Biotechnology in the Indian National Agricultural Research System: A Case for Institutional Reform

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Introduction
This article presents biotechnology as an opportunity to mend and improve the organizational and institutional basis of agricultural science and agricultural policy. Right from the stages of policy-making, problem identification and project planning to technology generation and technology utilization, biotechnology gives agricultural research the opportunity to enhance technology assessment capabilities. In India, the National Agricultural Research System (NARS hereafter) consisting of the Indian Council of Agricultural Research (ICAR), the State Agricultural Universities (SAUs), some selected General Universities, and the private and voluntary sector organizations, conducts agricultural research. This paper argues that biotechnology presents a unique and pressing case for institutional reform in agricultural technology generation and agricultural policy. Two crucial aspects of this institutional reform in the Indian NARS are (i) a shift in research paradigm from Green Revolution to sustainable agriculture, and (ii) participatory policy-making and technology assessment capabilities.

This paper examines the assessment capabilities in the NARS in India in the context of the biotechnology research and development effort in the

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country. Evaluation is the weakest component in research management in the national agricultural research system (NARS) in India. [Acharya, 1996, Raina, 1999(a) and 1999 (b)]. Biotechnology is explored as a powerful knowledge engine whose application in the agricultural sciences must be extended to more fundamental research with implications for agro-ecological improvements instead of being limited to applied research effort to improve yields or change the composition of purchased inputs used in agriculture. Biotechnology is a powerful ally in the transition of agricultural research systems from conventional Green Revolution research paradigm to a dynamic and evolutionary paradigm of science for sustainable agriculture.

Technological change has driven agricultural policy much the same way that it has been driven by policy. The history of agriculture reveals this mutually sustaining and co-evolving relationship between technology and agricultural policy. Modernization witnessed the evolution of institutions (rules of the game) and organizations (formal structures) for scientific research and policy-making. Agricultural science and technology are important tools used to achieve policy objectives. Instances where the availability of technology has dictated the formulation and implementation of major policy changes are also many. The Green Revolution is the best example of the latter.

Invariably, expert scientists and policy-makers made the decisions regarding the rate, direction and content of technology. That public sector scientists made research decisions during the Green Revolution, with a no-profit motive for enhancing public welfare, was an important legitimization for this expert-led decision-making. The ecological (soil, water and genetic) and human (economic, social and political) resources have gained from as well as lost (often heavily and irreversibly) from the technological change and policies that enabled the Green Revolution led by the public research system.

There is a wide range of opinions about whether modern biotechnology will deliver the benefits to the poor peasants and subsistence farmers, or help combat poverty, hunger and malnutrition in less developed countries. (US Senate, 2000, Altieri, 2000). The public sector in the ‘gene’ revolution seems to have abdicated the role it played in the Green Revolution in delivering the
technology package to poor peasants. (Paarlberg, 2000). The increasing private industrial consolidation in agro-biotechnology leads to legitimate fears about the reversal of the erstwhile contract between science and policy, with the private industrial interests dictating policy in the agriculture sector so as to ensure better business.

Modern agro-biotechnology has changed the erstwhile mutually sustaining co-evolving relationship between technology and policy. Biotechnology has forced the international community of policy-makers and experts to review this means-ends contract between technology and policy. Increased risks and uncertainties, as well as enhanced public awareness about the social and ecological consequences of biotechnology research products, has precipitated this rethinking. Contrary to the Green Revolution technologies, which could be put to multi-location trials and released for adoption after the scientific and economic assessments, the products of biotechnology question the use of “sound science” as the basis for trials or technology release. It has now become necessary to replace or complement sound science with policy action. (ESRC, 1999).

Biotechnology brings the precautionary approach in technology and policy decisions. The precautionary approach dictates that if we are not able to predict very well what the outcome of our actions will be, we should consider taking other, less risky alternatives. A major problem in using the precautionary principle in making decisions about research (scientific uncertainties) and products (business opportunities) is the wide range of interpretations possible when the precautionary principle is used as a policy tool. Nationally and internationally there are different value systems ranging from eco-centric risk averse to anthropocentric and utilitarian risk taking frameworks, and policy responses that vary with each of these approaches. Eventually, given all the scientific evidence, issues such as risk assessment, management and communication are political because definitions are not clear and costs and benefits are never shared or spread equitably (CID, 2000). There is no policy blue print for the application of precautionary principle or any regulatory policy relevant to biotechnology – the precise meaning, scope, and application of the precautionary principle
will be an exciting and controversial area for some time to come. What is evident now, is the lack of confidence in “scientific certainties” and therefore the need for policy action in the area of biotechnology.

Scientific relevance or use is always judged based on the cost-benefit analyses, within the neoclassical economics framework. Given that the economic advantages of biotechnology are neither clear nor straightforward, it is necessary to inform biotechnology decisions with insights from other social sciences (besides economics) and to use these insights to formulate and implement adequate policies for the safe and beneficial use of biotechnology. Nation states, bureaucracies, funding agencies, and agricultural research organizations (both private and public sector) now need to conduct regular ex-ante assessments and improve methodologies for these assessments. (Brenner, 1997, Gabriel, 1999, NAS, 2000). While much of established agricultural research continues to proclaim value neutral science-based expert-led technology evaluation and priority setting methods, there is an increasing evidence that these need to be replaced by or complemented with participatory deliberation and debate about technology generation and use. There is a significant contrast in the conventional neoclassical economics approach to priority setting in agro-biotechnology research (Falconi, 1999) and the open ended deliberative and inclusive processes identified for research decision-making for GM crops (ESRC, 1999). In the current highly polarized debate about agro-biotechnology, it is essential for the Government to be receptive to a wider range of advice, concerns and values. Public sector agro-biotechnology research now has the responsibility to be open to different political and ethical choices in its ‘scientific research’ decisions.

