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# Capitalizing the Potential of Private Sector in Strengthening Agri-Biotech R&D and Commercialization in India[§]

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**Abstract**

The paper has examined the emerging trends in growth and structure of agri-biotechnology product and innovation market in terms of institutional diversity, research orientation and capacities. It has also discussed industry perspective of incentives and constraints in commercialization of agri-biotech R&D. The study has revealed that though agri-biotech R&D industry has shown buoyancy in response to the increasing market-oriented production systems, still there is scope to utilize their potential for enhancing availability of quality seeds/planting materials/inputs, for the challenging agro-climatic conditions. Recognizing pervasive market failure and inertia in agri-biotech R&D industry, the study has advocated a leadership role taken by the public sector in addressing them, with the objective of establishing a fully functional and integrated R&D chain. This demands enhanced public investments and reorientation of public research agenda to generate not only unique public goods but also address research gaps, not much of private interests.

**Key words:** Agri-biotechnology, public and private investments, research & development

**JEL Classification:** O32, Q16

## Introduction

Globally, the role of science, technology and innovation in promoting economic growth is well established and this research-based development strategy has paid rich dividends to millions of people in terms of higher incomes, and better food and nutritional security. The public investments in agricultural sciences have largely driven this change and much of the basic and strategic research, improved seeds, especially in self-pollinated crops and resource management have been their domain. Of late, funding of agricultural research in developed countries has seen an increasing engagement of the private sector. In 2000, the private sector spent an estimated US$ 12,086 million on agricultural R&D, constituting a little more than half of total research expenditure of developed countries. The developing countries too experienced a rise in private sector agricultural R&D, but their level of investments remained very low (6% of the total agri-R&D expenditure) (Pardey *et al.*, 2006). More so, the private sector R&D remained centered around those sectors for which returns were easily appropriable such as seed, farm machinery, agricultural chemicals and food processing. In Asia, private sector R&D has remained focused mainly on hybrid seeds (rice, maize, millets, sorghum, vegetables), poultry, livestock, palm oil, tea and rubber (Gerpacio, 2003; Morris *et al*., 1998; Pray and Fugilie, 2001), while in Africa, the focus has been on export-oriented crops like coffee, tea and cocoa (Ndii and Byerlee, 2005).

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In India, the earliest biotechnological research and its commercialization took place in the early-1980s in the form of tissue culture, ELISA (enzyme-linked immunosorbent assay) and other formats of in-vitro diagnostics. Later, responding to the potential of advances in science, liberalization of seed market and improved intellectual property regime, several domestic and multinational agricultural and food firms entered into the commercialization of such research applications in the country. After the commercial approval of Bt cotton in 2002, the private sector has intensified research activities towards hybrids, transgenics, etc. and has also scaled up technology commercialization to tap the huge untapped market potential. As a result, the country's agri-biotech R&D landscape started changing and is presently dominated by the private sector's presence, especially in the niche areas of agri-biotech which has successfully evolved from the pre-commercial phase of basic science to market-oriented products and processes (Pray and Nagarajan, 2012).

As most of the agri-biotech research in the private sector is being spearheaded by the multinationals of developed countries, time and again concerns have been expressed in the developing countries about their relevance to the local needs (Pray *et al*., 2005). It was also debated that private research in agri-biotech may not focus on crops and traits that are important to the poor under marginal production environment; and monopoly pricing might adversely affect its access to small farmers. Beside this, whether increased private support can unduly influence the public R&D agenda and supply of innovations, was also debated in the literature (Klotz and Day, 1999). Lastly, apprehensions that incentives are for private research and development on plant biotechnology are waning on account of consumers resistance and government regulations, further jeopardize the private sectors' enthusiasm in agri-biotech research (James, 2012).

In the light of these changing realities and limited empirical literature on agri-biotech[1] industry, this paper addressed this information gap by examining the recent trends in agri-biotech product industry and agri-biotech innovation market in terms of institutional diversity, research orientation and capacities. The paper has also discussed industry perspective of incentives and constraints in commercialization of agri-biotech R&D and has suggested strategies to strengthen technological flow to meet the smallhoders' needs.

