Resources and priorities for plant biotechnology research in India

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Indian agriculture is facing unprecedented development challenges. The green-revolution technologies have lost their steam and increasing amount of off-farm inputs is required to sustain crop yields. There is tremendous pressure on natural resources, especially land and water, threatening their sustainable use. These coupled with issues of environmental concerns and shrinking land-holdings are not only affecting the economic viability of farms, but also eroding competitiveness of Indian agriculture. These challenges are unprecedented and strategic interventions to improve investments, incentives and innovations have been debated and contemplated during the XI Five-Year Plan. There is a consensus that technological interventions are a must to push yield frontiers up and therefore, improvement of plant genetic resources and associated crop and resources research should be accorded high priority. In particular, advancement in molecular biology and its applications in crop research, popularly known as plant biotechnology, hold great promise in raising yields and are expected to usher in the 'gene revolution' in agriculture.

The Government has rightly responded to this technological challenge by creating an institutional structure for governance, spending substantial public resources to strengthen research infrastructure, and putting in place a regulatory framework for biotechnology. The Department of Biotechnology (DBT), New Delhi established in 1986, is the nodal government agency for the governance of biotechnology. It also supports biotech research in all fields through core and competitive funding. Other scientific organizations like Council of Scientific and Industrial Research (CSIR) and Indian Council of Agricultural Research (ICAR) also invest considerably in biotech research. As a result, the research is spread over the entire scientific system and it is difficult to assess the research capacity presently available in the country. This note addresses this information gap. It specifically examines institutional profiles and research priorities with an objective to identify the research gap.

Investments, personnel and publications are the main indicators often used in the assessment of research capacity. Investment data are available only for DBT, which spent Rs 503 crore in 2006–07 and a large part of this expenditure was on non-plant biotech research. Investment and personnel information on biotech scientists for other organizations is not readily available. We therefore use the next best proxy, i.e. number of research papers abstracted in different sources of scientific publications, viz. plant and biotechnology abstracts (manual and electronic search) and other periodicals. The reference period for the study is 2005–07.

Institutions, personnel and publications

Nearly 1600 scientists associated with 180 different organizations work on plant biotechnology in India. One-third of these scientists work with the institutions of DBT, Department of Science and Technology (DST), CSIR and other centres of advanced study supported by the Central Government. Universities employ one-third of the scientists. The remaining one-third scientists work with ICAR institutes and State Agricultural Universities (SAUs; Table 1). The presence of private sector in research is negligible[1]. Another notable feature of scientific personnel is that the organizations under the Ministry of Science and Technology and SAUs employed 12–15 scientists per institution compared to those in ICAR institutions and universities with about seven scientists per university working on plant biotechnology.

Table 1 further shows that scientists in India published 843 research articles on plant biotechnology during 2005–07, giving an annual publication of about 280 articles. This means that, on an average, one scientist published one article in almost six years and this holds true across different groups of organizations. This number may appear to be low, but it may be noted that nearly half of the scientists work in universities and they spend a significant proportion of their time in teaching. Thus, actual number of full-time equivalent scientists (adjusting head-count number with actual time spent on research) will turn out to be quite low. This coupled with the fact that 61% of the total articles was published in reputed journals of the developed countries, research productivity can be stated as satisfactory. This is particularly important for organizations under DBT, DST, CSIR and other centres who have published 79% of their articles in international journals. ICAR and SAUs published nearly half of their publications in international journals, which is comparatively low for biotech publications, but significantly higher if the publications of all disciplines of agricultural sciences are considered[2].

Research capacity

Distribution of research articles by research themes indicates research capacity in various aspects of plant biotechnology in India. But this is not a simple task as some publications fall in more than one research theme. This is particularly true with the publications originating from general universities and the institutions of DBT, DST and CSIR (Table 2)[3]. A vast amount of research efforts is directed towards applied research areas like *in vitro* regeneration, transformation and evaluation of transgenics, as 44% of the publications are in these areas. This research is done in all the organizations. Molecular analysis, mapping, gene pyramiding and marker-assisted breeding fall under the second important research group containing 26% of the total publications. Only 10% of the publications are 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. Biochemical characterization, development of molecular markers, organelle diversity, genome construction and secondary metabolites have either received comparatively less attention from biotechnologists, or there is not adequate capacity to work in these comparatively advanced research areas. These are the areas which should receive high priority for research capacity development. Since a good deal of this work is strategic and capital-intensive in nature, further allocations of public resources should target this theme. Efforts in this

Table 1. Institutional profile, scientists and publications in plant biotechnology, 2005–07

Organization	Number of institutions	Number of scientists	Total publications	Papers in journals published in: Developed countries	Developing countries
ICAR	32	244	127	60	65
SAUs	30	371	164	74	90
DBT, DST, CSIR and other centres for advanced study	36	542	266	210	49
Non-agricultural universities	67	449	252	150	102
Private research organizations	15	60	34	20	14
Total	180	1666	843	514	320

Table 2. Number of research publications by area of specialization in plant biotech research, 2005–07

Research area	ICAR	SAUs	DBT, DST, CSIR and other centres for advanced study	Non-agricultural universities	Private research organizations	Total
Protein/biochemical characterization	5	8	11	13	2	39
Molecular analysis, DNA fingerprinting	35	38	29	28	6	136
Development of markers, organelle diversity, genome analysis/construction	13	7	24	12	6	62
Gene regulation, functional genomics, proteomics, transcriptomics	6	15	60	23	4	108
Protocol development	3	4	6	5	0	18
Molecular mapping, gene pyramiding, marker-assisted breeding	13	30	47	26	8	124
Transformation, transgenics, evaluation	16	11	74	54	11	166
In vitro regeneration	33	46	64	130	1	274
Secondary metabolites, plant vaccines	1	1	17	7	10	36
Bioinformatics and others	3	10	16	8	1	38
Total	128	170	348	306	49	1001

Column totals by organization may not tally with those given in Table 1, as some papers are classified into more than one research area or institution.

direction would support small to medium crop biotech firms and thereby provide some competition to transnational firms, which may otherwise dominate the market of biotech products.

