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India: Confronting the Challenge – The Potential of Genetically Modified Crops for the Poor

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Introduction

Can GM crops reduce poverty? Is this a likely outcome? This paper examines evidence of the impact of GM crops in India and what light, if any, it throws on these questions. Indian experience began in 2002 when the first GM crop was approved for commercial release, namely three hybrid varieties of *Bt* cotton. In 2004 and 2005 the government granted permission for the release of several other hybrid varieties of *Bt* cotton and more approvals are expected for the 2006 season. In addition, an unauthorized *Bt* cotton variety discovered in farmers' fields at the end of 2001 continues to be used, particularly in the states of Gujarat, Punjab and Andhra Pradesh. No other GM crop has been commercially released. Table 9.1 shows trends in areas planted to 2004/2005.

For economists, impacts that matter most are those affecting the economic welfare of growers, consumers and seed market agents such as suppliers. However, these are in some sense 'reduced form' impacts – the outcome of various processes including basic research, technology adaptation, biosafety regulatory procedures and their enforcement, seed pricing and competition in the seed market. As the government naturally has a large presence in these activities, its policies and the institutional mechanisms devised to formulate and implement them are among the 'structural' factors that explain the reduced form impacts, though government policies have been vigorously contested. While this chapter does not offer a 'deep' explanation, it attempts to demarcate the constituencies that have pressured policies and their enforcement.

Table 9.1 *Area planted with Bt cotton in India (acres)*

	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005
NB 151 F and F_2	200	6000	100,000	600,000	2,000,000
			100,000	200,000	800,000
					200,000
Total *Bt* cotton			200,000	800,000	3,000,000

Note: 1 acre = 0.405 hectares.

Source: Pray et al (2005)

Poverty reduction and GM crops: The links

The 2004 report of the Nuffield Council on Bioethics drew an analogy with the Green Revolution to delineate how GM crops could reduce poverty (Nuffield Council on Bioethics, 2004). Across much of Asia and Latin America available farmland is largely exhausted while expansion of non-farm employment opportunities in industry requires large investments in equipment, buildings and infrastructure. Thus, higher productivity and greater employment in agriculture is the most effective route to poverty reduction. The Green Revolution created employment for landless agricultural workers, increased yields for small farmers and reduced prices of food staples for poor consumers (Lipton and Longhurst, 1989). Now, as conventional plant breeding possibilities near exhaustion, use of GM crops could improve yields of food staples and other crops grown by the poor.

In India, the proportion of rural population living in poverty declined from above 50 per cent in the mid-1970s to about 31 per cent by the end of the 20th century.[2] During most of this period, the non-farm sector grew at twice the rate (or more) of the agricultural sector. Nevertheless, rural economic growth was found to have significant impact on reducing urban and rural poverty, while urban growth affected rural poverty very little (Ravallion and Datt, 1996). Higher farm yields is the key variable that reduces rural poverty and increases wage earnings (Datt and Ravallion, 1998).

Not surprisingly, poverty is highly correlated (inversely) with the level of agricultural earnings (Kijima and Lanjouw, 2005). As agricultural wages tend to reflect earnings of workers in other sectors, changes in agricultural wages are good indicators of changes in poverty. In India, real daily agricultural earnings increased by 69 per cent between 1983 and 1999 (Eswaran et al, 2006). In a simple two-sector equilibrium model, agricultural wages are determined by total factor productivity in agriculture and in the non-farm sector (Eswaran and Kotwal, 1993). So what have been the relative contributions of these two factors in explaining earnings increase? Despite its faster growth, the contribution of increased non-farm productivity was found to be quite limited (Kijima and Lanjouw, 2005; Eswaran et al, 2006). It was concluded that while expansion of non-farm employment does put some pressure on the agricultural labour market and help to raise agricultural wages, its impact on poverty reduction is minimal.

The Nuffield Council report emphasized the relevance of GM crops where non-farm sector growth is expensive and difficult to achieve. However, agricultural productivity growth can be central to reducing poverty even when non-farm growth is rapid. While the non-farm sector might become more important in the future, it seems very unlikely that it will be able to absorb the large numbers of poorly educated members of the labour force currently employed in agriculture.