## Data and Methodology

The agri-biotech industry in terms of its size, investments, R&D efforts, product segments, business models, activities, etc. was examined using two datasets. One related to the Biotech Consortium India Limited[2] (BCIL) survey - 2007 data which provided firm level information related to the number of firms in different market segments of biotech industry, their turnover, manpower employed, investments, product types, etc. We have confined our analysis to the agri-biotech segment only. The study has assessed the technological capabilities in two market segments of agri-biotechnology, one relates to the earliest and simple biotechnological application (tissue culture) and the other relates to its advanced application (transgenic). For developments in transgenic research, field trial data of Indian Genetically Modified Organisms Research Information System (IGMORIS) since 2007 were used as a measure of research activity. These data reflect current status of transgenic research by crops, traits and institutions. To explore the agri-biotech market opportunities with specific reference to the tissue culture technologies, product delivery strategies, constraints and emerging business models, information from the selected tissue culture firms through mailed questionnaires and personal interviews was gathered. Seventy firms were identified and questionnaires were sent seeking details of ongoing R&D, commercialized and pipe-line technologies, product types, business models and constraints in technology commercialization, etc., however, only 15 firms responded. Personal discussions with the key management and R&D personnels of selected tissue culture firms were also made in Benguluru district of Karnataka and Hoshur district of Tamil Nadu in the year 2013.

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1 It refers to a wide range of scientific techniques and products that can be used in numerous ways to boost and sustain the productivity of crops, livestock, fisheries and forests. In this study, biotechnology included tissue culture, biofertilizers and biopesticides, hybrid seeds, transgenics and diagnostics.

2 Biotech Consortium India Limited (BCIL), promoted by the Department of Biotechnology, Govt. of India, compiled biotechnology firm level data for the years 2001, 2003 and 2007 in the form of an industry directory.

## Agri-biotech Product Industry Structure

The Indian biotechnology industry has grown over the past few years at a very rapid pace to reach a sizeable scale in terms of turnover. The market size for biotechnological products has grown from ₹ 23 billion in 2002-03 to ₹ 204 billion in 2011-12. Of this, half of the revenue (48%) was earned from exports. The Indian biotechnology industry like its global counterparts is dominated by the pharmaceutical sector, as this accounts for a major share in the total turnover. In terms of number, the biotech industry in India has grown from 176 firms in 2001 to 706 firms in 2007. A majority of firms were engaged in pharma biotechnology (27%), followed by services sector (26%) and agriculture (25%). The industrial biotechnology (11%), bioinformatics (7%) and environment biotechnology (3%) played a relatively small role. Although in terms of numbers, the pharma biotechnology firms (including human and animal health care) are almost equal to those active in the agricultural sector, the former account for a much higher proportion in biotech industry's turnover, export and foreign alliances.

The product market segmentation within the agricultural biotech industry revealed that out of a total of 202 firms in 2007, about 35 per cent firms were primarily engaged in bio-fertilizer and bio-pesticide, 28 per cent in tissue culture-related activities, 19 per cent in hybrid seeds and only 13 per cent firms were engaged in the transgenic seeds. It was also interesting to note that there were substantial cases of cross participation of firms in different market segments within the agri-biotech sector, making it difficult to categorize firms into a unique market segment (Table 1). Many of the tissue culture and biofertilizer/ biopesticides firms are direct competitors of each other, as shown by their higher participation in each others' segment (13% of tissue culture firms and 16% of biofertilizer firms were found participating in each others' segment). A similar pattern was observed in the upstream agri-biotech product market, i.e. between hybrid seeds and transgenic market segment (54% of the firms dealing with hybrid seeds were also engaged in transgenic segment). This is an indicative of the fact that firms are following a portfolio approach rather than having specialization in a single market segment, thereby follow a risk reduction strategy of product diversification and economies of scale. The industry, over the years, has grown as an outward looking industry with a growing number of external alliances, especially in tissue culture of floricultural plants, transgenic and hybrid seeds.

