RIS
Research and Information System
for Developing Countries
www.ris.org.in/abdr.html

Asian Biotechnology and Development Review
Vol. 9 No. 3, pp 83-93

Reorientation of Agricultural Research for Addressing Food Security Issues through Agricultural Biotechnology

Harbir Singh*

Abstract: R&D capacity is an important factor in harnessing new technological pathways for increasing agricultural productivity, building food security and contributing towards economic stability of agriculture-based economies, like India. Agricultural R&D in India gives high priority to application of biotechnology to evolve new genetically engineered strains of plants, resistance to pest and diseases, animals and fishes of high nutritional quality, and attaining environment-friendly farm practices. The success of such technological intervention will largely depend on a re-furbished and reoriented agricultural research system which is efficient and cost effective and which addresses the problems of marginal environments and interests of small and marginal farmers who dominate Indian agriculture. This paper argues for the need for reorientation of agricultural research for harnessing the potential of biotechnology in agriculture. Since biotechnology research is complex and highly capital intensive, the research system should allocate scarce capital resources optimally so as to ensure research efficiency and restrain a thin spread of resources. This can be achieved by prioritisation of biotechnology research and development and delivery of such agricultural biotech products which contribute to food security. Therefore, proper research planning, prioritization of agricultural biotechnology research and an effective policy framework are the essential components of utilization of agricultural biotechnology in a way that contributes towards food and nutritional security in India.

Keywords: Biotechnology, agricultural R&D, research planning, research prioritization, food security, GE plants

---

An earlier version of this paper was presented in the Conference on Biotechnology and India's Development, held at ISEC, Bangalore during 22-24 November 2004. Encouragement and help from Dr Mruthyunjaya for preparing this paper is gratefully acknowledged. However, the usual disclaimers apply.

* National Centre for Agricultural Economics and Policy Research, New Delhi. Email: harbir@ncap.res.in

Background

Today, the world is driven by science and technology (S&T) as radical changes are taking place in all spheres of technology. The Indian agriculture sector too has seen major technological changes during the last four decades. The introduction of high-yielding varieties (HYVs) in the late 1960s led to a large increase in agricultural productivity and food production. This technology-led green revolution (GR) brought HYVs of wheat and rice varieties, developed with conventional breeding methods, to millions of small-scale farmers in Asia and Latin America and later in Africa as well. The yield of major food crops, particularly rice and wheat, more than doubled between 1960s and 1990s and India achieved self-sufficiency in food grains at the national level. But, the areas which experienced GR are facing second generation problems of soil-salinization, ground-water pollution, nutrient imbalances, emergence of new insects and diseases and environmental degradation.[1] The plateauing of yield of major food crops in recent years and loss of biodiversity has also added another dimension to the problems of Indian agriculture. Moreover, by 2020, India's population is likely to be around 1.3 billion and the country's overall employment scenario is less likely to change significantly.[2] An estimated 340 million people in India are very poor and chronically undernourished. The opportunities for area expansion being almost limited, an additional food output of 4-5 million tonnes per annum will have to come primarily through increased agricultural productivity.

Agricultural R&D capacity is an important factor in using new pathways for increasing agricultural productivity, achieving food security and contributing towards economic stability of agriculture-based economies, like India. Therefore, a well-developed agricultural research system is one of the important pre-requisites for a proper utilization of the cutting-edge and better-targeted technologies and for their effective adoption and dissemination along with the conventional methods of production. Accordingly, agricultural R&D in India gives high priority to application of biotechnology to evolve new genetically engineered strains of plants, resistance to pest and diseases, animals and fishes of high nutritional quality, and attaining environment-friendly farm practices.[3] In the interest of reaching the poor and the population in marginal environments, vigorous extension efforts should continue for maximum uptake of technologies on self. Unfortunately, our extension approaches and system are failing in this direction. But efforts should continue to make breakthroughs in science by application of biotechnological and other advanced scientific tools.