The Institutional Context: Biotechnology in the Agricultural Sciences in India.

The agricultural sciences are different from other applied sciences in two major aspects. (Thompson, 1995). First it expects all research results will be applied. Second, and partly the reason for this expectation, is that all agricultural research is caused or determined by the need to solve agricultural problems. The agricultural sciences as practised today, range from pure science disciplines such as molecular biology and organic chemistry, to
applied sciences such as plant breeding and genetics, soil physics, agronomy, water technology, agricultural statistics and agricultural economics. Most agricultural research organizations resemble the standard bureaucracy with “problem dis-aggregation and solution aggregation” both entrusted to experts. (Dryzek, 1997).

Biotechnology in agriculture is almost as old as agriculture. Public acceptance of the products of classical biotechnology has been almost spontaneous. The current excitement and controversy about modern biotechnology can be traced to the way science has pushed organisms beyond their natural balance. The national agriculture policy (NAP hereafter) document of the Government of India makes explicit the desire to use biotechnology for economic and ecological gains.

The use of bio-technologies will be promoted for evolving plants which consume less water, are drought-resistant, pest-resistant, contain more nutrition, give higher yields and are environmentally safe. (NAP, 2000, p. 4).

Several issues in the agriculture-environment nexus as well as some crucial institutional concerns have to be addressed before utilizing biotechnology to resolve some of the most urgent problems in Indian agriculture. It is likely that what we know and do not know about the environment will ultimately decide our perceptions of risks, the use of the technology, and the actual consequences of the technology in the ecology and society. The Bt cotton, and the genetically modified varieties of corn, soya bean, oilseeds (mustard and sunflower), vegetables (tomato and cabbages) and the staple crops rice and wheat, have all attracted attention from the myopic productionists, the pro-science and anti-science environmentalists. The biotechnology industry in India is now poised to release many of these transgenic varieties by the year 2003, and to move for commercialization of transgenic crops, nutraceuticals, seed genetic engineering and tissue culture. (ASSOCHAM, 2001).

Historically, the reinforcement of the productionist Green Revolution research paradigm in the agricultural sciences applied to the staples like wheat and
rice and made productivity enhancing technologies the sole objective of all applied and adaptive research. In the 1960s, the new disciplinary convergence and the first generation technologies enhanced production/productivity.

The ecology responded with more focused and more virulent strains of pests, pathogens, and weeds and specific forms of soil and water degradation. These were accompanied by vast losses in the diversity of crops and other flora and fauna. Research to maintain yields in the face of these second and third generation problems came to be known as maintenance research. It became the rule in NARS, that an increase in scientific knowledge and crop productivity would be accompanied by an increase in research resources allocated to maintenance research. (Ruttan, 1982, p.60). *This increase in applied and adaptive research became essential to “maintain” the unrelenting pressure of knowledge and technology on the ecosystem.*

Biotechnology, despite its immense potential to respond to specific ecosystems requirements, has now been cudgeled into the narrow grove of these marginal or incremental changes in technology, to maintain existing yield levels in the face of second and third generation problems such as weeds, pests or diseases. Current research content in and outputs of biotechnology research are part of this research paradigm to “maintain” pressure on the ecosystem so as to ensure continuous growth rates in yield. Research has focused on the identification and expression of one gene or sequence to enhance yield/quality of produce, push resistance to one pest of disease or weed that is manifest now in the ecological response to this unrelenting pressure of knowledge and technology.

All research on bollworm resistance Bt cotton, sheath blight resistant rice, high protein maize or Vitamin A enriched golden rice, fit into this paradigm. It is no coincidence that these marginal and incremental yield enhancements or cost reductions are technologies that can be appropriated, generated and sold in the agricultural technology market for profit! Biotechnology can study the genetic expression of organisms and interactions in complex
ecological systems, can possibly generate solutions for degraded ecosystems, and can help identify ecological safety limits for flora and fauna in different soil and water systems. But the nature of this knowledge and the technological or resource management processes associated with this knowledge are difficult to patent and impossible to sell in the agricultural technology market. This long-term, ecological knowledge base of agricultural production is the niche where public sector agro-biotechnology can and must focus upon to enable the transition from the Green Revolution agricultural research paradigm of maintaining pressure on the ecosystem to a paradigm of sustainable agricultural development with least ecological disruption and maximum conservation.

The social sciences fail to point out the role of biotechnology in more viable and sustainable agro-ecological research paradigms in contrast to the blanket genetic pressure of maintenance research on the crop and ecosystem. Biotechnology can promise the revival, modification and cultivation of thousands of varieties ideal to or now lost to specific ecosystems. The yield profile, pest or disease resistance, resource system (soil and water) impacts of these biotechnology research products belong to a new agro-ecological research paradigm that works with nature instead of using knowledge and technology to exert pressure against nature. (Jordan, 1998). The potential contribution to agricultural and ecological knowledge from biotechnology is ignored in the onrush of commercial avenues and exploitation of biodiversity. Yet, biotechnology offers several short and long term incentives for public sector research to shift from the Green Revolution research paradigm to a research paradigm of agro-ecological change for sustainable agriculture.