The firms' asset size, employment, turnover and R&D investments differed widely and on an average, the agri-biotech industry had an asset-turnover ratio of about 0.35:1 (Table 2). The results also revealed that the industry has a dominance of small and medium sized firms when size is measured in terms of turnover and manpower employed. Many of the small and medium firms in terms of annual turnover largely dealt with bio-fertilizers, bio-pesticides and tissue culture as against the presence of relatively large firms in transgenic and hybrid seeds (Table 3). Most of the tissue culture firms were small in size, hiring less than 50 employees and also having annual turnover of less than ₹ 50 million. In contrast, more than two-thirds of the firms had annual turnover of more than ₹ 100 million in the case of transgenics and hybrid seeds in 2007. However, in the case of biofertilizers and biopesticides, most of the firms had more than 150 employees, but had turnover of less than ₹ 50 million per annum.

**Table 1. Firms' cross participation in different market segments of agricultural biotechnology, 2007**

| Particulars | Tissue culture | Biofertilzers & biopesticides | Transgenics | Hybrid seeds |
|---|---|---|---|---|
| Percentage of total firms in each market segment | 28 | 35 | 13 | 19 |
| Percentage share in tissue culture also | - | 13 | 12 | 5 |
| Percentage share in biofertilzers & biopesticides also | 16 | - | 0 | 0 |
| Percentage share in transgenics also | 5 | 1 | - | 36 |
| Percentage share in hybrid seeds also | 4 | 0 | 54 | - |
| Total number of firms | 56 | 70 | 26 | 39 |

*Source*: Computed from BCIL (2007) database

**Table 2. Economic indicators of agri-biotech industry in India, 2007**

| Particulars | Highest | Lowest | Median | Average |
|---|---|---|---|---|
| Total asset value (in million ₹) | 17,389 | 0.50 | 20 | 339 |
| Total annual turnover ( in million ₹) | 28,959 | 0.38 | 53 | 969 |
| Number of employees | 4,307 | 6 | 51 | 237 |

*Source*: Computed from BCIL (2007) database

**Table 3. Structure of agri–biotech firms by size and subsectors, 2007**

(per cent firms)

| Firm-size | Biofertilizers & biopesticides | | Tissue culture | | Transgenics | | Hybrid seeds | |
|---|---|---|---|---|---|---|---|---|
| | Manpower | Turnover | Manpower | Turnover | Manpower | Turn-over | Manpower | Turnover |
| Small | 22 | 59 | 57 | 35 | 18 | 7 | 16 | 11 |
| Medium | 21 | 17 | 23 | 13 | 35 | 14 | 60 | 22 |
| Large | 57 | 24 | 20 | 32 | 47 | 79 | 24 | 67 |

*Source*: Computed from BCIL (2007) database
***Note***: Small firms **:** Less than 50 employees with annual turnover of less than ₹ 50 million; Medium firms **:** Employees between 51-150 with annual turnover of ₹ 50-100 million; Large firms : Employees more than 150 and turnover of more than ₹ 100 million

## Emerging Trends in Agri-biotech R&D: Public and Private Sectors Research Orientation, Investments and Capacities

The Department of Biotechnology (DBT) under the Ministry of Science and Technology (Government of India) has been instrumental in planning, funding, promoting and coordinating R&D programmes since late-1980s in all the four sectors of modern biotechnology, viz. agriculture, industry, healthcare and environment. The Department of Biotechnology budget allocation to biotechnology went up from ₹ 6,215 million in the Ninth Five-Year Plan to more than ₹ 50,000 million in the Eleventh Plan (DBT, 2012). Beside this, other institutions like Council of Scientific and Industrial Research (CSIR), Department of Science and Technology (DST), Indian Council of Agricultural Research (ICAR), University Grants Commission (UGC) and state universities are also engaged in biotechnological research.

The focus of agri-biotech research efforts of public research institutions, based on the number of research papers abstracted in different scientific publications[3], showed that 44 per cent of the publications were directed towards applied research areas like *in vitro* regeneration, transformation and evaluation of transgenics. Molecular analysis, mapping, gene pyramiding and marker-assisted breeding were viewed as the second important research group containing 26 per cent of the total publications. Only 10 per cent of the publications were in the advanced research areas like gene regulation, functional genomics, proteomics and transcriptomics, and most of this research is carried out in the institutions of the DBT, DST and CSIR.