This paper takes stock of the status and focus of agri biotech research and assesses the essential ingredients for research planning and the policy framework for utilization of agricultural biotechnology in a way that contributes towards food security. The success of such technological intervention largely hinges upon a re-furbished and reoriented agricultural research system which is efficient and cost effective in utilizing the cutting-edge technologies for the betterment of vulnerable sections of society and which addresses the problems of marginal environments. Focusing our research efforts towards enhancing the nutritional attributes of cereals and pulses and tackling biotic and abiotic stresses of these crops will particularly help in addressing the issue of food security.

Funding Support

Many Asian governments –including China, India, Indonesia, Malaysia, Philippines, Thailand and Vietnam have given high priority to plant biotechnology research in the hope of addressing the pressing challenges related to improving productivity, farmers' livelihoods, driving rural development and meeting food security demands.[4] The Indian government's spending for research projects related to biotechnology also increased significantly during the last few years. During the Ninth Five Year Plan, the government provided budgetary support for biotechnology to the tune of Rs.6690 million. This has substantially been increased to Rs.14500 million (116.7 per cent increase) in the Tenth Five Year Plan (2002-2007). In fact, the Government of India is proactively introducing sustained funding and fiscal initiatives to facilitate the growth of its biotech sector. For example, the Department of Biotechnology's budget increased from approximately $30 million in 1999 to nearly $120 million in 2005. The government has promised to nearly double its science budget from 1.1 per cent of its gross domestic product in 2005 to 2 per cent by 2007.[5]

Nonetheless, public biotechnology investments in India still appear to be quite small compared to the size of the country and the urgent need for innovative and sustainable agricultural technologies. A comparative view of R&D investment in India *vis-à-vis* that in some major countries indicates that our investment on R&D in agriculture is only 0.48 per cent of Ag GDP as compared to developed countries like

Australia (4 per cent) and around 3 per cent in the US, UK and Japan. We have also less scientists (158) per million of population as well as expenditure per scientist (US $ 17.5 thousand) as compared to developed countries like the US (4103, US $ 213 thousand), Japan (4960, US $ 203 thousand). Even China (459, US $18.5) is far ahead of India on these counts (see Table 1). In the private sector the level of R&D activity is substantially higher. For example, the R&D expenses of Monsanto Inc. alone accounted for 11 per cent of sales for the fiscal year 2004.

Table 1: Support to R&D by Public Sector in Different Countries

Country	Agri. Share (%) in GDP	People dependent on agriculture (%)	Public expenditure on Agri. R&D (% of Ag GDP)	Scientists per million of population	Expenditure per scientist ('000 US $)
USA	0.7	1.6	2.80	4103	213
Japan	2.3	2.9	2.80	4960	203
UK	1.8	1.5	2.89	2678	164
Australia	3.1	4.8	4.02	3320	101
China	15.2	59.8	0.43	459	18.5
India	26.3	63.2	0.48	158	17.5

Source: World Bank (2001).

Institutional Focus

Different public and private agencies in India are engaged in modern biology research. These include the Council of Scientific and Industrial Research (CSIR), the Indian Council for Agricultural Research (ICAR), the Indian Council of Medical Research (ICMR), the Department of Science and Technology. However, biotechnology received a boost in 1982 with the establishment of National Biotechnology Board (NBB) within the Department of Science and Technology. Its initial impact prompted the government to establish a separate Department of Biotechnology (DBT) under the Ministry of Science and Technology in February 1986. At this stage, its mandate was broadened to include the promotion of large-scale use of biotechnology, the support of university and industry interaction and the development of biosafety guidelines, among others. There have been major accomplishments in areas of basic and applied research in agriculture, health, environment, human resource development, industry, safety and ethical issues.[6] A great part of the agricultural biotechnology research in India is carried out in laboratories that already existed before the founding of DBT. Many of these are supported and coordinated by ICAR. In total, there are about 56 public research units in India using tools of modern biotechnology for crop improvement.[7] Out of these, more than ten are engaged in plant genetic engineering, with rice, chickpea, different oilseeds, cotton and a number of horticultural species being the main target crops. Apart from national institutes, an Indian branch of the International Center for Genetic Engineering and Biotechnology (ICGEB) was established in late 1980s in New Delhi. Furthermore, there are about 50 private companies (domestic and foreign) engaged in agricultural biotechnology research in India.