Institutions as Rules of the Game, Values and Norms

Our argument here is that the mission, utilization and consequences of agro-biotechnology are a function of the existing institutional framework or rules of the game of the agricultural sciences. Institutional features, such as disciplinary convergence, or legitimization function of the social sciences, or the hierarchy between the ICAR and the SAUs, are the unstated rules that decide how agricultural research organizations conduct research.
and generate technology. In our discussion on biotechnology in the context of agricultural policy and technology, we need to be aware of the distinction between institutions and organizations. “Institutions are sets of common habits, routines, established practices, rules, or laws that regulate the relations and interactions between individuals and groups.” (Edquist and Johnson, 1997, p. 46). Institutions are the “working rules for going concerns”; institutions define organizations. (Bromley, 1985). “(O)rganizations are formal structures with an explicit purpose and they are consciously created. They are players or actors.” (Edquist and Johnson, 1997, p.47). In the Indian NARS, the ‘dead wall of rules’ or the rigid institutional framework within which the Indian Agricultural Research Institute (IARI) operates has been documented. (Mondal, 1999). Research decision-making within the Council is designed to fit these rigid rules, and it is often the case that research organizations and programmes under the ICAR do not attempt to change or reinterpret the “given” rules using new information or evidences, but operate “on the basis of precedence”. (Mondal, 1999, p. 78; Biggs, 1989) This institutional inflexibility, consequent internal legitmization of research decisions within the organization are responsible for keeping research repetitive and ritualistic. (ICAR, 1988). There is little attempt to question the legitimization (based on the current trend and popularity) of biotechnology within a narrow incremental research framework, thereby diminishing the potential of biotechnology to increase stakeholder participation and contribute to a larger goal of sustainable agriculture.

The distinction between organizations and institutions is important to understand organizational and institutional change. Visualizing institutional change from this theoretical perspective helps us identify institutions such as incentives and evaluation criteria, and the organizational structures such as research networks, programme contents and participants that are necessary for the biotechnology aided shift from Green Revolution paradigm to a sustainable agriculture paradigm. “If organizations are the players and institutions the rules, then how are the rules changed?” (ibid. p.57). This is the specific concern when we discuss ‘institutional’.

With a view to improving the performance of agricultural research, the NARS in India, and the ICAR in particular has been asked to undergo
Institutional reform since the 1950s. But the history of agricultural research in India reveals much organizational change with little or no institutional reform. [Raina, 1999(a)]. Institutions or rules and norms to improve working conditions for professionals (personnel policy), to enhance social accountability of agricultural science (norms for co-ordination and peoples participation), to do away with the dichotomy between bureaucratic and administrative controls, to improve information systems and effective decentralization of research decision-making, have been recommended time again. (Ministry of Agriculture, 1964; Chowdhry et al. 1972; ICAR, 1973; ICAR, 1988; Gupta et al. 1991, World Bank, 1990). But the NARS has done little to introduce these institutional reforms. Over the years, the organizational changes consolidating, centralizing and integrating agricultural science to meet the requirements of the policy regime aimed at food security, has pushed most of these recommendations for institutional reforms to oblivion. (Raina, 1999). Indian agriculture now needs a policy regime targeting sustainable agriculture with enabling institutional reform to use biotechnology within a new research paradigm. Within a policy for sustainable agriculture, biotechnology policy can be articulated with less bureaucratic controls and more participatory decision-making, where institutional and organizational changes for biotechnology (research and release of products) are debated openly within civil society and stakeholder forums.

In the Indian context the HYVs - water-chemical/mechanical inputs package led to increased yields. But the growth rate has been declining over the past decade. These yield growth rates are, however, the subject of great concern now, because there is a deceleration or stagnation in the growth of yield. Agricultural GDP which was Rs. 42466 crores in 1980-81 grew to Rs. 267079 crores in 1998-99 (in constant 1993-94 prices). Growth rate of agricultural GDP is a mere 1.95 pre cent during 1990-91 to 1998-99, compared to 3.94 pre cent between 1980-81 and 1990-91. (Economic Survey, 2000). The country has not been able to sustain the growth in yield from the Green Revolution technology package. Declining soil and water quality is an important reason for this stagnation or deceleration in growth rate of productivity. (ICAR, 1998). Clearly there are several other problems besides declining soil and water quality associated with this deceleration.
Declining public investment in the agriculture sector is a major reason.\(^6\) Given that more than 75 percentage of the total labour force in the country depends on agriculture and allied rural activities for their livelihoods, these trends of deceleration proclaim a bleak future for Indian agriculture and the rural economy. The political and ethical choices open to biotechnology research decision-making are located in this ground reality of Indian agriculture.

The Government of India has consciously encouraged research investment in biotechnology. The Department of Biotechnology (DBT) spent a total of Rs. 270 million (roughly US $ 6 million) between 1989 and 1997 on research in plant and molecular biology. (Ghosh quoted in Paarlberg, 2000).

Though this investment in agro-biotechnology is way below international investments by other countries or by private biotech corporations, this investment has made a substantial difference to Indian biotechnology research capabilities. Some of Indian biotechnology research is at the cutting edge.\(^7\) Most of the public investment has gone into low-end technology development and adaptation (such as tissue culture or micro-propagation). There are fundamental questions to be answered about biotechnology investments in and solutions for specific problems in Indian agriculture. Are transgenic salt-tolerant rice varieties the most effective solution to increasing salinity and alkalinity in Haryana and Punjab? Within this allocation (Table 1), the specific application of biotechnology and the opportunity for the scientific community or the public to assess such research investment is not clear. For instance, the DBT investment within plant biotechnology 1998-99 is roughly Rs. 51 million which were allocated to investments in transgenic plant biotechnology research but the issue is what are the expectations from this investment?

**Institutional Change for Evaluation of Agro-Biotechnology Research**

Evaluation is an input to the decision-making process. Several types of evaluations are practised within an agricultural research system, at different levels outside and inside the system – within research organizations, research programmes and projects, and for personnel assessment. (Horton, et al. 1993). These evaluations range from project appraisal (ex ante) to impact...
assessment (ex post), all feeding into effective research management. Decision-making, ranging from research priorities and research resource allocation, to project closure and incentives for research personnel is based on these evaluations of research, conducted at regular intervals. Critical decisions about adequacy or otherwise of aggregate research funding at the national level, and the mobilization of existing research capacity to meet national objectives, are often based on judgements by policy makers. These judgements can and must be informed by appropriate evaluations; but in practice these judgements are made without the aid of evaluation methods and often in conditions of imperfect information marked by uncertainty. (Tabor, 1998).