The crop trait which received most research attention, by both public as well as private institutions, has been biotic stress management (Table 4). The crops targeted for this trait were paddy, cotton and horticultural crops. This was followed by abiotic stress management, nutrition and qualitative improvements. The majority of research publications belonged to the public research institutions, and the contribution of private sector was relatively very small, one-fifth of the total (Table 4). This may be due to the fact that the market-oriented nature of private research limits the publication opportunities in scientific journals, and mostly they showcase their technological strength and knowledge creation through trade secrets, patent protection, etc.

[3] The reference period for the study is 2005-07.

**Table 4. Agri-biotechnology research focus by institutions, crops and traits, based on number of publications during 2005-07**

| Particulars | Biotic stress | Abiotic stress | Herbicide resistance | Nutrition & quality improvements | Improved breeding materials | Total |
|---|---|---|---|---|---|---|
| **Institutional focus** | | | | | | |
| Public sector | 167 | 63 | 29 | 56 | 34 | 349 |
| Private sector | 44 | 10 | 16 | 12 | 1 | 83 |
| Total | 211 | 73 | 45 | 68 | 35 | 432 |
| **Crop-trait focus** | | | | | | |
| Cereals | 75 | 25 | 8 | 28 | 17 | 153 |
| Horticulture crops | 31 | 4 | 8 | 7 | 11 | 61 |
| Fodder crops | 15 | 23 | 2 | 10 | 3 | 53 |
| Fibre crops | 22 | 2 | 6 | 2 | 6 | 38 |
| Others (pulses, oilseeds, etc.) | 37 | 8 | 10 | 15 | 12 | 82 |
| Total | 180 | 62 | 34 | 62 | 49 | 387 |

*Source*: Pal *et al.* (2008)

The participation of private sector in agri-biotech R&D activity, especially in transgenic and hybrid seeds, received a major impetus after the introduction of new seed policy (1988), economic liberalization policies (1991) and commercial approval of Bt cotton (2002) in the country. Consequently, the Indian seed market has grown manifold in terms of size and is currently valued at ₹ 100 billion. The private sector dominates with 76 per cent of the market share, of which 43 per cent is under the organized sector. In value terms, cotton claimed the highest share (23%), followed by paddy (18%), maize (11%) and vegetables (11%) (Rabobank, 2006). The R&D in this sector has expanded to include adaptations to local varieties suited to different agro-ecologies by deploying modern biotechnological tools; and also the backcrossing of the genetically engineered traits (licensed from different sources including multinational corporations and others). A three-fold rise in R&D investments by the private seed firms in crop improvement between 2003 and 2009 was estimated (Table 5). The market size of Bt cotton hybrid seed segment, which grew to touch ₹ 30 billion in 2011-12 (BioSpectrum, 2012), claimed the highest share of private R&D resources by witnessing a five-fold rise since 2003. The number of new firms and foreign alliances also grew within the industry, making it more competitive. As a result of these developments, the release of new Bt hybrids increased exponentially and currently 1,128 Bt cotton hybrids are being sold in the market. Sixty-four firms sold forty million packets (450 gram each) of Bt cotton hybrid seeds during 2011-12 (James, 2012).

**Table 5. Private sector R&D investments in cotton crop improvement, 1987-2009**

| Year | Total R&D investments by seed firms in crop improvement (million ₹) | R&D Investment in cotton-crop improvement (million ₹) | Number of firms with cotton R&D |
|---|---|---|---|
| 1987 | 417 | 40 | 9 |
| 1995 | 1549 | 270 | 27 |
| 2003 | 2000 | 500-700 | 30-32 |
| 2009 | 6000 | 2500-3000 | >50 |

*Source*: Adapted from Pray and Nagarajan (2010)

The rising number of applications filed by the private sector for registration of plant breeders' rights to The Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA) also confirmed the increasing presence of the private sector in seed research. So far, a total of 57 crop species have been notified for registration by the Authority and as of now, 67 private companies have applied for registration for protection under the Act. During 2005-07, a total of 3,886 applications were received for registration of various plant varieties, and of these 1,735 applications were from the private sector (Govt of India, 2012). In the case of tissue culture, the survey of selected firms showed that up to 26 per cent of the annual turnover was allocated for R&D purposes, with an industry average of 12 per cent. This may seem to be little higher[4], but it also includes the considerable investment on on-farm demonstrations and product promotion. Based on the available information on the market size of agri-biotech industry (₹ 69.75 billion in 2007[5]) and estimated R&D expenses to sales ratio, the size of private investment in agri-biotech research turned out to be ₹ 8,369 million in 2007.

