The Indian seed industry: Its history, current status and future

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SEED is the most important input component for productive agriculture. In the significant advances that India made in agriculture in the last four decades, the role of the seed sector has been substantial. The expansion of seed industry has occurred in parallel with growth in agricultural productivity. Given the fact that sustained growth to cope with increasing demand would depend more and more on the pace of development and adoption of innovative technologies, the seed would continue to be a vital component for decades to come. The organized seed industry of the country is just forty years old. Yet, its growth has been phenomenal. India is one of the few countries where the seed sector is already reasonably advanced[1]. The private seed industry is no more confined to just production and marketing of seed. It has as well acquired technological strength to cater to the varietal needs of tomorrow.

The Indian seed industry is currently valued around Rs 2500 crores ($ 500 million) and is proposed[2] to be around 3750 crores ($ 750 million) by 2002. There are about 150 organized seed companies in India today. Several companies have Government of India (DSIR) recognized research and development departments and have produced and released a large number of varieties and hybrids in several crops. The contribution of private research in terms of value is steadily increasing. The share of research hybrids in total turnover of crops like pearl millet, sorghum-sudan grass, 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[3]. A study made over nine private seed companies indicates that the amount spent on R&D ranged from 0.78% (0.49 crores) to 15.08% (22.62 crores) (Companies Annual Reports 1998–99). Some of the companies initiated the work on development of transgenic crops. In March 2002 the first transgenic hybrid cotton seed was allowed for commercial cultivation in the farmer's field.

This article provides a historical perspective to the development of seed industry in India, its current status and future. Besides, some suggestions are also provided for improvement and modification in the regulatory procedures, particularly in case of transgenic crops.

Historical perspective

The National Seed Corporation was established in 1963. The Government of India enacted the Seeds Act in 1966 to regulate the growing seed industry[4]. The sixties were the most eventful times for Indian agriculture, not only because of introduction of high-yielding cereals, particularly wheat and rice but also for many other positive developments related to seed such as, constitution of Seed Review Team, enactment of Seeds Act, 1966 and formation of National Commission on Agriculture. This was the period, during which the private sector significantly stepped into the seed business. The Seeds Act stipulated that seeds should conform to a minimum stipulated level of physical and genetic purity and assured percentage germination either by compulsory labelling or voluntary certification. Further, the Act provided a system for seed quality control through independent State Seed Certification Agencies which were placed under the control of state departments of agriculture.

The eighties witnessed two more important policy developments for the seed industry, viz. granting of permission to MRTP/FERA companies for investment in the seed sector in 1987 and the introduction of 'New Policy' on seed development in 1988 (ref. 5). The 1991 Industrial Policy made a radical departure from the earlier policy on foreign investment. Under this policy seed production was identified as a 'high priority industry'. The New Policy on Seed Development greatly liberalized import of vegetable and flower seeds in general and seeds of other commodities in a restricted manner and also encouraged multinational seed companies to enter the seed business. More than 24 companies initiated research and development activities and have made substantial commitments for investment on research and development in response to this policy initiative. The investments are expected to increase with increasing volumes of seeds of proprietary hybrids and preparedness of farmers to pay higher price for quality seed.

A draft Seeds Act 2001 is being finalized on the basis of the recommendations of Seed Policy Review Group. It

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would replace the existing Seeds Act of 1966 and Seed (Control) Order of 1983. The proposed legislation features establishment of National Seeds Board (NSB) and compulsory registration of any seed with the board before sowing or planting could be done for commercial purposes[6].

Current status of the seed industry

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 public sector component comprises two central corporations, viz. National Seed Corporation (NSC) and State Farm Corporation of India (SFCI) and 13 State Seed Corporations. The private sector comprises around 150 seed companies, which include national and multinational companies and other seed producing/selling companies. The industry has made impressive strides from a modest beginning in seed production in 1962–63 to over 5 lakh hectares by 1995–96. The quantum of seed produced and sold has gone up by five times from 14 lakh quintals to 70 lakh quintals during the corresponding period[7]. In 1990–91 the area planted with bought seed was about 10.35%. The total bought seed in 1990–91 was estimated at around 5.91 lakh tonnes valued at Rs 679.80 crores (tables 1 and 2).