While the public sector played a strong role in R&D and technology diffusion during Green Revolution periods, the majority of agricultural biotechnology research and its commercialization is taking place in private firms based in industrialized countries. The moot question is whether farmers in developing countries, particularly poor farmers, will benefit from appropriate biotech innovations or these would be beyond their reach in economic terms. Therefore, the R&D in agricultural biotechnology has to re-orient itself to allay such concerns which prove a deterrent to fast track development and application of agricultural biotechnology.

In India, initially the focus in the 1980s was on institution building and capacity development followed by specific, problem-oriented R&D efforts in the 1990s. However, in general, it must be stated that India lacks hard-core agricultural biotechnology research and we are still on the periphery of recent advances which are propelling biotechnology research in this century. In fact, there is a dearth of human resources trained and skilled in use and application of modern biotechnology methods particularly in agriculture. Fully realizing this, the ICAR has provided to young scientists advanced training in biotechnology abroad under the National Agricultural Technology Project (NATP). Such capacity building efforts are necessary to develop a critical mass in frontier areas of technology.

Need for Research Reorientation

Re-orienting our research efforts towards, productivity enhancement, loss minimization, post-harvest management and value addition will be critical for ensuring sustainability and increasing farm incomes and profitability. A number of transgenic R&D activities, at different stages of development, are in the pipeline in India which are likely to produce technology products over the short to medium term (see Table 2). It can be seen from the table that field experiments have already been carried out with six different crop species, mostly vegetables.

The ICAR is also giving due attention to application of biotechnology for crop protection and improvement. Current research efforts, among others, include development of transgenic tomato resistant to tomato spotted wilt tospo virus, the study of molecular events during fruit ripening in banana and mango in order to decide the right strategy for genetic manipulation of these crops for delayed ripening, and developing strategies for micro-propagation in mango through nuclear embryo-genesis. Since the tomato spotted wilt virus (TSWV) cannot be controlled by chemical means or other conventional methods, development of transgenic lines of tomato resistant to the virus is considered a viable approach. Further, post harvest losses in

Table 2: Focus of Transgenic Research in India, 1994-2004

Crop	Trait	Status
Mustard	Herbicide tolerance (*bar, barnase, barstar*)	Field trials
Tomato	Insect resistance (Bt), delayed ripening	Field trials, Experimental phase
Eggplant	Insect resistance (Bt)	Field trials
Brinjal	Insect resistance (Bt)	Field trials
Tobacco	Insect resistance (Bt)	Field trials
Aflatoxin producing fungi	Monoclonal antibodies	Experimental phase
Brassica	Moisture stress	Field trial
Cabbage	Lepidoptera	Experimental phase
Cardammon	Micropropagation	Experimental phase
Coffee	Micropropagation	Experimental phase
Cotton	Gene cry1Ac Cultivars	Commercialized
Cut flowers, Mango	Micropropagation	Experimental phase
Potato	Starch composition	Experimental phase
Potato	Vitamin content (AmA1 gene)	Experimental phase
Rice	Virus and fungi resistance, gene cloning, salt tolerance	Experimental phase
Wheat	Protein content, grain size, microsatellite markers and cold tolerance	Experimental phase

Source: Qaim (2001) and www.fao.org.biotech/inventory_admin/dep/stat_result.asp?country=IND tropical fruits like banana and mango due to low shelf life are quite significant. Studies are in progress focusing on enzyme activities and their regulation by ethylene during fruit ripening, differential expression of ripening-related genes.

These research efforts have generated some intermediate research products. For example, transgenic tomato with resistance to tomato spotted wilt virus, will greatly help in reducing the yield loss caused by this disease which is between 20 to 90 per cent depending on the stage of the crop. Strategy to increase the shelf-life of mango and banana will lead to minimizing post harvest losses which can be to the extent of 40 per cent in these two important horticultural crops. The complete protocol for micropropagation of mango will be helpful in making available large numbers of elite planting material as well as pave the way for genetic transformation of mango with traits of importance, like increased disease resistance and increased shelf life. However, it is difficult to estimate the overall impact of these technologies at this juncture.