Table 1: Financial Commitment for Agro-Biotechnology from the DBT

(Rs. in Lakhs)

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<tr>
<td>Aquaculture and marine biotechnology</td>
<td>189.80</td>
<td>200.00</td>
<td>200.00</td>
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<tr>
<td>Plant biotechnology</td>
<td>419.70</td>
<td>629.00</td>
<td>630.00</td>
</tr>
<tr>
<td>Basic Research and Emerging Areas</td>
<td>514.79</td>
<td>500.00</td>
<td>450.00</td>
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<tr>
<td>Biofertilizer</td>
<td>190.00</td>
<td>170.00</td>
<td>140.00</td>
</tr>
<tr>
<td>Medicinal and Aromatic Plants</td>
<td>199.88</td>
<td>150.00</td>
<td>130.00</td>
</tr>
<tr>
<td>Animal Biotechnology</td>
<td>296.68</td>
<td>315.00</td>
<td>300.00</td>
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<tr>
<td>Seri Biotechnology</td>
<td>149.94</td>
<td>150.00</td>
<td>125.00</td>
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<tr>
<td>Trees and woody species application of Tissue Culture</td>
<td>650.02</td>
<td>630.00</td>
<td>600.00</td>
</tr>
<tr>
<td>Development of biological pesticides</td>
<td>300.00</td>
<td>250.00</td>
<td>200.00</td>
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<tr>
<td>Biodiversity Conservation and Environment</td>
<td>196.46</td>
<td>290.00</td>
<td>250.00</td>
</tr>
<tr>
<td>Total in Agriculture and allied sectors</td>
<td>3107.27</td>
<td>3284.00</td>
<td>3025.00</td>
</tr>
<tr>
<td>Grand Total</td>
<td>11425.51</td>
<td>12826.30</td>
<td>13608.00</td>
</tr>
<tr>
<td>% of Grand Total allocated to agriculture and allied sectors</td>
<td>27.20</td>
<td>25.60</td>
<td>22.23</td>
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It is acknowledged even within the conventional neoclassical schools of technology assessment that the methods and processes for assessing agro-biotechnology ought to be different from those used for assessing conventional agricultural technology. (See Falconi, 1999). While much of the literature on evaluation of agricultural research has concentrated on methods and tools, little has been said on the need for a change in perspective. Rather innocuously, the same neo-classical theory of market based technology generation and use informs the literature on evaluation and priority setting in agricultural research; principally in the name of cost effectiveness, real-world limitations on available information, and want of a complete theory of aggregation. (See Alston, Norton and Pardey, 1995, Chapter 2). It is also acknowledged that “to a great extent this literature has neglected” issues of externalities and environmental sustainability. (ibid, p. 77). Much of the controversy about the application of modern biotechnology in agriculture stems from the unknown or immeasurable externalities. Moreover, biotechnology no longer produces technologies that can be assessed with criteria of scientific soundness or economic viability (even in the absence of sound science). The precautionary principle and other policy actions now complement and/or replace the erstwhile technology assessments based on sound science.

In India, the biosafety and other precautionary assessment of any biotechnology research project is performed according to the guidelines of the DBT. There are two committees with policy authority, the RCGM (Review Committee on Genetic Manipulation) and the GEAC (Genetic Engineering Approval Committee). The RCGM and GEAC are empowered respectively to approve (not approve) small-scale research projects and large-scale actual industrial or environmental release of biotechnology products. The relatively permissive nature of small-scale research evaluations by the RCGM and the more precautionary nature of the GEAC decisions on large-scale adaptive trials or release give the Indian biotechnology assessment and regulation a balanced policy approach.

But response of the regulatory mechanisms to the demands for biosafety and plant variety protection are still far from satisfactory. (Damodaran,
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1999). All biotechnology research projects handled within the NARS go through the relatively permissive pro-research evaluation of the RGMC. Similarly, all agrobiotech products need GEAC clearance for large-scale trials or releases.9

Given that biotechnology is regulated and assessed (ex-ante only since no genetically modified variety has been released thus far – as of April 2001-in India) by a combination of sound science and policy, there has thus far been little pressure on the NARS in the country to equip itself with necessary reforms and modifications in existing evaluation methods and practices. Maintaining status quo seems to suit the ICAR. The institutional conditioning of the ICAR is not disturbed with either the responsibility (for biotechnology research and release of genetically modified varieties) vested with authorities outside the ICAR or the disjointed, irregular and highly inadequate scientific evaluation of research within the ICAR. Within the ICAR evaluation of biotechnology is no different from the evaluation of any other agricultural science discipline. Research evaluation experiences in the ICAR reveal that efficiency and impact of research are not central concerns in evaluating research proposals or products. Both ex-post and ex-ante impact assessments of agricultural research and technology have been relatively few in India. Though the terms of reference given to the regular agricultural research evaluation groups, such as the Working Groups of the Planning Commission, the Quinquennial Review Teams, and the intra-institute research management units such as the Staff Research Councils and Management Committees, includes impact assessment, none of these impact assessments are actually performed. Internal evaluations within the ICAR are a series of disjointed evaluations; none feeds into the other or reach any comprehensive follow up decisions on institutional reform or for better management of agricultural research. (Raina, 1999 (b), Mondal, 1999).