This seed component in 1990–91 comprised of proprietary hybrids, public-bred hybrids and open-pollinated varieties. In terms of quantity and value, seed of open-pollinated varieties was the largest followed in order by public hybrids and proprietary hybrids. Seed of 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%. In contrast to the 1991 scenario, the estimates in 1998–99 presented a different picture with proprietary hybrids growing at the expense of the public hybrids. The area planted to bought seed increased by 3% over that of 1990–91 and the market size expanded significantly in terms of quantity and value. 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 public bred hybrids came down to 38,704 tons in 1998–99 as against 59,671 tons in 1990–91. The volume of seed of open pollinated varieties (OPV) increased by 51% to 774,881 tonnes (tables 3 and 4).

The present contribution of OPV in the total bought seed market segment has expanded indicating greater use of bought seed by farmers. The price paid by farmers for all hybrid seeds was higher than that in 1990–91. The trend is suggestive that price of seed is not considered a constraint in usage by the farmers, if the seed ensures higher return through higher productivity and other value added traits[8].

Table 5 gives data on the quantity of seeds marketed in 1990–91 and 1998–99 for cereals, oilseeds, fibres, potato

Table 1. Indian seed market (Quantity in tonnes)

Year	Saved seed	Bought seed	Total
1998–99	8,953,523	864,899	9,818,422
1990–91	5,125,299	591,200	5,716,499
Quantity increase over 1990–91	3,828,224	273,699	4,101,923

Source: (a) The Market for Seed in India: a syndicated report based on secondary research (1991) by Francis Kanoi.
(b) Marketing database, benchmarking the seed market: Mahyco, 1999.

Table 2. Indian seed market 1990–91 and 1998–99 (Rs in crores)

Category	1990–91	1998–99
Proprietary hybrids	95.00	636.00
Public-bred hybrids	124.65	245.00
Varieties	460.15	1368.55
Grand total	679.80	2249.55

Source: (a) The Market for Seed in India: a syndicated report based on secondary research (1991) by Francis Kanoi.
(b) Marketing database, benchmarking the seed market: Mahyco, 1999.

Table 3. Composition of Indian seed market – 1998–99. Bought seed (Seed purchased by the farmer in 1998–99 and 1990–91) (Quantity in tonnes)

Category	Proprietary hybrid	Public hybrid	Variety	Total
Cereals	43,287 (15,600)	30,208 (52171)	496,841 (297,329)	570,336 (365,100)
Oilseeds	5233 (2200)	2720 (1800)	142,298 (76,300)	150,251 (80,300)
Fibres	2475 (1500)	5776 (5700)	25,280 (17,400)	33,531 (24,600)
Pulses	– (–)	– (–)	41,900 (–)	41,900 (–)
Vegetables	319 (–)	– (–)	1662 (17,000)	1981.11 (17,000)
Potato (seed)	– (–)	– (–)	66,900 (70,000)	66,900 (70,000)
Others	– (–)	– (–)	– (34,200)	– (34,200)
Grand total	51,314 (19,300)	38,704 (59,671)	774,881 (512,229)	864,899.11 (591,200)

Figures in parenthesis refer to the year 1990–91.
Figures without parenthesis refer to 1998–99.
Source: (a) The Market for Seed in India: a syndicated report based on secondary research (1991) by Francis Kanoi.
(b) Marketing database, benchmarking the seed market: Mahyco, 1999.

and pulses. It is seen that the quantity in saved seeds significantly reduced in 1998–99 compared to 1990–91 in case of oilseeds and fibres whereas it increased in cereals and potato. A reverse trend is seen in case of bought seeds. The quantities increased significantly in 1998–99 compared to 1990–91 in all categories except potatoes; the increase is almost one and a half times. 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.

Table 4. Composition of Indian seed market. Value of marketed seeds over different categories of crops in 1998–99 and 1990–91 (Rs in crore)

Category	Proprietary hybrid	Public hybrid	Variety	Total
Cereals	254 (26)	90.00 (63.15)	560.00 (153.55)	904.00 (242.70)
Oilseeds	109 (26)	20.00 (4.50)	312.60 (145.60)	441.60 (176.10)
Fibres	138 (33)	135.00 (57.00)	84.20 (24.00)	357.20 (114.00)
Vegetables	135 (10)	– –	217.35 (65.00)	352.35 (75.00)
Pulses	– –	– –	127.40 (33.00)	127.40 (33.00)
Potato (seed)	– –	– –	67.00 –	67.00 –
Grand total	636 (95)	245.00 (24.65)	1368.55 (460.15)	2249.55 (679.80)

Figures in parenthesis refer to the year 1990–91.
Figures without parenthesis refer to 1998–99.
Source: (a) The Market for Seed in India: a syndicated report based on secondary research (1991) by Francis Kanoi.
(b) Marketing database, benchmarking the seed market: Mahyco, 1999.