In the case of transgenic research, the field trials conducted by the Indian Genetically Modified Organisms Research Information System have depicted research orientation, technological capabilities and investments of public and private sector. A close scrutiny of field trials data, which show direction of transgenic R&D in pipeline, revealed that the number of firms/research organizations engaged in field trials had increased from 6 in 2007 to 25 in 2010. Though, the number of crops on which transgenic research trials were conducted increased over time, the insect resistance trait has received an overwhelming importance than any other trait in the transgenic research portfolio since 2007 (Table 6). During 2007, only two traits, viz. insect resistance and herbicide tolerance, received research attention, that too mainly by the private sector on crops like cotton, brinjal, rice and okra. However, over the years new traits like virus resistance, abiotic stress have also gained importance by public institutions and private firms. Since 2009, many public research organizations have started conducting trials on traits like virus resistance on cotton, tomato, papaya and watermelon; fungal resistance in groundnut; and improving cold resistance to potato sweetness. Pulse crops like pigeonpea and chickpea, which are important crops for marginal production environment, received priority for developing transgenic resistance against pod borer and abiotic stress by public sector research organizations. Of late, improving product qualities as well as traits like enhancement of lycopene in tomato, delayed fruit ripening, etc. have received research attention of the public sector.

These trends show that there are a number of crop-trait combinations for which public sector is a major player in terms of being the first or only sector to conduct trials. The private sector, on the other hand, specializes and focuses their R&D mostly on areas with established product markets. The evidences also indicated that the public sector invested in a broader research portfolio; and their research efforts were complementing the private research by mainly targeting those commodities that were relatively neglected by the private sector, but were important to inclusive agricultural growth. However, the potential of public sector has yet to be demonstrated, especially for addressing productivity challenges of orphan crops and marginal production environments.

## Industry Perspective and Experiences in Commercialization of Agri-biotech: The Case of Tissue Culture

In the innovation process, commercialization is the process of taking new knowledge, process or product beyond R&D phase and translating it into production or market place. M/s A.V. Thomas & Co., Cochin, was the first to put India on the modern tissue culture technology map of the world in 1987. Since then, there has been an exponential expansion in production capacity of Indian tissue culture industry which rose from only 5 million plants per annum in 1988 to 190

[4] Pray and Nagarajan (2012) have estimated the research intensity in seed industry as 6.9 per cent in 2009, an increase from 3.5-3.8 per cent in the mid-1990s.

[5] Of the total of 202 firms in agri-biotechnology subsector reported in the BCIL 2007 data set, details of turnover, investments, manpower employed, product types, etc. were available only for 109 firms. This might be a underreporting of the data as many firms were not covered in the BCIL survey.

**Table 6. R&D in GM crops by type of institutions, crops and traits, 2007-2010**

| Crop group | Crop | No. of public institutions | No. of private institutions | Same traits research groups, if more than one |
|---|---|---|---|---|
| Vegetable crops | Brinjal | 3 | 3 | Insect resistant |
| | Cauliflower | | 1 | Insect resistant |
| | Cabbage & Cauliflower | | 1 | Insect resistant |
| | Okra | | 1 | Insect resistant |
| | Potato | 1 | | Dwarf potato and disease resistant (late blight of potato), product quality |
| | Tomato | 3 | 1 | Virus resistant, increased lycopene content, insect resistant and delayed fruit ripening |
| Cash crops | Cotton | 1 | 5 | Insect & herbicides resistant, insect resistant, herbicides resistant, virus resistant |
| | Sugarcane | 1 | | Insect resistant |
| | Rubber | 1 | | Stress tolerant |
| Oilseeds crops | Groundnut | 2 | | Drought resistant, viral resistant, fungal resistant |
| | Mustard | 2 | | Abiotic tolerant, male sterile female inbred lines |
| | Gram | 2 | | Drought resistant, insect resistant |
| Fruit crops | Watermelon | 1 | | Virus resistant |
| | Papaya | 1 | | Virus resistant |
| Cereals crops | Maize | | 4 | Insect & herbicides resistant, insect resistant |
| | Sorghum | 2 | | Drought resistant, insect resistant |
| | Rice | | 5 | Insect resistant & male sterile female inbred rice lines |