The policy regime for agro-biotechnology in India, with the Plant Variety Protection Act (PVP A), and the formulation and implementation of biosafety guidelines, committees and organizations for screening GM crops, has thus far been favourable. Policy and infrastructure changes are also seen in the trade and research investments. Indian agriculture being GM-free, the
country is now seeking a premium price for several agricultural products marked GM-free in the international market. The move from the biotechnology industry to initiate reforms in the regulatory processes for quick and efficient approval of biotech products, and the demand a loan of US $ 100 million from the World Bank to establish Biotech Parks, are proof of massive policy and investment changes being sought to favour the biotech revolution. (See, AIBA, 1999).

It is in this national agricultural science context that agro-biotechnology has grown as a research area with immense potential to resolve some of the fundamental problems in Indian agriculture. To exploit the problem solving potential of this field of biological science, the NARS must heed the call for greater integration of commodity based and natural resources based research. (See, Goldsworthy and DeVries, 1994). Assessment of biotechnology research requires much more information and several rounds of cross-checking across environments. This is because of the risks and uncertainties associated with modern biotechnology and also because increased fundamental bioscience knowledge can be used strategically to understand, conserve and manage specific agro-ecosystems. Thus, the range of biophysical and socio-economic data required is much higher than in the assessment of other conventional breeding technologies. Biotechnology research and assessment of technologies should ideally be more ecologically grounded than conventional research.

It is known that the data and information available with and used by the ICAR or the SAUs for research management, research priority setting, or for research programme formulation is rather weak and limited. (Biggs, 1989). The lack of time series State level or district level data on extent of alkalinity in Haryana, a State where alkaline soils have been major problem since the early 1970s, fortifies the case for enhancing our information base on natural resource status and other environmental data. The ecologically and socially appropriate ex-ante assessment of the salt tolerant transgenic rice variety needs information about how the salt affected soils have behaved, and the extent and intensity of spread or reclamation over time (at least over the previous two decades), besides several biophysical variables in
each typical saline/alkaline tracts. The research on salt tolerant transgenic rice can never be assessed satisfactorily unless this data is available. Participatory processes of data generation, monitoring and utilization and systems perspectives are necessary for data on resource status and resource use planning. (Goldsworthy and DeVries, 1994, and Raina, 2000). Moreover, the data on changes in soil quality can be cross-checked only with the help of an effective extension system which directly handles the technology diffusion for reclamation or improvement of degraded soils. This demands that the hierarchy between research and extension, and between extension and the farming community be broken, encouraging the flow of knowledge and information across organizational boundaries. (Nitsch, 1994, Raina, 2001).

Public participation, and careful deliberation of different technological options within each value system is important. Green Revolution technology generation was based on the ideology of value-neutral productionism and assumptions of uniform ecological spaces, social contexts, political and ideological bases. The environmental and social consequences of these allegedly neutral technologies have now forced research managers and policy-makers to review research decision-making processes. Unlike conventional research decision-making and technology generation that was never exposed to a wide range of value judgements, biotechnology research in this era of post-normal science demands a wide range of value judgements – ecocentric, anthropocentric or merely technocentric values. Does the ICAR or any of the SAUs have sufficient social science support or interaction between the natural and social sciences to bring these different value judgements to bear upon research decision-making? While the answer is definitely not in the affirmative, the more alarming trend within the agricultural sciences in general is the dominance of neoclassical economics as the (only) social science relevant to agricultural research and technology generation.

Neo-classical economics, the utilitarian theoretical formulations therein and the evaluation methods such as the Cost-Benefit Analysis (C-BA) are anti-environmental and anti-democratic. (Dryzek, 1997; Soderbaum, 1999). It is impossible to have a satisfactory assessment of biotechnology when only a
few environmental variables amenable to monetary reductionism are included in the analysis and a few measurable or technically unobtrusive attitudes or cultural variables are considered relevant for research decision-making. The introduction of and significant investment in agro-biotechnology within the NARS in India demands fundamental changes in the content and role of the social sciences.

**Agro-biotechnology and Paradigm Shift in the Agricultural Sciences**

Biotechnology has entered the spectrum of agricultural technologies at a crucial historical juncture when the conventional Green Revolution paradigm is shifting to a more ecologically and politically sound paradigm of sustainable agriculture. This sustainability transition within the agricultural sciences necessitates an examination (of the unstated and untested assumptions that motivate conventional agricultural research. (Clark, 1999). Some of the key assumptions of agricultural research in the industrial model of agricultural growth and in a hypothetical model of sustainable agriculture (defined to suit each specific context) are given in Table 2 below.

Sustainable agriculture is a complex and dynamic goal. Research for sustainable agriculture demands changes in these assumptions of conventional Green Revolution research methodology. The need for a radical ecological reorientation of the agricultural research paradigm is perfectly complemented by the potential of agro-biotechnology to understand and work within the existing features and complexities of each ecosystem. But the vision and policies for biotechnology as another tool for maintaining the relentless pressure on the ecosystem to enhance yields has almost closed this option of using biotechnology to further the cause of sustainable agriculture. The enhancement of sustainable production systems and ecologies that sustain these production systems demands changes in policies and technology. Process and problem analyses with reference to sustainable development have invariably arrived at the conclusion that sustainable development entails a new paradigm for policy making and science as well as increased participation of the lay public in decision-making. (Jacob, 1994; Dryzek and Schlosberg, 1998, Dryzek, 1996). Social movements in the recent past have highlighted different paradigms and models of political
## Table 2: Changing Key Assumptions in Biotechnology Research: within Productionist Agriculture and Sustainable Agriculture