The pro-poor potential of GM crops is more often than not asserted through Malthusian arguments that increased population pressure requires more productive technologies (Herring, 2005). However, it is well known that hunger is equally an outcome of unequal entitlements to food. The pro-poor potential of GM crops is more properly seen in improving agricultural productivity and rural incomes. Even if population growth rates are low, agricultural productivity growth can be critical to poverty reduction (Eswaran and Kotwal, 1993).

Government policy: Objectives, priorities, commitment

Biotechnology has received explicit and special attention in Indian public policy. In 1986 the government set up the Department of Biotechnology (DBT) in the Ministry of Science and Technology, giving this field the same status as atomic energy and space exploration within its science portfolio. The DBT has invested resources in education, training, research labs and networks and in its official documents it lauds biotechnology for its potential in agriculture, healthcare and other areas. It is seen as a sector where India could possess comparative advantage and be competitive globally (GoI, 2005).

The potential of crop biotechnology is seen with reference to limited natural resources, especially land, low productivity in dryland farming areas (bypassed by the Green Revolution), and loss of momentum in yield advances (Sharma et al, 2003; GoI, 2005).[3] As the official in charge of India's agricultural research programme recently asserted, 'the search, characterization, isolation and utilization of new genes through application of biotechnology are essential for the revitalization of Indian agriculture' (Rai, 2006).

Nevertheless, official support in practice has been sporadic and modest. In 2004, the government accepted a strategy for agricultural biotechnology that has two essential components (GoI, 2004). The first defines the scope of crop biotechnology by listing applications to be discouraged. GM research is not to be undertaken on exportable crops. Transgenes will not be commercialized in certain parts of the country defined as 'agro-biodiversity sanctuaries' or 'organic farming zones'. Low priority is to be given to biotechnology applications that are potentially labour-saving (such as herbicide tolerant traits).

The second component sets priorities, calling for high priority to be accorded to biotech applications that do not involve GM such as biopesticides, biofertilizers, bio-remediation agents, plant tissue culture and molecular assisted breeding. It also lists the traits and crops that deserve priority GM research. The strategy's priorities largely overlap those of Grover and Pental's 2003 survey of the research priorities of agricultural scientists involved in improvement of 12 major field crops, suggesting a consensus among the research community. Breeding for resistance to biotic stresses, pests and pathogens are major objectives for all crops. While improving water use efficiency and GM approaches to abiotic stresses are also recognized as deserving high priority, payoffs here are seen as less immediate.

For each specific crop, GM approaches are suggested for problems that are intractable using conventional breeding techniques. For instance, in the case of rice, conventional plant breeding is regarded as adequate for providing resistance to blast, bacterial leaf blight, tungro virus, gall midge, brown plant hopper and whiteback plant hopper. However, germplasm resources for stem borer, leaf folder, sheath blight and sheath rot are deemed as inadequate and requiring GM techniques. Between the two major cereal crops, rice receives higher priority for GM approaches as most of the biotic stresses in wheat can be dealt with by conventional breeding technologies.

Public sector research: Agenda and results

Situated outside the public sector agricultural research institutes, the DBT funds plant biotechnology projects both within and outside of these institutes. It also occupies a central position in the regulatory apparatus (discussed below). Thus, a wider range of expertise than could be found in traditional centres of plant breeding has been applied to plant biotechnology. This is a positive development in that it has broken the long-standing institutional monopoly of the public sector in agricultural research. However, it also gives rise to new concerns. Because of their distance from the final users of new biotechnology (i.e. the farmers) those engaged in public sector agricultural research must constantly redefine their priorities and allocate resources accordingly, especially the public sector researchers outside the specialized agricultural research institutes. The researchers within these facilities have the advantage of links with allied plant disciplines (including traditional plant breeding) and agricultural extension services, at least in principle.

The DBT supports research projects at different research institutes and agricultural universities throughout the country. It has also established specialized centres for plant biotechnology research. Specific activities funded include basic research in plant molecular biology and genomics, particularly rice genomics, in collaboration with the international genome sequencing programme. Other 'knowledge-building' types of work include tagging of quality traits in rice, wheat and mustard, and molecular methods for heterosis breeding.