Table 5. Composition of Indian seed market. Quantity of the seeds marketed over different categories of crops in 1998–99 and 1990–91 (Quantity in tonnes)

Category	Saved seed	Bought seed	Total
Cereals	4,208,162 (3,592,806)	570,336 (365,100)	4,778,498 (3,957,906)
Oilseeds	1,165,552 (1,313,680)	150,251 (80,300)	1,315,803 (1,393,980)
Fibres	16,709 (21,602)	33,531 (24,600)	50,240 (46,202)
Vegetables	– –	1981.11	1981.11
Potato (seeds)	3,563,100 (171,680)	66,900 (70,000)	3,630,000 (241,680)
Pulses	– –	41,900 –	41,900 –
Grand total	8,953,523 (5,125,299)	864,899 (591,200)	9,818,422 (5,716,499)

Figures in parenthesis refer to the year 1990–91.
Figures without parenthesis refer to 1998–99.Source: (a) The Market for Seed in India: a syndicated report based on secondary research (1991) by Francis Kanoi.
(b) Marketing database, benchmarking the seed market: Mahyco, 1999.

Table 6 gives a break-up of saved seeds and bought seeds in five cereal crops, viz. jowar, bajra, maize, paddy and wheat. The increase in saved seeds in cereals in 1998–99 is contributed only by wheat while in other crops the quantity of saved seeds decreased in 1998–99 compared to 1990–91. There is a significant increase in the sale of proprietary hybrids in case of jowar, bajra and maize, particularly in bajra (~ t 8 times) and maize (3 times). In case of jowar the increase is around 20%. Only 537 tonnes of hybrid rice seeds are sold in 1998–99. In case of public bred hybrids, in contrast to proprietary hybrids of private companies, sales in jowar reduced to 18,545 tonnes from 30,400 tonnes in 1990–91. A similar decrease was observed in bajra; in 1998–99 quantity sold was reduced by 3418 tonnes from the total sale of 10,100 tonnes in 1990–91. The sales of public bred maize hybrids remained at 11671 tonnes in both years for which a comparison has been made here. The scenario in the sales of varieties was different. In case of wheat and paddy there has been increase in the sales of varieties in 1998–99 compared to 1990–91. There were no sales of maize varieties in 1998–99 when 5729 tonnes were sold in 1990–91. It was seen that there was significant reduction in sales of varieties in bajra in 1998–99 whereas there was an increase in case of jowar varieties.

Table 7 gives figures on the sales of oilseed crops in 1998–99 and 1990–91. There is a definite increase in the sales of saved seeds in sunflower, mustard, soybean, safflower and sesame in 1998–99 compared to 1990–91. As a matter of fact, there were no sales of safflower and sesame in 1990–91. There has been a significant decrease in sales in 1998–99 in groundnut and castor compared to 1990–91. There were no sales of proprietary hybrids in case of mustard, soybean, groundnut, safflower, sesame in both the years as there was no technology for hybrid seed production in these crops. In castor only 333 tonnes of proprietary hybrid were sold in 1998–99 compared to no sales in 1990–91. In sunflower there has been a definite increase in the sale of proprietary hybrids in 1998–99 (more than double) than in 1990–91. No public bred hybrids were sold in both the years except in castor. In castor 2700 tonnes of public bred hybrids were sold in 1998–99 compared to 1800 in 1990–91. As far as varieties are concerned, there has been a decrease in sales in 1998–99 in case of sunflower (from 4900 tonnes to 1943) whereas in the case of mustard, soybean, groundnut and castor there has been definite increase in sales in 1998–99 compared to 1990–91. There were no sales of varieties in safflower and sesame in 1990–91, while in 1998–99, 1600 tonnes of safflower and 1000 tonnes of sesame seed were sold.