The external R&D funding has contributed significantly for strengthening and promoting biotechnological approaches for the improvement of horticultural crops. Since application of biotechnology is a costly proposition, the external R&D support to ICAR has enhanced the skills of research staff and therefore, enhanced the pace and efficiency of research.[8] To meet the challenges of globalization and to harness the potential of upcoming technologies, the ICAR has outlined the roadmap for biotechnology research for the coming years. A gist of the reoriented research focus relating to crop production, crop protection and crop improvement is provided in Table 3.

Since biotechnology research is characterized as complex and high capital intensive, the research system should allocate the scarce capital resources optimally so as to ensure research efficiency and restrain a thin spread of resources. This can be achieved by prioritization of biotechnology research keeping in view the national and regional goals. For example, the Analytical Hierarchy Process (AHP) can be used to prioritize the research projects on biotechnology. The AHP is a decision support tool to tackle complex multi-criteria problems such as assessing research priorities. The method helps to structure and analyse decision problems by breaking down the complex problem in a hierarchic order, and employing pair wise comparisons of its elements to determine the preferences among the set of alternatives.[9] Joshi, *et al.* (2002) used this process to establish an objective criteria for ranking the biotechnology

Table 3: ICAR Road Map for Biotechnology Research on Crop Production and Crop Protection

Thematic area	Research focus
Crop improvement	● Identification of sources of resistance to biotic and abiotic stresses ● Quality traits in crop plants for diversified utilization ● Molecular mapping and integrated gene management ● Commercially viable varieties of commercial crops - high sugar content, improved fibre quality and capable of diversified uses ● Gene pyramiding for biotic and abiotic stresses. ● Precision agriculture and integrated farming
Crop production technologies	● Integrated plant nutrient management and genetic analysis of responses in relation to nutrient uptake efficiency under both stress and non-stress environments
Crop protection technologies	● Studies on plant-based agro chemicals/ biopesticides ● Herbicidal chemicals, IPM

***Source*:** Compiled from various sources of ICAR.

research proposals for ranking research priorities for future research funding in a resource-crunch scenario. The analysis revealed that priority scores of all the projects were quite high indicating their relevance at the national and regional level (Table 4). The ranking of the projects based upon objective criteria show how incremental research resources should be allocated. Out of the ten research projects, three projects addressing submergence tolerance and cold tolerance in rice and salt tolerance in brassica were among the top three research priorities for allocating the research resources. At the

Table 4: Indices of Different Indicators Expected from each Research Project

Project	Criteria						
	Economic	Trade	Equity	Environ mental impact	Social impact	Success of research	Success of adoption
Cold tolerant lines in rice	4.69	0.27	0.41	0.62	0.37	0.68	1.58
Submergence tolerance in rice	4.67	0.73	0.14	0.51	0.03	0.43	0.73
Expression of genes in B. juncea for salt tolerance	2.09	0.59	0.23	0.16	0.00	0.54	2.30

Source: Joshi, *et al.* (2002).

same time, the broader issue of acceptance/rejection of biotechnology in the changing social milieu could well be addressed by more socio-economic studies on the public perception of GM foods in India and their risk and cost-benefit analysis which should be undertaken concurrently with all the biotechnology research programmes.

Policy Environment

A flavour of biotechnology policy objective is imparted by the Vision Statement of DBT which reads as "attaining new heights in biotechnology research, shaping biotechnology into a premier precision tool of the future for creation of wealth and ensuring social justice - specially for the welfare of the poor". States like Andhra Pradesh, Maharashtra, Karnataka, Punjab and Tamil Nadu have formulated their state biotechnology policies for giving a boost to biotechnology R&D. Notwithstanding these initiatives in pockets, efforts are still on for developing a biotechnology policy at the national level for fully utilizing its potential in priority research areas.

The time is ripe to work out clearly the essential elements of agricultural biotechnology policy. One simple thumb rule can be applied that it should primarily accelerate development process. Unfortunately, most often we talk in generic terms and loose real focus where our research efforts should be directed for making agricultural biotechnology work for the poor. At the same time, we should have a realistic assessment of comparative advantages of both public and private sector. Private sector operates at cutting edge level, makes speedy decisions and have professional work culture which is essential for utilizing the fast changing dynamics of this technology. However, the private sector hesitates to make huge investments due to some grey areas concerning the protection of intellectual property rights (IPRs).