In 2003, 47 projects in the public sector aimed at developing transgenes in various crops, 33 of them with resistance to insects, viruses or fungal infections. Among these, 14 projects aimed at using a *Bt* gene to develop insect resistant varieties of cotton, potato, tobacco, rice and vegetables. Other projects aimed at transgenes with male sterile and restorer lines for hybrid seed production, to delay fruit ripening, to enhance nutrition, to withstand moisture stress or flooding, and to supply edible vaccines. About half of the projects involved rice or vegetables. Other crops researched included chickpea, mustard/rapeseed, tobacco, cotton and blackgram. Because of complex genetic mechanisms, field deployment of abiotic, stress-tolerant GM crops is still regarded as distant (Grover et al, 2003). Here, more funding for research as well as collaboration among plant molecular biologists, crop physiologists and agronomists would be required.

India's public sector research programme has been criticized for spreading resources too thinly and not orchestrating a concerted research effort with select crops and well-defined goals. In 2002/2003, the annual DBT budget for crop biotechnology was only about US$3 million and total spending planned for five years (starting in 2002) was no more than US$15 million (Sharma et al, 2003). Not a single product from the public research system is in large-scale trials or close to commercialization.

Several factors seem to be responsible. First, within the traditional agricultural research institutions expertise in plant biotechnology has remained limited (Pental, 2005) and there has not been an aggressive move to acquire it. Second, the development of transgenes for commercial use requires teams proficient in various disciplines such as agronomy, plant breeding, plant pathology, entomology and biotechnology. The public sector has failed to develop such coordinated approaches. Third, the public sector has not incorporated regulatory know-how in the design of its research projects (Pray et al, 2005). Research budgets do not earmark funds for regulatory costs and delays in the regulatory process are common. A case in point is the work on insect resistance for *basmati* rice, an exportable with major markets in Europe and the Middle East. A regulatory advisor could easily have anticipated the project's difficulties in this area.

Biotechnology in the private sector

Private sector investments in biotechnology have been largely in cotton, rice and vegetables, and in a single trait – insect resistance – through *Bt* genes.

The exception was Bayer's research on genetically modified hybrid mustard. Interviews with a large number of seed/biotech firms in 2003 and 2004 (Pray et al, 2005) found that the regulatory climate had induced private firms to shift research and technology transfer priorities away from rice, vegetables and mustard toward cotton.

Both global and local factors caused the decline in rice biotech research. Globally, multinational biotech firms have reduced their research on GM rice and in India, a centre for rice biodiversity, there are special ecological concerns about it. If a GM rice variety is exportable, or if it cannot be segregated from exportable varieties, regulators have to take this into account. Bayer withdrew from commercialization of GM mustard in 2003 because of continued regulatory costs and uncertainty about whether this product would ever be approved. Among vegetables, Mahyco's *Bt* eggplant, in large-scale trials, could be the first food crop to be seriously considered by the regulatory system.

Cotton biotech research, by contrast, is on the rise. No major company has dropped out and new companies are starting applied and basic biotech programmes. In India, the first approvals to *Bt* cotton were given to three hybrids released by Mahyco Monsanto Biotech (MMB), a joint venture between an Indian seed company, Mahyco, and the major American biotech, Monsanto. These hybrids contained the *Bt* gene *Cry*1*Ac* owned by Monsanto under the brand name Bollgard. Subsequently, MMB sub-licensed the gene to other firms in India (20 as of April 2005) allowing them to incorporate it into their cotton hybrids. Monsanto is pushing the next generation of *Bt* technology – Bollgard II – which stacks C*ry*1*Ac* and C*ry*2*Ab*, through the Indian regulatory system.

Non-Monsanto *Bt* genes are still going through the regulatory process. Syngenta has been working with their VIP gene for insect resistance. JK Seeds is using a modified C*ry*1*Ac* gene developed in collaboration with the Indian Institute of Technology, Kharagpur. Nath Seeds has sourced a *Bt* gene from the Chinese Academy of Agricultural Sciences.

Biosafety regulation: How has it worked?

Indian regulatory institutions have three layers. At the bottom, an institutional biosafety committee (IBC) must be established in any institute using DNA in its research. These committees comprise institute scientists and also a member from the DBT. The IBC can approve research done at the institute unless it involves a particularly hazardous gene or technique. That type of research must be approved by the Review Committee on Genetic Manipulation (RCGM), the next layer of the system.

The RCGM, within the DBT, regulates agricultural biotech research up to large-scale field trials. It requests food biosafety, environmental impact and agronomic data from applicants wishing to do research or conduct field trials and gives permits to import GM material for research. It consists primarily of scientists, including agricultural scientists, and can request specialists to review cases. Its Monitoring-cum-Evaluation Committee monitors field trials of GM crops.