Indian agriculture *vis-à-vis* future of seed industry

Accounting for approximately 30% of the national GDP, agriculture is the backbone of Indian economy. It is the source of livelihood for over 70% of its population. Having the largest arable area (170 million ha), India ranks second only to USA in sheer size of agriculture. By virtue of its large arable land area, sizeable irrigated area, rich agri-biodiversity, diverse agro climate and well-developed research system, the country has all the potential to emerge as a global power in agriculture. The impressive growth registered in agricultural production in general and food grains in particular during the last 30

Table 6. Composition of Indian seed market. Cereal seeds marketed in 1998–99 and 1990–91 (Quantity in tonnes)

Category	Saved seed	Proprietary hybrid	Public-bred hybrid	Variety	Total
Jowar	48,195 (63,256)	7400 (6200)	11,855 (30,400)	3425 (2100)	70,875 (101,956)
Bajra	38,445 (49,806)	11,350 (1400)	6682 (10,100)	3523 (6500)	60,000 (67,806)
Maize	55,793 (63,336)	24,000 (8000)	11,671 (11,671)	– (5729)	91,464 (88,736)
Paddy	1,138,654 (1,144,408)	537 –	– –	200,402 –	1,339,593 –
Wheat	2,927,075 (2,272,000)	– –	– –	289,491 (145,000)	3,216,566 (2,417.000)
Grand total	4,208,162 (3,592,806)	43,287 (15,600)	30,208 (52,171)	496,841 (297,329)	4,778,498 (3,957,906)

Figures in parenthesis refer to the year 1990–91.
Figures without parenthesis refer to 1998–99.
Source: (a) The Market for Seed in India: a syndicated report based on secondary research (1991) by Francis Kanoi.
(b) Marketing database, benchmarking the seed market: Mahyco, 1999.

Table 7. Composition of Indian seed market. Oilseeds marketed in 1998–99 and 1990–91 (Quantity in tonnes)

Category	Saved seed	Proprietary hybrid	Public-bred hybrid	Variety	Total
Sunflower	4755 (2354)	4900 (2200)	0 (0)	1943 (4900)	11,598 (9454)
Mustard	29,469 (27,791)	0 (0)	0 (0)	9823 (6600)	39,292 (34,391)
Soybean	430,153 (186,996)	0 (0)	0 (0)	53,165 (9100)	483,318 (196,096)
Groundnut	684,500 (1,091,075)	0 (0)	0 (0)	72,700 (55,000)	75,720 (1,146,075)
Castor	1322 (5464)	333 (0)	2720 (1800)	2067 (700)	6442 (7964)
Safflower	7988 (0)	0 (0)	0 (0)	1600 (0)	9588 (0)
Sesame	7365 (0)	0 (0)	0 (0)	1000 (0)	8365 (0)
Grand total	1,165,552 (1,313,680)	5233 (2200)	2720 (1800)	142,298 (76,300)	1,315,803 (1,393,980)

Figures in parenthesis refer to the year 1990–91.
Figures without parenthesis refer to 1998–99.
Source: (a) The Market for Seed in India: a syndicated report based on secondary research (1991) by Francis Kanoi.
(b) Marketing database, benchmarking the seed market: Mahyco, 1999.

years has made the country self-sufficient in cereal grain with a sizeable surplus which can be exported. Even to remain where we are today in terms of level of per capita consumption of food, the country has to add another 40 million tonnes by 2010 (refs 9, 10). With no more arable land and productivity of major crop plants plateauing, the prospects of achieving the target especially with the aid of currently available technologies is a challenging proposition.

Many of the problems that impede the productivity of our varieties and hybrids have defied solution through conventional breeding approach. These include widespread moisture stress (> 65% of the area particularly under rainfed and dryland conditions), expanding salinity, new pests and biotypes of higher virulence and poor shelf-life. There is thus a distinct need for innovative technologies to find solutions to existing and emerging problems and thereby increase the overall productivity and stability of our major crops. Unlike in developed countries, population growth in India is far in excess of its growth in agricultural production warranting continued inputs to achieve a steady increase in food production. The route to increase in production lies through improved agronomic practices and availability of high quality seed[1].