*Source:* Compiled from www.igmoris.nic.in/field trialdata2011.asp

million plants in 1996 (Govil and Gupta, 1997), and more than 300 million plants in 2010[6]. There are about 70 established commercial tissue culture units with average production capacity ranging from 0.5 million to 10 million plants per annum, and two-thirds of these firms are located in the states of Karnataka, Maharashtra and Andhra Pradesh, due to climatic advantage, more commercialized agriculture and better infrastructural facilities. An analysis of the BCIL data showed that 28 micro-propagation units were engaged in fruit crops, the majority of them produce banana, while only a few units multiply strawberry, papaya and pineapple. Twenty-one units produce a large number of ornamentals like gerbera, carnations, anthurium, orchids, limonium, etc. A few vegetable crops and some plantation crops like cardamom, vanilla, sugarcane and potato are also being multiplied. The production of a large number of ornamental and horticultural plants reflects their rising demand by the consumers as well as their willingness to pay for quality products. The survey of the firms revealed that firms specializing in tissue culture ornamental plants and floriculture are mainly producing plants for the export market, though there is a considerable increase in the domestic demand of micro-propagated plants in recent years. Contrary to this, banana tissue culture is almost entirely driven by the domestic market. There is an increasing demand for new banana planting material by the banana growers as a result of high demand and practice of replanting orchards once in 2-3 years. In many other perfected technologies related to crops like plantations, ornamentals, and other fruits, demand is relatively less due to either their perennial nature or allocation of less area to these crops.

[6] Personal communication from the industry experts

The process of micro propagation usually consists of four distinct stages, viz. initiation of explants, multiplication, rooting and hardening. The initiated tissue, subsequently under disease-free and controlled environment of laboratory is multiplied several-fold to obtain the required number of cultivars, depending upon the market demand. The rooted plants are periodically released from the laboratory to a climate controlled green-house for acclimatization by primary hardening. Subsequently, after secondary hardening of 8-12 weeks in nurseries, plantlets are ready to be planted in the field. These stages are universally applicable in large-scale multiplication of plants. The existing commercial tissue culture units offer products in the market at various stages such as stage II or stage III cultures in vessels, rooted plantlets, and hardened plantlets. The product type largely depends on whether the company possesses acclimatization and greenhouse facilities. Firms generally produce hardened plants for the domestic market and bare root or ex-agar plantlets for the export market.

The major consumers of tissue cultured raised plants are farmers (banana, other fruits and potato), traders / corporates / institutions (floriculture & ornamental plants), sugar factories and contracted farmers (sugarcane) and state governments for plantations under different schemes, agri-export zones, state agencies, etc. Based on our interactions with firms' representatives, it came out that the market potential for tissue culture plants is huge and competitive, but relatively volatile. Commercial units need firm forward orders to deliver plants in a defined time schedule which is a major constraint in a country like India with a majority of small farmers. Hence, there exists an unmatched gap between demand and supply.

Since the industry is dominated by small- and medium-sized firms, the model for commercialization of technology is not always a linear assembly like model consisting of R&D, production and marketing activities. Firms' survey revealed that mostly medium-sized and large units have strong R&D facilities, but in many small units, R&D is less self-generated and more outsourced. Since the technology is often relatively difficult to access, this drives many of these firms to develop linkages with large technology firms that are better able to supply the plantlets at in-vitro stage. These, generally, are small firms or nurseries that undertake hardening (primary and secondary) and market the product under their distribution network. Such partnering arrangements are mostly for the established product types and play a key role in the development of technological and production capabilities in start-up firms. It was also revealed that the industry is experiencing a mushrooming growth of small and tiny units as cottage industry in recent years. Discussions with industry experts revealed that these units often do more harm than good as many of them resort to higher multiplication cycles, resulting into loss of vigour and poor product quality, but manage to reduce the cost of technology. Since neither labelling of product types with full specifications is mandatory nor the NCS-TCP certification[7] is necessary for the firms to position their products in the market, this sometimes results into flooding of sub-standard quality products in the market at lower prices.