The Genetic Engineering Approval Committee (GEAC), under the Ministry of Environment and Forests, is the agency that gives permits for commercial production, large-scale field trials and imports of GM products. Although scientists are members of this committee, bureaucrats representing different ministries predominate.

Experience with regulation is exemplified by the first product that was commercialized. It contained the first event to be approved, the *Bt* gene, *Cry1Ac* from Monsanto, which was inserted in three cotton hybrid cultivars (MECH 12, MECH 162 and MECH 184) belonging to the Indian seed company, Mahyco. The first biosafety tests were done in 1997, after backcrossing, and approval for commercial release came five years later when the varieties were accepted for cultivation in southern, western and central India for a three-year period.

As the first GM product to go through the regulatory system, MMB *Bt* cotton attracted media attention. Several Indian and international NGOs opposed the application and the regulatory process was repeatedly challenged. On the basis of environmental and biosafety tests and field trials, MMB sought commercial release in 2001. However, the regulator rejected its request and asked MMB to conduct field trials at 40 locations under the direct supervision of the public sector research body, the Indian Council of Agricultural Research (ICAR). This cautious stand of the regulator and its involvement of ICAR seemed aimed at deflecting the pressure from NGOs, suspicious of the data generated from Mahyco's experiments. According to newspaper reports, the scientist members of GEAC, favouring approval, were outvoted by the bureaucrats (Jain, 2001).

This controversy led to the regulator requiring at least a year of ICAR-supervised field trials for all subsequent product approvals. Varietal testing therefore goes through small-scale trials with RCGM and large-scale trials with both GEAC and ICAR. This has indeed diffused challenges to regulatory decisions, but it has also highlighted the role of large-scale field trials in the regulatory process. The primary purpose of those conducted by ICAR is not environmental but agronomic and economic. It is assumed that farmers are unable to compare alternative varieties and must therefore be protected from potentially disastrous choices. Thus, the regulator is not merely a guarantor of the food and environmental safety of GM products but also of the agronomic and economic performance of GM crops. The redefinition of the job testifies to the pressures exerted by GM crop opponents.[4]

The 'illegal' seeds

Regulators have also had to cope with pressures from farmers. In November 2001 they discovered that some farmers in Gujarat had planted a cotton hybrid containing the *Cry1Ac* gene. This was NB 151, a variety registered with the Gujarat government as a conventional hybrid, but actually illegal as it had not been approved for release by the biosafety regulators. Multiplication and distribution of illegal seed occurs through an underground network of seed producers, small seed companies and their agents. Despite government prosecution of the guilty firm and its officials, plantings of illegal *Bt* cotton have spread across Gujarat and to other parts of India, notably Punjab.

While the state government is responsible for prosecuting violations of biosafety law, in the face of strong farmer support for illegal seeds, it has chosen to turn a blind eye. Seed law exempts farmer-to-farmer exchange of seed from inspection and this has allowed the state government to claim ignorance of the extent of illegal plantings. Moreover, illegal seed sellers try to mask their sales as seed exchange; illegal seeds are often sold loose in packets without a company seal and with no bill of sale.

The discovery of the illegal plantings with the complicity of the state government in late 2001 probably reassured GEAC that it was correct to approve the MMB hybrids in 2002. The GEAC also faces direct pressures from farmer representatives, including chief ministers of agriculturally prosperous states like Punjab (Jain, 2002). The initial approvals of the MMB varieties did not extend to Punjab and, worried by the illegal plantings, state government officials pressed the regulators for approval of varieties for their region. The latter appear to have responded, wishing to combat the spread of illegal seed. Since 2004 they have approved several other *Bt* hybrids, some from MMB, but most from other seed companies who have licensed the *Cry1Ac* gene from MMB. The regulators have used this fact to do away with food safety and environmental tests, basing their approval on large-scale field trials for agronomic and economic performance. Approval of a cotton hybrid with a *Bt* gene other than *Cry1A* is expected in 2006.

Implementation process: Political economy dynamics

The normative view of biotech regulation is that it is a process of risk assessment based on rigorous science. However, as the Indian experience attests, it is an intensely political process, contested at many levels. NGOs and civil society organizations have debated and questioned the direction of agricultural technology and forms of corporate control. Farmers have challenged the enforcement of biosafety laws that they consider out of touch with their interests. Corporations use their public relations officials to influence the process. Three government departments – biotechnology, environment and agriculture – are actively involved, each with its own interests.[5] The regulatory process has had to deal with turf disputes between scientists with different types of expertise (for example, biotech lab experience, agricultural field experience) as well as between scientists and bureaucrats.