Relevance and need for biotechnology

At the current pace of growth, meeting the future food grain demand would be an uphill task. The new technologies for increasing yield should also be sustainable in the long run. 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[11]. Any scope for pest control through host plant resistance is becoming limited on account of shrinking sources of resistance. 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[12]. Beyond herbicides, which are weed specific, there are no means to manage the wide weed spectrum. Limited variability for yield-related traits is slowing down the progress in yield enhancement. Hybrid technology, though a potential technological option, has not yet become a reality in several crop plants for want of stable cytoplasmic male sterility–fertility restoration system, as is found and exploited in sorghum, pearl-millet, sunflower and rice. In crops like wheat, heterosis is being commercially exploited in India from this year. In crops like Indian mustard and in pulses like pigeonpea and safflower though exploitable hybrid vigour is quite sizeable, for want of stable male sterility/restorer systems and lack of economic hybrid seed production technology, the scope for increasing yield has been limited. Many of our staple food are characterized by deficiency of one or the other nutrients and excessive dependence on the same has led to nutrition deficiency-related health disorders.

Need for transgenics

Plant breeders can rectify problems in a crop only when there is variability available for the desired character within the compatible species complex. Transfer of useful traits from distantly related species which do not sexually cross with the crop plant is not possible through conventional recombination breeding procedures. Considering that many problems still remain unsolved and that the currently available technologies are inadequate to solve them, there is need for alternate technologies. 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[13,14].

Recognizing the potential of genetic engineering and biotechnology and its relevance to India, the Ministry of Science and Technology established the Department of Biotechnology (DBT) in 1986, exclusively to develop and apply biotechnological approaches in agriculture, animal science and human health[15]. The Ninth Plan outlay of DBT was around at Rs 1026 crores, more than double that in the Eighth Plan (Rs 427 crores)[16].

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[11]. Genetically engineered hybrids and hybrids with unique characteristics such as pest resistance are of special interest to the private sector institutions, as they provide a degree of certainty, offsetting the risks to their investments in biotechnology[1]. Two transgenics now under field-testing, viz. *Bt* cotton hybrids against bollworm complex and Indian mustard (*Brassica juncea*) for exploitation of hybrid vigour are of this kind.

Several large and medium-seed companies with turnovers ranging from Rs 35 crores to 100 crores are intensively pursuing full-fledged in-house agro-biotech research and development either on their own or through joint ventures with foreign companies. The fact that 23 private sector institutions have today their own Institutional Biosafety Committee (IBSC), which is mandatory under the guidelines for institutes engaged in genetic engineering research, is indicative that private companies are as serious and interested as public institutions in pursuing transgenic research[17]. Transgenics will have a major impact on seed business. For instance, as new varieties with improved performance enter the market, shares of individual varieties will shift quickly. Dramatic increase in the annual research expenditures of private companies engaged in biotechnology research is yet another indicator to the increasing involvement of private sector in biotechnology research.

Institutional infrastructure for promotion of biotechnology products

A strong regulatory system for assessing biosafety of genetically engineered plants and food items before they are released in the environment is mandatory. A 3-tier regulatory system for field-testing of transgenic plants structured on the basis of guidelines issued by the DBT under the Environment Protection Act 1986 is in place. The rules for the manufacture, use, import, export and storage of hazardous microorganisms, genetically engineered organisms or cells were framed in 1989 under the Environment (Protection) Act of 1986. Biosafety guidelines were formulated by RDAC (Recombinant DNA Advisory Committee) in 1990 and were adopted by the Government. They were revised in 1994 and 1998 incorporating allergenicity and toxicity evaluation of transgenic material. The guidelines incorporating changes up to August 1998 have been published recently[18]. These guidelines prescribe the codes for experimentation and field-testing of transgenic material for assessing safety. It is pertinent that no testing of transgenics can be done without permission of the RCGM under the Environment Protection Act. The Act provides penalties including prosecution for violation of the Act.

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 set-up to authorize large-scale trials and environmental release of genetically modified organisms[19,20].

Suggestions to overcome problems encountered in the development and adoption of transgenics

Need for promoting joint ventures

Biotechnology research requires substantial investment and time to get a product commercialized. It is becoming increasingly difficult for even large companies to pursue biotechnology research alone because of large investments needed and the inevitability of using already protected genes and protocols in developing transgenics. These limitations/hurdles necessitate collaborative research/joint ventures at national/international levels today than at any point of time before. At the national level, scope for such collaborative research between advanced public institutions and prospective private companies is unlimited. The Government of India has invested substantially for biotechnology development, the impact of which is seen in the emergence of several lead laboratories in various aspects of genetic engineering research including discovery of novel genes. Cloning of high protein AmA_1 gene from *Amaranthus* spp. and its successful intro into potato by the Centre for Plant Genome Research, Delhi, the refinement of *barnase–barstar* system and its use in Indian mustard for exploitation of hybrid vigour by the University of Delhi South Campus, identification of a salt-tolerance gene from a mangrove species by the M.S. Swaminathan Research Foundation, Chennai, are some of the original pieces of work done in India. This kind of research creates intellectual property for the institutions involved and provide leverage to get access to technologies from other technology holders.