Notably, the emerging IPR issues have started influencing the quality of agricultural research carried out and the nature of research collaborations between the public and private sector and between developing and developed countries. In the ultimate analysis, it is the scope of patentability, protection of 'enabling technologies' and the multiplicity of patents required to develop an agricultural product and structure of agricultural industry (public/private concentration) which would determine the impact of IPRs system on research investments in agricultural biotechnology. The national biotechnology policy should address these issues in a transparent and unambiguous manner.

Summing up

Today, the world is driven by S&T and radical changes are taking place in all spheres of technology. In case of Indian agriculture too though the rate of technical change has not declined (due mainly to the continuous R&D efforts), it is certainly decelerating in recent times. Therefore, the business as usual approach is not going to help in the present context. A complete re-orientation of the research system is called for which can fully utilise the potentials of frontier technologies like agricultural biotechnology. This needs to be complemented by an enabling policy environment and effective implementation of research goals. The socio-economic policy instruments should be designed to take care of the poverty, equity and sustainability implications of emerging technologies.

Biotechnology application in agriculture has opened new vistas for tackling production and post-harvest operations which in turn can contribute towards food security. But we are still working on the periphery of agribioteh research issues and our impact factor is insignificant. There are a lot of scale as well as skill problems. In reality, we don't have real biotechnologists who are skilled enough to harness the potential of cutting-edge technologies. Since, biotechnology research is characterized as complex and high capital intensive, the research system should allocate scarce capital resources optimally so as to ensure research efficiency and restrain a thin spread of resources. This can be achieved by prioritization of biotechnology research keeping in view the national and regional goals. The government may consider identifying a few priority research areas, and create a dedicated fund for the development and delivery of such agricultural products which contribute to food security. However, to figure on the global biotechnology map, we need substantial resources for capacity building, institutional infrastructure and effective policy implementation.

Endnotes

1 ICAR (2000).
2 ibid
3 ibid
4 Hautea and Escaler (2004).
5 Dhawan, et al. (2005); Mayor, (2005).
6 Sharma (2000).
7 www.biotechsupportindia.com
8 Mruthyunjaya, et. al. (2004).
9 Saaty (1980); Braunschweig (2000).

References

Braunschweig, T. 2000. *Priority Setting in Agricultural Biotechnology Research*. *Research Report* 16, ISNAR, The Hague, International Service for National Agricultural Research.

Dhawan, J., Gokhale, R.S. & Verma, I.M. 2005. "Bioscience in India: Times are Changing". *Cell* 123 (5), 743–745.

Hautea, R.A. and Margarita Escaler. 2004. Plant Biotechnology in Asia, *AgBioForum*, 7 (1&2): 2-8.

ICAR. 2000. *Vision 2020*. Indian Council of Agricultural Research, New Delhi, p.42.

Joshi, P.K., Raka Saxena and Suresh Pal. 2002. 'Assessing Priorities in Agri-Biotechnology Research.' *Annual Report, 2001-02*, National Centre for Agricultural Economics and Policy Research, New Delhi.

Mayor, S. 2005. 'Coming Home'. *Nature* Vol. 436, pp. 488–489.

Mruthyunjaya, Suresh Pal, LM Pandey, AK Jha and Raka Saxena, 2004. 'Early Impacts of Selected Research Projects Under NATP', *Draft Report,* National Agricultural Technology Project, ICAR, New Delhi.

Qaim, M. 2001. 'The Situation of Agricultural Biotechnology in India', Draft Paper, *Center for Development Research (ZEF)*, University of Bonn, Bonn.

Saaty, T.L. 1980. 'The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation'. New York, NY: McGraw Hill.

Sharma, M. 2000. 'Biotechnology Research and Development' In: G.J. Persely and M.M. Lantin (eds.) *Agricultural Biotechnology and the Poor,* CGIAR, Washington DC.

World Bank. 2001. *World Development Indicators*, The World Bank, Washington DC.