With so many pressures, the regulatory process is subject to delays and not entirely predictable. Compliance costs of four products that went through the regulatory system or are still under regulation have been surveyed (Pray et al, 2005). These were MMB's first *Bt* cotton hybrids, Bayer's GM mustard hybrid and *Bt* eggplant and high-protein potato from public sector research institutes. Compliance costs were found to be high for MMB and Bayer. In the case of MMB, pre-approval costs were about US$1.8 million, of which US$300,000 was spent on field trials. (The largest value of cotton seed sales from any single firm is approximately US$30 million per year.)

Bayer's compliance costs were even higher, in the range of US$4–5 million. The genes used to produce hybrid mustard have been used in canola to produce hybrid canola cultivars in Canada and the US, where they have cleared the biosafety regulations. However, use of these genes in mustard has not been commercialized anywhere in the world. Because of continued costs, uncertainty about whether GM mustard would ever be approved and the market potential for this product, Bayer decided not to continue trying to commercialize it in India.

By contrast, compliance costs have not been a major constraint to research or commercialization efforts in the public sector. Regulatory delays have been the principal issue. In the case of *Bt* eggplant from the Indian Agricultural Research Institute, small-scale multi-location trials were delayed by three years. When a project has the full support of the DBT, the time and cost of regulation can be reduced. For example, regulatory costs have been minimal for high protein potato research at the Centre for Plant Genomics Research in New Delhi, often cited by the previous head of the DBT as exemplifying the consumer benefits from GM technology, though the product has not yet been approved for commercial release.

Private companies have also been polled about the costs of meeting biosafety regulations (Pray et al, 2005). These vary widely based on the type of crop; whether the gene already had been approved by regulators in India or elsewhere (i.e. in the US or Europe); and whether the tests could all be completed in India. Other differences may occur if companies wish to do more research than is required by Indian regulators in order to document certain qualities of the crops other than those required in the country.

The least expensive new events (costing about US$100,000) will be in non-food crops like cotton, involving events that have been in commercial use elsewhere like Monsanto's *Cry1Ac Bt* gene. Much basic information and the results of many field and toxicity/allergenicity tests are available from the US and other countries. US and European companies now spend from US$5–10 million for each new gene, assembling a package of information for regulators and customers in each new country in which they introduce the gene. They then perform whatever additional tests are required, taking into account differences in the way the crop is consumed, local nutritional issues and specific agricultural and environmental conditions. Ethical or political values may also enter the picture (for example, India's requirement that new varieties be tested for 'Terminator' genes, which it prohibits). New events in food crops are likely to cost the most – in the range of US$4 million.

survey must be designed so that the selection of growers is truly random and not biased towards a region or other grower characteristic. Second, the correct counter-factual must be identified. In the absence of *Bt* cotton, what would the adopters do? Would they be growing the check variety? Third, a comparison of adopters and non-adopters must control for differences in observable and unobservable characteristics. The easiest way to do this would be to compare *Bt* and non-*Bt* plots of the same farmer. This has been done in a few studies and it would work wherever there are large numbers of partial adopters.

Table 9.2 compares the difference between group means of *Bt* adopters and non-*Bt* adopters across five different studies. Of these, Bennett et al (2004) and Sahai and Rehman (2004) have results for the years 2002 and 2003, giving us comparisons from seven surveys across the years 2001 to 2003. The surveys differ in terms of sample size, states surveyed and whether they control for individual grower characteristics. Among them, Sahai and Rehman's 2004 study stands out as the only one showing a worse performance for *Bt* cotton compared to other commonly grown hybrids. Otherwise, all the papers present a common picture despite differences in methodologies. Net returns to the grower (relative to the non-*Bt* alternative) range from Rs3400 to Rs8800 (US$76–196) per acre. The increase in percentage terms varies from 49 per cent (Bennett et al (2004) for the year 2002) to 480 per cent (Qaim (2003) for the year 2001). The Qaim study uses data from MMB field trials in 2001. The Bambawale et al (2004) analysis uses an experimental setting to compare *Bt* cotton hybrids with non-*Bt* cotton hybrids under similar production practices. All the other studies use data from farmers growing *Bt* cotton under normal field conditions. It is difficult to explain the poor performance of *Bt* cotton in the Sahai and Rehman analysis and how it can be reconciled with the rapid adoption of *Bt* cotton overall. It has been suggested (Naik et al, 2005) that performance of *Bt* cotton has not been uniform across states and that its advantage over non-*Bt* cotton has been minimal in Andhra Pradesh – the state from which Sahai and Rehman draw their analysis.