What we lack at present is the framework/system for bringing together researchers in public institutions and the private seed industry. In the national interest, the evolution of a viable system for joint ventures should be given priority attention.

Need for a single window system for evaluating a new product

The presence of a stringent regulatory system for assessing biosafety of transgenics is in the general interest of the country. However, if the system is cumbersome and time-consuming, the very purpose for which it was created will be defeated. The system in place at present is rationally planned and structured. But the need for an applicant to deal with four different organizations, viz. Department of Biotechnology, Ministry of Environment, the Indian Council of Agricultural Research and several state governments for getting the entries evaluated under the 3-tier system, is daunting in itself and may scare away industry from investing in the development of transgenics. In the absence of referral laboratories for evaluating the transgenic products for biosafety, the applicant is required today to come up with such information on its own.

The current regulatory system requires coordination among 3–4 ministries, viz. Ministry of Health, Ministry of Agriculture, Ministry of Environment and Forests, and Ministry of Science and Technology.

For assessing the agronomic superiority of the transgenics, large scale multi-location trials are necessary. Though it is being practised under the 3-tier system, there is scope for improvement. When the transgenic variety is sent for field-testing, multi-location trials could be conducted simultaneously by the ICAR if required, so that the time taken for testing is reduced. There is a need to simplify the system towards a single window clearance so that the applicant need not deal with multiple institutions as indicated above.

Need to control illegal activity

This is a great challenge to all concerned including the governments at central and state levels. An effective control and monitoring system can genuinely promote biotechnology. Any individual in our democratic set-up is at liberty to make a statement, take potshots at Government Institutions and indulge in illegal activities like uprooting experimental material undergoing testing/evaluation. It is imperative that the Government machinery with greater assertiveness checks such unlawful activities perpetrated by vested interests so as to ensure adequate testing/evaluation of the genetically modified crops.

There is an immediate need to address these problems objectively and on priority for ensuring larger and rapid acceptance and adoption of the technology which is of immense value to our country and which can contribute towards the country's growth as a global agricultural power.

Need to collaborate with international institutions

Biotechnology is the science of tomorrow. It has the potential to find solutions to problems that have defied solution so far. Biotechnology ventures need substantial upfront investment, hard and concerted work and intense interphase with regulatory system. For this, coupled with changing market conditions, it would therefore be wise and prudent for majority of the private companies to forge links with public research institutions, especially universities. Collaboration with transnationals is a hotly debated issue. There is no reason why collaboration with international institutions and transnationals should be shunned. Such ventures may be in high national interest. Collaborations with advanced laboratories enable development and delivery of a technology in the shortest time possible. This would enable faster development of products leading to generation of resources which could be invested in industry for enhancing future capabilities. Given the complexity of development and regulations in the area of transgenic crops, collaboration with appropriate laboratories would be most cost effective and time saving.

There are many areas and issues relevant to Indian agriculture where joint ventures would prove rewarding. Development of resistance to leaf curl virus in cotton and tomato, yellow stem borer in rice, pod borer in pigeonpea, male sterility/restorer system in oilseed *Brassica*, nutrition enrichment in rice and potato, tolerance to drought in rainfed crops, etc. are some of the areas where novel solutions would help immensely. Revenues can only be maintained through savings on costs and increasing market shares and sales by collaborating with other organizations in the business. The alliances may include joint ventures, acquisitions etc.

A sense of partnership has to be created between government and private sector institutions to ensure that biotechnology takes big strides for advancement of Indian agriculture.

Capital intensive biotechnology research generates not only transgenics of value but also valuable knowledge and skills. Their protection through appropriate legislative mechanism is of utmost importance to motivate more and more entrepreneurs to invest in this area of science. It is gratifying, that the Parliament of India has recently approved the Protection of Plant Varieties and Farmers Rights Act. Speedy operationalization/implementation of the same is critical for protection of national wealth. IPR in patents or PVP form will not only provide a legislative framework but also a suitable environment for large-scale upfront investment in biotechnology research. The products developed by R&D efforts in recognized private research establishments would be protected and unethical practices in contract farming could be prevented.