<table>
<thead>
<tr>
<th>Assumptions for biotechnology research</th>
<th>Conventional productionist research methodology</th>
<th>Research methodology in sustainable agriculture*</th>
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<tr>
<td>1. Problem solving</td>
<td>The purpose of research is to solve problems – these problems and their solutions are founded upon linear thinking.</td>
<td>The purpose of research is to avoid problems to illumine decision situations. Problems and the application of science to understand problems, are perceived as part of the dynamic matrix of agriculture, the ecology, the economy, and the social and political context in which these are located.</td>
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<tr>
<td>2. Value neutrality</td>
<td>Science is objective.</td>
<td>Science is part of the value laden (political and cultural society). There is a significant ideological basis for every scientific decision.</td>
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<td>3. Zone of inference</td>
<td>Research results derived from research station plots or a plot located on a few farms will be generalizable and ecological recommendation domain.</td>
<td>Experiments or appropriate processes of innovation can be taken up only after the spatial and temporal as well as anthropological over some dimensions of the ‘zone of inference’ are established or understood.</td>
</tr>
<tr>
<td>4. Main effects</td>
<td>Experiments assume that parameters of interest (yield/pest population) respond primarily to main effects.</td>
<td>The interactions of all variables in the experiment with the on-farm edaphic, topographic, use-history, and managerial factors are important and must be documented as well as analysed. The collective ‘ide effects’ may be more important than any main effect.</td>
</tr>
<tr>
<td>5. Independence</td>
<td>Research studies individual enterprises in isolation from other enterprises within the farm, across farms and within the rural ecological context.</td>
<td>There is no isolated farm enterprise. The information embedded in a given field in a given year, is a function of information from several years of land use and current ecological and weather variables. SA must capture the useful, operational synergies of enterprises.</td>
</tr>
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</table>

*Source:* Adapted from Clark (1999). *I have added column 3 here.*
ecology to organize their discourse on biodiversity, social life, culture, and work where deliberative democratic processes play a critical role. (Escobar, 1998). The involvement of scientists and stakeholders/lay people in these discourses and decisions is way removed from the dominant discourses on sustainability and biodiversity.

These policies and the industrial consolidation within India, must be viewed with a mixture of excitement and concern. Biotechnology policies and programmes must be integrated within a sectoral framework, within the range of “problems confronting agriculture and agricultural research”. (Brenner, 1997). An important lesson from the Green Revolution applies to biotechnology too; a technology or a range of complementing technologies in itself can contribute little to agricultural development unless several complementing institutions and policies are in place.

The institutional and policy changes in demand now are those that will permit the transition from conventional agriculture to sustainable agriculture. Biotechnology within a policy framework of sustainable agriculture has a much wider and varied role to play than mere yield enhancement. Perhaps production and productivity enhancement can be accomplished better with conventional technology once the ecological disruption caused by conventional technology is rectified. For biotechnology the real challenge is to maintain and improve the sustainability of production and of the ecosystem. Given the fact that private sector biotechnology research will continue to focus on appropriable profit oriented technologies, with little or no regard to the environment, the public agricultural research system now shoulders the responsibility for generation of frontier knowledge in an exhaustive applications of biotechnology for augmentation of the natural resources for sustainable agricultural development.

**Participatory Decision-making**

Simple and compartmentalised policy making and S&T initiatives for sustainable development will lead us to further institutional and organizational confusions and waste precious public resources. More critical would be the damage done to science, in terms of loss of credibility and public
faith. Public participation is a necessity. In this day and age of post-normal science, scientists cannot weigh and assess the various uncertainties at different stages of the analysis and research decision-making processes. (Funtowicz and Ravetz, 1990).

Much of the literature on participatory technology development has addressed the ways and means by which stakeholders can and must gain access to decision-making processes within agricultural research organizations. Biotechnology takes this impetus for participatory research decision-making out of the hands of the concerned stakeholders, and places it squarely as an inevitable responsibility of the agricultural research system. Sustainable agriculture and research for sustainable agriculture are viable conceptually and practical if and only if there is scope for deliberative processes in civil society and direct participation of stakeholders in research decision-making. (Raina, 2001). In an era where policy and political decision-making have openly replaced sound science as the basis for research decision-making, or are equally legitimate tools, participation of the stakeholders in research decision-making is a necessity for the credibility and survival of the NARS.

Drawing from the altered technology-policy relationship in the context of biotechnology, it is clear that the decisions for research or for release of research products in agro-biotechnology will now depend not so much on sound science but on a judicious mix of public informed public opinion, political safeguards, social contracts and scientific judgements. The NARS in its biotechnology phase of research for sustainable agriculture is now virtually dependent upon participatory decision-making processes. Contrary to the participatory ‘technology development’ option, biotechnology demands participation of stakeholders from the very decision to invest in a biotechnology research programme. While the NARS and all biotechnology research groups must encourage basic research in the area, it is important for civil society to have adequate control over the strategic, applied and adaptive research programmes. Given the high investment demand for each biotechnology research programme it is important to examine if the solution to a particular problem exists elsewhere, and whether the costs of
and time required to resolve the problem through those alternatives justify the time, investment and personnel deployed for the biotechnology research programme. Coming back to the transgenic salt-tolerant rice varieties, is it more advisable to alter the options that are open to the rice-wheat farmers in the Indo-Gangetic Plains with changes in agricultural policy, than to invest in salt-tolerant transgenic rice? Bringing corn and gram back to Punjab and Haryana (classified as semi-arid agro-ecological zones) will reduce the need for standing water in the rice crop and the need for repeated tractor tillage (which increases the hard pan formation in the soil), thereby eliminating two of the crucial root causes of sodicity in their soil and water systems. Further diversification of agriculture in these States demands a new policy on food security and trade policy. This case briefly illustrates why biotechnology research investments must be accompanied by public debate on the agricultural sector and the policy, research, extension, information, traditional technologies applicable to the particular problem and ecosystem.