Taking a conservative view of the performance of *Bt* cotton, let us suppose the return from it relative to non-*Bt* alternatives is Rs2161 (US$48) per acre, the lowest figure in Table 9.2 (except for Sahai and Rehman's). We can interpret it as the average all India figure. From the Bennet et al and the Naik studies, we see that the cost of *Bt* seed for 1 acre is Rs550 (US$12) and that of non-*Bt* seed is Rs500 (US$11). The net surplus to the seed industry from *Bt* cotton is therefore Rs1050 (US$23) per acre. The total surplus per acre generated by *Bt* cotton is the sum of grower returns and seed industry profits, which works out to Rs3211 (US$71) per acre. The share of the seed industry is 33 per cent and the remaining 67 per cent remains with the grower. Table 9.2 suggests that 67 per cent is lower, bound to the share of the grower in the surplus. In terms of aggregate gains, applying the gains to growers to the 2004 diffusion level (1 million acres of legal *Bt*) means an increase in aggregate gains of over Rs2 billion (US$44.5 million). As a proportion of overall farmer income from hybrid cotton, the gains amount to 7 per cent. The above calculations assume

Table 9.2 *Differences between Bt and non-Bt variety*

		Bambawale et al (2004)	**Bennett et al (2004)**	**Naik et al (2005)**	**Sahai and Rehman (2004)**	**Bennett et al (2004)**	**Sahai and Rehman (2004)**
Year	2001	2002	2002	2002	2002	2003	2003
Sample size (no of growers)	157	NA	2709	341	136	787	136
States	Maharashtra, Madhya Pradesh, Tamil Nadu	Maharashtra	Maharashtra	Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu	Andhra Pradesh	Maharashtra	Andhra Pradesh
Controls	Yes	Yes	Yes	No	No	Yes	No
Seed + pesticide cost	651	839.68	301.21	213		46.15	
Total cost	1159	940.89		1217	983	–	950
Yield (kg)	283	214.98		168	–70	352.23	0
Revenue	5573	4948.99		3378	–2425	8809.72	0
Returns	4414	4010.53		2161	–3408	8755.06	–950

Note: all in Rs/acre (except yield, which is kg/acre) that the additional supply due to *Bt* cotton does not affect prices. As *Bt* cotton diffuses, it will reduce cotton prices. Consumers will benefit and producer gains will therefore not be as much as when prices remained unchanged. However, the sum of consumer and producer benefits will continue to add up to 67 per cent. The exact division of gains between these two groups of agents depends on the elasticity of demand for cotton.

GM cotton seeds market: Is it competitive?

India's cotton seed market consists of three segments: varieties, public bred hybrids and private bred hybrids. By value, private bred hybrids dominate, accounting for 86 per cent of the value of the market. A *Bt* cotton hybrid seed is priced three to four times higher than a non-GM hybrid seed. Therefore, as *Bt* cotton diffuses, the value of the cotton seed market rises rapidly. It is estimated that more than half of the increase in the value of the seed market between 2002/2003 and 2004/2005 was due to *Bt* cotton and projections are that *Bt* seeds will increase the seed market by 22 per cent in 2005/2006 (Murugkar et al, 2006). If most of this increase in value accrues to owners of the technology, would that not become a force for consolidation?

In fact, the rapid growth of the private bred hybrid segment has not been accompanied by greater consolidation. With market growth, more players have come in, eating away at the share of the market leaders. Murugkar et al (2006) show that there are at least 15 firms with successful hybrid products. They argue that when judged by commonly used concentration indices – the entry of new brands, the fluctuation in market leaders and the number of established brands – the hybrid seed market has become more competitive over the last decade.