The other strategy relates to the emerging trends of tissue culture firms that focus on R&D of niche products (energy plantations like bamboo, ornamentals and floriculture) to have a profitable business. This strategy of diversification towards specialty products having different peak demands along with a judicious mix of steady revenue-generating items, helps the firms in making optimum use of facilities round the year and reducing market risk. This also enhances their bargaining power in the market, capacity utilization and in establishing the premium product market. As their bargaining power increases, technology firms can raise the prices of their products and services and appropriate higher economic benefit from the technology they had developed. The bargaining position of biotechnology firms gets further strengthened when they market their R&D along with specialized services in the form of consultancy or make specialized investments for product development on turnkey basis. This is similar to the Build-Operate-Transfer (BOT) model and relies on not only 'expansion of scale' but also 'expansion of scope' approach. Further, such partnering is useful in promoting the adoption of good management practices and industrial production standards, especially in the

[7] DBT has established National Certification System for Tissue Culture Raised Plants (NCS TCP) to facilitate certification of the tissue culture raised plants up to laboratory level.

new and emerging fields. Many respondents expressed that this has enhanced their capacity utilization and has covered partly the sunk cost.

Based on the responses received from the companies visited and the mailed questionnaires, major constraints to successful commercialization of tissue culture products in the market were identified. During the early years of technology development, firms faced difficulties in selling tissue culture products because of farmers' low awareness and availability of cheaper conventional planting material. This problem has been addressed by inventing reliable and cost-effective tissue culture methods without compromising on quality. The major problem relating to the industry now relates to the rising input cost and limited access to low-cost technology options. As this industry is land-labour-energy-intensive, it requires high initial investments. Firms having R&D and production units of their own, found the rising labour wages and electricity tariffs coupled with its timely availability as the major constraints. The commercial electricity tariff rates coupled with its erratic supply have forced the entrepreneurs to install generators for power supply or even shut the units temporarily, thereby raising cost of production and squeezing profit margins.

Apart from this, gaps in demand and supply and weak enforcement of quality regulations are also affecting the supply side parameters. Enforcement of NCS-TCP should be made mandatory and should essentially cover small and cottage industries to ensure quality for greater market confidence. Firms with less-developed or no R&D facilities have reported the lack of facilitating linkages with the public R&D to be a major obstacle. Farmers, the ultimate consumer, need to be convinced about the potentialities of technology to harness the vast untapped market. Programmes that educate farmers and showcase the potential benefits of biotechnology, can empower farmers to make informed choices. In this regard, the government schemes (NHM, RKVY, etc.), which provide subsidized planting material and inputs to the farmers, can be used as an effective platform to demonstrate the potentialities of the technology. It should also be made mandatory to purchase good quality planting material from NCS-TCP certified lab only. In this regard, a new guideline of Tamil Nadu government regarding mandatory setting-up of tissue culture lab for new sugar firms in the state is a welcome step.

## The Way Forward — Leveraging National Research and Commercialization Strategies to Meet Smallholders' Technological Needs

Though, the private sector investment in agri-biotech R&D has shown buoyancy in response to the increasingly market-oriented production systems, still there is scope to utilize their potential for enhancing availability of quality seeds/planting materials/inputs, for the challenging agro-climatic conditions. To address this concern, an array of bio-technological interventions, ranging from genetic modification to tissue culture, need to be exploited adequately. Recognizing pervasive market failure and inertia in agri-biotech R&D industry, the study advocates a leadership role taken by the public sector in addressing them, with the objective of establishing a fully functional and integrated R&D chain. This demands enhanced public investments and reorientation of public research agenda to generate not only unique public goods but also address research gaps, not much of private interests. The increasing private interest in the agricultural R&D has opened varied opportunities of partnerships and strategic alliances to enhance returns on private R&D, and the private companies' incentive to capitalize on new opportunities for innovation from public investments in agricultural sciences. This will also encourage interaction of public and private R&D at different phases of technological development and thereby will increase incentives for firms to invest in downstream development, marketing, and production.