Given that research on transgenic varieties of salt tolerant rice is being conducted in our NARS, India has perhaps lost this stage of participatory research decision-making. But there are several areas, even within rice biotechnology where public participation and open debate can enhance the quality and focus of research. It is important to point out here that the SAUs and ICAR are important, but not the only players in public sector agro-biotechnology research. Frontier research areas such as basic biology, molecular biology (of rice flowering, of rice insects, etc.), gene characterization, plastid transformation, submergence tolerant genes, etc., are handled mostly by biotechnology research groups in the Indian Institute of Science (Bangalore), the National Center for Biological Sciences, Tata Institute of Fundamental Research (Bangalore) and Delhi University (Delhi). In rice, the range of biotechnology research in the NARS begins with the Tamil Nadu Agricultural University (Coimbatore) and Punjab Agricultural University (Ludhiana) where they conduct excellent strategic and applied research (gene mapping, transformation, transformation for drought tolerance and pest resistance, MAS, methodology development, tissue culture, gene cloning, and transgenic varieties) and ends with the low end research on
wide hybridization conducted at the Orissa University of Agriculture and Technology (Bhubaneswar). It is no coincidence that institutes outside the NARS, and the SAUs and not the ICAR research institutes are at the forefront of rice biotechnology in India. The internal organizational problems, hierarchy, lack of leadership and lack of flexibility in research decision-making to exploit opportunities have been marked as important deterrents in the active participation of ICAR Institutes in the Rockefeller funded International Programme on Rice Biotechnology. (Evaluation Team, 1999). The SAUs are found to be much more pro-active and flexible. It is obvious now that some SAUs have moved way beyond the stage where they need the support of and incessant advice or directives from the ICAR. The SAUs in India can and must use the authority of their expertise (in areas such as biotechnology) and the local State level stakeholder participation and guidance as the basis for institutional reform towards location specific policies and technologies for sustainable agriculture. The Land Grant Colleges in the USA (the models for Indian SAUS), and agricultural science policy and decision-making processes in the EU, have changed primarily with new policy regimes and the demand for technologies for ecologically friendly agriculture, as well as with biotechnology research and development opportunities. [Loka Alert (2001), European Commission (1999)].

Assuming that the policy objective is to generate and utilize biotechnology research products to meet the goal of sustainable agriculture, the first and most directly involved group whose ‘purposive action’ is relevant would be the agricultural science community. To utilize biotechnology for sustainable agriculture, the agricultural science paradigm has to shift from conventional productionism to participatory sustainable development. Drawing from Table 2 here, the research effort in agro-biotechnology will now have to re-consider experiments in an inclusive framework, instead of delimiting consequences and requirements of the research effort or technology to a specified ‘zone of inference’. Given the environmental risks and uncertainties associated with biotechnology, the NARS and the responsible nation State will now have to keep open and transparent, the evidences, decisions, doubts, or probabilities of main effects and a series of collective ‘side effects’ over time and across space.
Organizationally these two changes in basic assumptions will require new disciplines such as geography, social anthropology, history, and truly multidisciplinary analysis with people’s participation in recording and analyzing local observations. The public sector NARS should also be cautious now in directly releasing varieties the social and environmental consequences of which may well be beyond the control of science. Biotechnology not only demands institutional and organizational reform within the scientific research system but also a radical change in the relationship between State and science.

The arguments about why policies in some countries allow commercialization of agro-biotechnology (as in the USA and China), and why some have prohibitory or cautious policies towards commercialization of anti-agro-biotechnology (as found in India, Brazil, Kenya) do often boil down to the deployment of the precautionary principle in different frameworks. (Paarlberg, 1999). It is also argued that the difference, say between China and India or Brazil, may be the presence of a democratic system. (ibid) Democratic and ecological values, and social capabilities are important in deciding the policy for and sanction (or otherwise) granted to scientific research and the commercialization of certain scientific research results. The assessment capabilities in the NARS in India have a long way to go before the complexities and different ethical and political concerns in each decision situation are considered carefully.

**Conclusion**

It is for tangible and most often direct causal evidences of degradation or disruption of the ecology, that agriculture has led the environment movement for over half a century. The issues that are at the core of these environmental concerns have to do with the ecological, political and economic concerns of people, albeit in different forms in different countries. It is for these issues that the environment has led the arena of democratic innovations. (Paehlke, 1988). This article locates biotechnology in the context of these democratic innovations in the concerns related to sustainable agriculture, environment, science and society. *The relationship of the agricultural sciences and animal husbandry with society has been altered by the potential gains to be*
Biotechnology is currently seen as another tool in the black box for yield enhancement. Biotechnology, we argue, is a powerful stream of knowledge that can be used to study and interpret this agro-ecological black box - the yield, quality, or other genetic and ecological expressions of each crop as well as flora and fauna in soil and water systems. This requires that modern biotechnology be viewed as a new input in agricultural research systems that can help make the transition from conventional productionism to sustainable agriculture. Institutional reform, especially in \textit{ex-ante} and \textit{ex-post} research decision-making, is an essential element in this change in vision for agricultural policy and technology. This entails appropriate social science inputs and deliberative democratic decision-making. The
environmental movement seeking alternative (or anti-) science and policy inputs in the agriculture sector exerts incessant pressure for institutional and organizational change in agricultural technology generation and utilization. Biotechnology is an opportunity for the research system to respond to these demands with affirmative pro-environmental changes in the institutions and organizations of agricultural science.