Analysis of research publications originating from the ICAR–SAU system, which is expected to conduct and commercialize biotech research on various crops, reveals some interesting patterns. Most of their publications are in the area of *in vitro* generation, molecular analysis, DNA fingerprinting and marker-assisted breeding. These are applied crop biotech areas falling under the responsibility of the agricultural research system. However, this system needs to intensify its activities in the discovery of novel genes and their introduction for improvement of plant types. Although contribution of private organizations in terms of research publications is rather small, these are spread over a number of research areas. This is expected because of the diversity of private organizations, ranging from research foundations to high-tech laboratories and commercial entities working on different aspects of plant biotechnology.

Crop priority

What are the crops and economic traits currently targeted by plant biotech research in the country? This question is addressed in this section. All the research publications are classified by major traits of high economic value and crops (Table 3). Table 3 shows that nearly 400 publications of a total of 843 are related to research on the production constraints of economic significance for various crops. This is essentially applied research. The most important category under applied research is the application of biotechnology to manage biotic stress in plants, contributing nearly half of the total publications. All the research organizations have accorded high priority to this kind of research. The crops targeted for this trait are cereals, especially paddy, pulses, horticultural and commercial crops (mainly cotton). This is justified, as biotic stress causes high production losses in these crops[4]. The second important objective of plant biotech research is to manage abiotic stress. Although such research is done in all the institutions, DBT, DST, CSIR and other similar institutions contribute half of the publications in this category. The main traits targeted under abiotic stress are improving tolerance of crops to moisture and salt stress. Target crops under this category are cereals, horticultural crops, and surprisingly, perhaps because these are easy to work with for standardization of protocol.

Improvement in the quality of agricultural produce and nutrition is another important research objective of biotech research and this is equally targeted in all research institutions. Research focus is

Table 3. Number of publications by crop and trait for biotech research, 2005–07

	Biotic stress tolerance	Abiotic stress tolerance	Herbicide tolerance	Nutrition and quality improvement	Improved breeding materials like CMS line, dwarfing, etc.	Total
Plant traits focus by research organizations						
ICAR	30	2	2	11	15	60
SAUs	48	13	5	15	1	82
DBT, DST, CSIR and other centres for advanced study	39	35	5	13	9	101
Non-agricultural universities	50	13	17	17	9	106
Private research organizations	44	10	16	12	1	83
Total	211	73	45	68	35	432
Crop trait research focus						
Cereals	75	25	8	28	17	153
Pulses	21	2	3	1	2	29
Oilseeds	11	2	2	10	8	33
Horticultural crops	31	4	8	7	11	61
Fibre and other commercial crops	22	2	6	2	6	38
Medicinal and aromatic plants	4	2	3	3	0	12
Tree species	1	2	2	1	2	8
Fodder and other crops	15	23	2	10	3	53
Total	180	62	34	62	49	387

on cereals which account for half the total publications in this category, followed by oilseeds. Horticultural crops which are important from the nutrition point of view, are less targeted. Imparting herbicide tolerance to crops is an important research objective of the private sector, but equal emphasis is accorded by general universities. Crops studied in this category are cereals, horticultural crops and commercial crops. These are the crops where use of market-based inputs like seed is quite high and the private sector is an important player[5].

One of the immediate applications of biotechnology is to accelerate plant breeding efforts in field crops. Since this is an applied aspect, a good amount of work has been carried out to develop improved breeding materials like CMS lines, mainly in ICAR institutions and surprisingly not in SAUs. Private sector and other research organizations also conduct some research in this area. Cereals, horticultural crops and oilseeds are the crops targeted for this kind of work. Medicinal and aromatic plants and trees are rather less targeted for the traits discussed here, perhaps due to the fact that these plants are already of high economic value, and their conservation and multiplication are more important.

Conclusion

Here we have presented data pertaining to scientific personnel associated with plant biotechnology research in India and research priorities addressed by them. Research is conducted in a variety of R&D organizations. Although the number and quality of research publications are reasonably good, advanced biotech research is rather limited. Applied research addressing crop-specific constraints as well as that applicable to a number of crops are equally emphasized. The main thrust of applied research is enhancing tolerance of crops to biotic and abiotic stresses and improving product quality, and the priority crops are cereals, horticultural crops and commercial crops. Therefore, reduction in yield losses, better product quality and increase in efficiency of plant breeding are expected to be major outcomes of plant biotechnology in the near future. These priorities are broadly in line with the agricultural development needs of the country. However, efforts to strengthen basic biotech research in the institutions of advanced studies and fostering their linkages with applied research organizations will help exploit the potential of biotech research.

1. Some private for profit organizations mainly seed companies are active in applied and adaptive research on transgenics, which seldom appears in scientific publications.

2. Pal, S., Mathur, P. and Jha, A. K., Policy brief 22, NCAP, New Delhi, 2005.

3. Sum of publications for these institutions in Table 2 (last row) is higher than total number of publications given in Table 1.

4. Gover, A. and Pental, D., *Curr. Sci.*, 2003, **84**, 310–320.
5. Pal, S., Tripp, R. and Louwaars, N. P., *Econ. Political Wkly*, 2007, **XLII**, 231–240.

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