With *Bt* cotton, the seed industry encompasses a seed market as well as a technology market. As of now, the technology market consists of only one supplier – MMB, which has licensed its *Bt* gene to almost all of the leading cotton seed companies. For a seed company, developing a *Bt* product means a substantial hike in R&D investment. However, that has not constituted an entry barrier as more than 20 firms have licensed *Bt* genes from MMB. Also, not all of these firms yet have products in the market. For instance, in the 2005 season, besides MMB, hybrids from three other firms – Ankurt, Rasi and Nuziveedu were available to growers. Hybrids from other firms are still in large-scale trials awaiting GEAC's approval or at more preliminary stages of testing. Some licensees concluded their agreement with MMB in 2005 and are just beginning to do backcrossing. By contrast, Rasi's agreement with MMB dates from 1998. It conducted large-scale trials in 2002 and 2003 and obtained GEAC's permission to commercialize in 2004. The fact that not all firms started their *Bt* programmes at the same time means that those that got a head start temporarily enjoy monopoly power. GEAC's insistence on agronomic testing (through large-scale trials) favours firms that have already received commercialization approvals. Such testing is not mandatory for non-*Bt* hybrids. Although private firms can get their hybrids 'notified' by having them tested in public sector research trials they have preferred to rely on their own quality systems to build brands and push sales.

While the entry of additional *Bt* hybrids would offer growers more choices, the impact on price would be muted because, by the licensing agreement, all firms pay a fixed sum per packet of seed as trait value to MMB. *Bt* hybrids with non-Monsanto genes are expected to be approved for commercial release in 2006 or 2007. The competition from alternative genes could lead to a more serious impact on the seed price than the competition between hybrids with the MMB gene if the alternative gene providers target a trait value lower than that fixed by MMB. Whether this will happen and to what extent will depend on: first, the performance of these alternatives as compared to MMB's genes, especially Bollgard II, which promises protection against lepidopetran and the rapidly emerging spodoptera pests; and second, MMB's first mover advantage in sub-licensing the Monsanto genes to firms that have some of the best performing hybrids. Even if the alternative gene constructs prove successful, they may not be able to combine with quality germplasm. Thus, the market for the new genes may well be limited by the contractual restrictions of the major seed firms with MMB.

MMB's position as the sole gene supplier is not protected by intellectual property laws. Although India now provides for plant breeders' rights, these have not been operationalized. Even if they are, the private seed industry will be unlikely to utilize them because these rights provide few incentives for innovation (Srinivasan, 2004). As for patent laws, India's compliance with TRIPs norms means that technology suppliers can patent genes. However, the patents office has not yet granted any claims.

MMB has derived a measure of protection for its gene through biosafety laws. As biosafety approvals are obtained for the composite of the gene and the germplasm, hybrids that incorporate MMB's gene but do not go through the biosafety process are illegal. While this has not stopped the diffusion of illegal *Bt* seeds, it has led the seed companies wishing to work within the law (all of the established firms with branded products) to either deal with MMB or consider an alternative *Bt* strategy. At this point, most of the firms have chosen to license the *Bt* technology from MMB.

MMB would have gained even more from its legal monopoly but for the illegal *Bt varieties* that originated and are still dominate in Gujarat and have also spilled over into Maharashtra, Punjab and Andhra Pradesh. In the 2004 season, illegal *Bt* was priced anywhere between Rs800 (US$18) and Rs1200 (US$27) compared to Rs1600 (US$36) for a packet of legal seeds.[7] With its seemingly effective performance and its lower price, illegal *Bt* is a threat to legal seed, *Bt* or otherwise. This threat is particularly acute for non-*Bt* hybrids. With legal *Bt*, the non-*Bt* market has some protection because of the large difference in seed price. With illegal *Bt*, there is much less protection. In Gujarat, for instance, the market leader, Vikram Seeds, lost its non-*Bt* market rapidly because of illegal *Bt*.

A huge concern for the suppliers of legal *Bt* seeds is whether the illegal seeds will wipe out their market. The geographical spread of illegal seeds could be limited by its underground nature as illegal *Bt* seeds are also hybrid seeds, not reproduced by farmers but produced and distributed by a network of seed producers and distributors. The production of hybrid cotton seed requires skill, experience and access to parent lines. Gujarat has a long history of cotton seed production and some seed producers have a male parent with a *Bt* gene. NB 151 is now a generic name for illegal *Bt*. It is believed that the male parent (with the *Bt* gene) used in this variety has been crossed with a variety of female lines to generate many different versions of illegal *Bt*, often well adapted to local environments. For illegal *Bt* to diffuse widely, either seed production has to migrate or the seeds themselves have to be distributed. The second possibility is easier to imagine but even here, seed suppliers cannot use normal commercial channels to deal with first time buyers and transactions cannot be made with banking facilities but must be based on trust. An additional difficulty is that the seed cannot be branded and illegal seed producers therefore have no formal means of communicating quality to growers outside their traditional areas of operation.