References Cited


Biotechnology in the Indian National Agricultural Research System


End notes

1 The NARS in India consists of four major components, the ICAR, the SAUS, the general universities and the voluntary/private sector.

   i. The ICAR, accounting for a little over 65 percentage of the national agricultural research expenditure, conducts and co-ordinates research and education in 49 National Institutes, 30 National Research Centres, 10 Project Directorates, 80 All-India Co-ordinated Research Projects/Network Projects, one Central Agricultural University, and about 14 other research organizations.

   ii. The SAUs numbering 29 in all, and accounting for roughly a quarter of the total national agricultural research expenditure, undertake research, education and extension education at the State level. Each SAU has its own research stations, colleges, and farms.

The ICAR and the SAUS, funded directly from the public exchequer and conducting research exclusively on basic, applied and adaptive agricultural problems, are the two main components in the NARS.

2 These differences in valuations and value systems/ideologies have led to different policy approaches to biotechnology in different countries. Broadly four policy modes of policy response have been identified with reference to biotechnology: they are promotional, permissive, precautionary, and preventive. Each country can have different combinations of these policy approaches to different components of a broad biotechnology policy; i.e. a promotional policy for public research investment and a preventive policy for intellectual property rights. (Paadberg, 2000).

3 The genetic modification of rice to produce Vitamin A, and thereby combat a major malaise of malnourishment induced blindness in much of the tropical developing countries, has been called the Golden Rice. The controversy surrounding this remarkable genomic product draws from the political-economy in which it is located. Since there are clear indications of massive private profiteering and lack of any evidence or participatory research on environmental changes induced due to this transgenic crop, there is need for precaution here. Farmers who express willingness to cultivate the genetically modified crop varieties are absolutely lacking in environmental concerns, about gene flows, gene transfers across varieties, genetic or physiological transformations of soil micro flora and fauna, or any such irreversible ecological phenomenon. This proves the need for active and informed civil society questioning of agro-biotechnology. This questioning is far from “anti-science zealotry” (Borlaug, 2000) and is essential in this day and age of post-normal science. (Funtowicz and Ravetz 1990). It also highlights the need to replace the jaded philosophy of stewardship (farmer’s enlightened self-interest in preserving his soil and water resources), with the philosophy of and systems theory of sustainability.
These institutions and their features vary between organizations and even within organizations: between the SAUs and the ICAR and within each SAU or the ICAR. For instance, strong leadership and flexibility in research decision-making (when exposed to different constraints or social realities) are crucial institutions. A team of expert evaluators assessing the Rockefeller Foundation funded International Programme for Rice Biotechnology, note that leadership and flexibility to take advantage of opportunities (in research avenues and training) are easier to come by in Indian SAUs than in research organizations under the jurisdiction of the ICAR. (Evaluation Team, 1999).

All-India Compound Growth Rates of Area, Production and Yield of Principal Crops: (Base: T.E. 1981-82=100)

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<tbody>
<tr>
<td></td>
<td>Area</td>
<td>Production</td>
</tr>
<tr>
<td>Rice</td>
<td>0.45</td>
<td>4.29</td>
</tr>
<tr>
<td>Wheat</td>
<td>0.57</td>
<td>4.24</td>
</tr>
<tr>
<td>Total food grains</td>
<td>-0.11</td>
<td>3.54</td>
</tr>
<tr>
<td>Total Oilseeds</td>
<td>1.45</td>
<td>5.45</td>
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<tr>
<td>Total non food grain</td>
<td>1.21</td>
<td>4.02</td>
</tr>
<tr>
<td>All crops</td>
<td>0.21</td>
<td>3.72</td>
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Source: Ministry of Agriculture (@000) Table 16.2 (b).

The increase in private investment in recent years has been largely due to the seed industry, selected inputs and some agro-processing investments.

There has been a narrowing, in some frontier research such as mapping and gene sequencing, of the expertise available in developed and less developed countries like India. Two cases, at the University of Delhi and the Tamil Nadu Agricultural University, where (a specific protein isolated and a specific gene identified) the results were patented by the developed country collaborating (individual/institution) have necessitated institutional reform, as in the carefully drafted MOU (by the TNAU). (Evaluation Team, 1999).


The Bt cotton field trials approved by the GEAC have been stalled by legal proceedings raised by anti-biotechnology groups within civil society.
The debate about whether representative or direct participation must be sought in participatory research decision-making processes, is unresolved till date. (Lafferty and Meadowcroft, 1996).

The weaknesses in organization and science were the justification for continuing Central (ICAR) assistance to SAUs, and for maintaining that all SAUs conform to ICAR rules and formats. (ICAR, 1978, ICAR, 1988).
Promoting new technologies and reforming agricultural research and extension: Major reform and strengthening of India’s agricultural research and extension systems is one of the most important needs for agricultural growth. These services have declined over time due to chronic underfunding of infrastructure and operations, no replacement of aging researchers or broad access to state-of-the-art technologies. There is too little connection between research and extension, or between these services and the private sector.

Improving Water Resources and Irrigation/Drainage Management: Agriculture is India’s largest user of water. However, increasing competition for water Biotechnology in the Indian National Agricultural Research System: A Case for Institutional Reform. Rajeshwari S. Raina.* In India, the National Agricultural Research System (NARS hereafter) consisting of the Indian Council of Agricultural Research (ICAR), the State Agricultural Universities (SAUs), some selected General Universities, and the private and voluntary sector organizations, conducts agricultural research. This paper argues that biotechnology presents a unique and pressing case for institutional reform in agricultural technology generation and agricultural policy. Biotechnology is a powerful ally in the transition of agricultural research systems from Agricultural Research Communication Centre Journals are one of the best online open access journal site in the field of publishing research articles in Agricultural, animal, dairy, food, home, legume Research Journals on a Global platform. It should comprise the experimental design and techniques with experimental area and institutional with year of experiment. Authors need to indicate when (year/period) and where (university/institute) the present experiment was conducted. Results and Discussion: It should be combined to avoid repetition.