Another key observation was that owing to increasingly capital-intensive nature of agri-biotech R&D, many of the small and medium domestic firms, which dominate the agri-biotech product industry, had dearth of strong R&D base. Further, the observations clearly showed that on one hand, rising input cost especially on power and labour might not allow the firm to lower the cost of technology, and on the other, spurious quality and low awareness about technology might further jeopardize the inherent growth potential of the industry. Hence, policy attention is urgently required on the two fronts. One, technological capabilities of small and medium firms need to be enhanced so as to increase their competitiveness in the domestic and export markets for medium and high-technology goods. And second, attention is required on strengthening the pull mechanisms that increase not only the expected returns to firms' R&D by improving market conditions, but also strengthen capacities particularly for those crops and technologies that are most relevant to resource-poor smallholders.

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## References

BCIL (Biotech Consortium India Limited) (2007) *Directory of Biotechnology Firms*. New Delhi.

BioSpectrum (2012) A fast clip growth for Agri-biotechnology <http://biospectrumindia.ciol.com/content/BSTOP20/110061423.asp,>

DBT (Department of Biotechnology) *Annual Report* (various years). Ministry of Science and Technology, Government of India, New Delhi.

Gerpacio, R.V. (2003) The roles of public versus private sector in R&D and technology generation: The case of maize in Asia. *Agricultural Economics*, **29**: 319-330.

Government of India (2012) *State of Indian Agriculture*: 2012-13. Department of Agriculture and Cooperation, Ministry of Agriculture, New Delhi.

Govil, Suman and Gupta, S.C. (1997) Commercialization of plant tissue culture in India. *Plant Cell, Tissue and Organ Culture,* **51**: 65–73.

IGMORIS (Indian GMO Research Information System) (2012) *Indian GMO Research Information System.* <http://igmoris.nic.in/>.

James, C. (2012) *Global Status of Commercialized Biotech/GM Crops: 2012*. ISAAA Brief No. 44. International Service for the Acquisition of Agri-biotech Applications, Ithaca, New York, USA.

Klotz-Ingram, C. and Day-Rubenstein, K. (1999) The changing agricultural research environment: What does it mean for public-private innovation? *AgBioForum*, **2**(1): 24-32.

Morris, M.L., Singh, R.P. and Pal, Suresh (1998) India's maize seed industry in transition: Changing roles for public and private sectors. *Food Policy*, **23**: 55-71.

Naseem, A., David J.S. and Steven, W.O. (2010) Private sector investment in R&D: A review of policy options to promote its growth in developing country agriculture. *Agribusiness*, **26** (1): 143-173.

Ndii, D. and Byrelee, D. (2005) Realizing the potential for private sector participation in agricultural research in Kenya. In: *Transformation of Agricultural Research Systems in Africa: Lessons from Kenya*, Eds: C.G. Ndiritu, J.K. Lynam and A. N. Mbabu. Michigan State University Press, East Lansing, MI. pp.339-360

Pal, Suresh, Devi, Vimala and Choudhary, U.N. (2008) Resources and priorities for plant biotechnology research in India. *Current Science*, **95**(10): 1400-1402.

Pardey, P.G., Beintema, N.M., Dehmer, S. and Wood, S. (2006). *Agricultural Research: A Growing Global Divide?* International Food Policy Research Report, Washington DC, USA.

Pray, C.E. and Fugilie, K.O. (2001) Private investment in agricultural research. In: *Handbook of Agricultural Economics*, Vol.3, Eds: R. Evenson and P. Pingali. Elsevier, Amsterdam.

Pray, C., Oehmke, J.F. and Naseem, A. (2005) Innovation and dynamic efficiency in plant biotechnology: An introduction to researchable issues. *AgBioForum*, **8:** 52-63.

Pray, C.E. and Nagarajan, L. (2010) Price controls and biotechnology innovation: Are state government policies reducing research and innovation by the Ag-biotech industry in India? *AgBioForum*, **13**(4): 297-307.

Pray, C.E. and Nagarajan, L. (2012) *Innovation and Research by Private Agri-business in India.* Discussion paper 01181, IFPRI, Washington DC, USA.

Rabobank (2006) *Indian Seed Industry: Market Overview and Outlook.* Industry Note 184, Global Department of Food and Agribusiness Research and Advisory, Rabobank International, Utrecht, The Netherlands.