Education and creation of awareness among farmers and the general public on the benefits and risks associated with transgenic crops is important to blunt the negative campaign on transgenics. The government along with all stakeholders should make all-out efforts to disseminate such knowledge.

Conclusions

The Indian seed industry is currently valued at more than Rs 2500 crores with about 150 organized seed companies. 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. The proposed legislation features establishment of National Seeds Board and compulsory registration with the Board of any seed for the purpose of sowing or planting.

The seed industry has Government of India (DSIR) recognized research and development departments which has resulted in a large number of private research varieties and hybrids. A study based on the 1998–99 annual report of nine seed companies has indicated that 0.78% (0.49 crores) to 15.08% (22.62 crores) of the total turnover of the companies is spent on R&D.

The availability of data for analysis of the Indian private sector is problematic because it is often inaccessible and considered strictly confidential. Therefore recognized National Seeds Associations have an important role to play.

The first transgenic crop, cotton hybrids with *Bt* gene, have been cleared for commercial cultivation. The current regulatory system requires coordination among 3 to 4 ministries. A single-window clearance is recommended for faster release of useful transgenic crops.

The speedy implementation of the Enactment of the Protection of Plant Varieties and Farmers' Rights Act is urged. There is a need for promoting joint venture collaborations between industry and national and international institutions. The need for creation of awareness among farmers and general public on the benefits and risks associated with transgenic crops is also very important.

1. Heijbroek, A. M. A. and Schutter, E. M. L. de *The World Seed Market, Development and Strategies*, Rabobank, Food & Agribusiness Research 1996, p. 19.
2. Vivek Damle, *Times Agric. J. (Taj)*, 2001, **1**, 38–39.
3. Kuldip, R. Chopra, *Asian Seed Planting Material*, 2000, **7**, 6–9.
4. *The Seed Act 1966*, Legislation on Seeds, National Seed Corporation Publication, New Delhi, 1990, pp. 1–9.
5. GOI Circular Ref. No. 11–71/88-SDI dated 16 September, on New Policy on Seed Development, Department of Agriculture & Co-operation, Ministry of Agriculture, New Delhi, 1988.
6. Panel Finalises draft Seeds Act, *The Economic Times*, Mumbai, Section 'Commodities', 18 March 2002.
7. Report of the expert group on Seed, Department of Agriculture & Co-operation, Ministry of Agriculture, GOI, New Delhi, 1989, pp. 1–2.
8. Benchmarking the Seed Market, Mahyco Marketing Database, 1999.
9. Joshi, S. N., *India Too Can Feed Her Billion Plus*, *Anvesak*, 1998, **28**, 29–45.
10. Thamarajakshi, R., Food production in the new millennium, *The Economic Times*, New Delhi, 24 July 1999.
11. Conway Gordon, *The Doubly Green Revolution: Food for all in the 21st century*, Penguin, London, 1997, p. 334.
12. Sahoo, K. M. and Saraswat, V. N., Pesticides Information, April–June 88 1988.
13. Paroda, R. S., Biotechnology and future of Indian Agriculture, keynote address at IIC New Delhi, 24 June 1999.
14. Swaminathan, M. S., Cotton and Rural Livelihoods, Silver Jubilee Lecture Series–Indian Society for Cotton Improvement (ISCI), Mumbai, 1999, pp. 11–12.
15. Annual Report 1998–99, Department of Biotechnology, New Delhi, 1999.
16. Report of the Working Group for the formulation of ninth Five-Year Plan (1997–2002), Department of Biotechnology, New Delhi, 1996.
17. Selvarajan, S., Joshi Dinesh, C. and Toole, John, C. O., *Agro Biotechnology Capacity and Demand: The Indian Private Sector Seed Industry*, The Rockefeller Foundation, Island Publishing House, Manila, 1999.
18. Recombinant DNA safety guidelines, Department of Biotechnology, New Delhi, 1998, pp. 14–16.
19. Revised guidelines for research in transgenic plants and guidelines for toxicity and allergenicity evaluation of transgenic seeds, plants and plant parts, Department of Biotechnology, New Delhi, 1998, p. 2.
20. Ghosh, P. K. and Ramanaiah, T. V., *J. Sci. Ind. Res.*, 2000, **59**, 114–120.