9]. Grow-out test (GOT) is evaluation of the seeds for their genuineness to species or varieties or seed borne infection. Here the samples drawn from the lots are grown in the field along with the standard checks. Growing plants are observed for the varietal purity. GOT test were conducted to evaluate foundation seed mostly but sometimes it is also tested in certified and truthfully labelled (TL) seeds in special conditions.

Need to enhance SRR

For achieving the desired levels of Seed Replacement Rates (SRR), adequate seed of good variety needs has to be produced first. Each state needs to prepare a State Seed Plan to meet the seed requirement specific to concern region. In last two decades the ICAR institutes and SAUs have made significant progress in meeting fully the breeder seed requirement. In less than a decade, even the breeder seed production has been doubled from 62231 quintal (2005-06) to 122633 quintal (2010-11) (Table 4).

Production of Breeder Seed in different crops is adequate to achieve a desired seed replacement rate i.e. around 30% in self pollinated species, 50% in often cross pollinated species and 100% in hybrids (DSR/ICAR, 2012). Yet the organized seed sector is estimated to cater to only 25-30% of total seed requirement in the country (Agrawal, 2012 [1] and Rabobank, 2012 [16]). Hence, even if the SRR is increased to 50%, the domestic seed market will exceed to US$ 5000 million thus bringing India's position to 3rd rank.

Table 4: Indent and Production of Breeder Seed (BS) in India

Year	Indent for BS production (qtls)	Actual production of BS (qtls)	Excess BS production than indent (%)
2004-05	43057	60793	41.19
2005-06	47879	69507	45.17
2006-07	55547	77666	39.82
2007-08	73687	92060	24.93
2008-09	79913	91883	14.98
2009-10	91410	115867	26.76
2010-11	90266	115867	28.36
2011-12	87215	115696	32.66
2012-13	90577	117827	30.08
2013-14	98791	95012	(-) 3.83
2014-15	112152	128312	14.41
2015-16	122305	124843	2.08

(Paroda, 2013 [13] and Prasad *et al*., 2017 [14])

Need to innovation

The seed sector had been quite active to outscale new innovation in agriculture. Such innovation encompasses development of superior hybrids, transgenics and advanced seed treatments especially in crops like rice, maize, sorghum (rabi), pigeon pea, rapeseed mustard, castor, vegetables etc. If ICAR provides the parental lines of new vegetable hybrids to private companies without any cost, may be a progressive steps. If government provides subsidy to public bred hybrids the farmers also take interest in same. A collective and targeted approach by government and research institutes will be made and also need to develop better climate resilient hybrids as well as varieties both by public and private sector.

Need to exchange Germplasms

National Bureau of Plant Genetics Resources (NBPGR) was established in 1976, which houses the world's third largest Gene Bank. This not only acts as a national repository of plant genetic resources, but also acts as an apex organization facilitating germplasm conservation, access and exchange for research purposes. NBPGR has a rich collection of 3,95,000 accessions of more than 1500 plant species, which can be of great significance in plant breeding programs.

Need for Biotechnology

The high-yielding technology that heralded the Green Revolution has, no doubt, rescued the country from chronic food deficiency and starvation but it has had its adverse effects too. The high input cultivation of rice and wheat has led to excessive water use and eroded soil quality; indiscriminate use of chemical pesticides has led to pesticide resistance making pest management increasingly difficult (Gordon, 1997) [8]. Weed infestation causes heavy crop losses, if not controlled in time. The estimates of losses caused due to pests and weeds range between 10% and 40% but in some cases the losses could be much more (Sahoo and Saraswat, 1999) [18]. Hybrid technology, though a potential technological option, has not yet become a reality in several crop plants for want of stable male sterility/fertility restoration system and lack of economic hybrid seed production technology, the scope for increasing yield has been limited (except sorghum, pearl-millet, sunflower, rice, mustard, pigeonpea and safflower).

Application of biotechnology should be focused to develop new improved varieties particularly resistant to biotic and abiotic stresses. Recombinant DNA technology that enables movement of genes of interest across sexual incompatibility barriers is one approach plant scientists are relying upon worldwide today to find genetic solutions to specific problems (Paroda, 1999 [12] and Swaminathan, 1999 [20]). We must ensure that our regulatory process efficient and safe from environment and health point of view. The first transgenic *Bt* cotton underwent field-testing in 1995. Today 185 institutions, which include both public research institutions and private research laboratories, are engaged in transgenic research. Currently, transgenic research is being done on several field crops, viz. cotton, Indian mustard, corn, potato, tobacco and rice and in vegetable crops namely tomato, brinjal, cauliflower, cabbage, chillies and bell pepper. The problems receiving priority attention include insect pest control, hybridization systems and nutrition improvement (Gordon, 1997) [8]. Only *Bt* cotton hybrids against bollworm complex was released during March, 2002.

The Indian regulatory system is a 3-tier structure. It comprises the following:

- Institutional Biosafety Committee (IBSC), set-up at each institution for monitoring institute level research in genetically modified organisms.
- Review Committee on Genetic Manipulation (RCGM) set-up at DBT to monitor ongoing research activities in GMOs. A Monitoring and Evaluation Committee (MEC), comprising agricultural scientists, was constituted in July 1998 by RCGM to monitor and supervise field trials permitted by the government.
- Genetic Engineering Approval Committee (GEAC) in the Ministry of Environment and Forests has been setup to authorize large-scale trials and environmental release of genetically modified organisms (DBT, 1998 [17] and, Gosh and Ramanaiah, 2000 [7]).

Conclusion

Thus, the Indian Seed Programme is now occupying a pivotal place in Indian agriculture and is well poised for continued growth in the years to come. NSC, SFCI, States Seeds Corporations and other seed producing agencies are continuously and gradually expanding all its activities especially in terms of its product range, volume and value of seed handled, level of seed distribution to the un-reached areas, etc. Production of hybrids/HYVs needs to be promoted on high priority to improve productivity and increase production especially in crops like, rice, maize, sorghum (rabi), arhar, rapeseed & mustard, castor, many vegetables etc. There is a need for promoting joint venture collaborations between industry and national and international institutions related to seed. if Government also extends the benefit of subsidy to truthfully labeled seed of promising hybrids produced by the private sector, may be beneficial for seed

sector. Sharing of germplasm is imperative for crop improvement, while the national repository makes available the germplasm to the researchers and national seed companies, the private sector must also come forward and share their valuable germplasm with the public sector institutions for research purpose. Also these need to be stored in the Gene Bank for posterity.

Innovation and adoption of biotechnology and nanotechnology would be critical for desired impact on livelihood of resource poor small holder farmers. Application of biotechnology should be focused to develop new improved varieties particularly resistant to biotic and abiotic stresses. Research also have related to quality enhancement technologies such as cereals with higher proteins, minerals and vitamin contents. The Golden rice, QPM and Fe and Zn enriched millets are some such examples.

Only *Bt* cotton hybrids against bollworm complex as the first transgenic crop in India was released for commercial cultivation during 2002. Even after a long gap none of crops as transgenic permitted for commercially cultivated, on some crops field trials were conducted successfully in india like, Bt-mustard, Bt-brinjal, Bt-corn etc. The current regulatory system in India requires coordination among 3 to 4 ministries and a 3-tier structures system like Institutional Biosafety Committee (IBSC), Review Committee on Genetic Manipulation (RCGM) and Review Committee on Genetic Manipulation (RCGM). A single-window clearance is recommended for faster release of useful transgenic crops. The need for creation of awareness among farmers and general public on the benefits and risks associated with transgenic crops is also very important.

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