Revisiting the impact of GM crops on the poor

The hope is that GM crops will revitalize crop productivity, increase the incomes of small farmers and landless workers and reduce poverty. How realistic is this possibility? And what will be needed to make it happen? In the view of crop improvement experts, GM technologies are the only way to deal with many kinds of biotic stresses in numbers of crops (Grover and Pental, 2003). Using them could reduce crop losses and significantly increase productivity, especially in dryland agriculture. GM solutions to abiotic stresses (for example, moisture stress, salinity) would have major impacts. But these require more basic research and a longer timeline is forecast for their development.

As mentioned, India's private sector has a strong presence in the distribution and marketing of seeds as well as in the development of new varieties of certain crops. The diffusion of *Bt* cotton has been the handiwork of private agents, with legal *Bt* backed by large firms with technical and marketing prowess. Unofficial *Bt* has spread on the strength of a network of skilled seed producers, small companies and their agents. The demand for both kinds of seeds has been strong because of their considerable advantages over conventional hybrids in protecting yields from pest losses. Thus, if farmers perceive gains from using certain types of seeds, the private sector has sufficient capabilities to supply them. Constraints to the adoption of beneficial GM crops do not arise from distribution.

What is of concern is appropriability. Private sector activity is confined to hybrid seed. Although India has plant breeders' rights, it is unlikely to stimulate any private sector interest in open pollinated varieties because the rights protection does not apply to seed saved or exchanged by farmers. For poverty impacts, crop productivity must rise in the major food staples, namely, the open pollinated crops of rice and wheat as well as the essentially self-pollinated grain legumes (chickpeas, pigeon peas, mung beans, groundnut, soybeans) that are extensively grown in the rainfed and dryland areas. Except in the case of wheat, scientists believe that GM technologies are essential to develop varieties resistant to pests and pathogens (Grover and Pental, 2003). Hence, governments need to solve the appropriability problem. Conventionally, what has been done is to invest the responsibility of public goods type research with the public sector, as was done with the Green Revolution. In India, however, the public sector is not yet well equipped to play this role with regard to GM crops.

Several difficulties will have to be overcome. First, the level of funding is presently too low (especially in relation to potential benefits) to support initiatives on a large scale. Second, funds need to be deployed in a focused and sustained manner. Third, there is a lack of relevant expertise within the public agricultural research sector. Public–private partnerships have been proposed in this context though none yet exist. Fourth, most of the public sector is not yet in tune with regulatory demands.[8]

If the private sector will not invest in R&D for a large number of crops, and if it is unable to take up the slack, what can be done? Experts distinguish between 'push' and 'pull' programmes to encourage R&D (Kremer and Zwane, 2005). Public sector research has typically been of the push kind. While push programmes are appropriate for basic research it is argued that they do not work as well in inducing development of products that receive wide adoption among farmers. Kremer and Zwane advocate pull programmes where the reward to technology owners is tied to adoption. Clearly, this is an attractive option whenever it is infeasible to create intellectual property rights, as with seeds.

As regards regulation, India is on a learning curve. While the regulatory process for initial products was costly and suffered delays, a more streamlined one should apply henceforth. However, this process will continue to reflect pressures from both anti- and pro-GM voices, resulting in uncertainty. If regulatory costs remain high, the private sector will focus on hybrids with large markets. Large firms that can manage regulatory procedures and expenses are unlikely to fear them. The first entrant into the *Bt* cotton market in India earned non-competitive profits but the growers were still better off.

A tricky issue is how the government should deal with illegal *Bt* seeds. By many accounts, these seeds have done well in Gujarat where they are well adapted to local growing conditions and have been backed by an effective if informal governance system reassuring farmers of quality (Herring, 2005; Lalitha et al, 2006; Murugkar et al, 2006). Not surprisingly, NB 151 and its variants have been widely adopted and a government that tried to enforce the law would suffer politically. It cannot be economically efficient to deprive farmers of a well-adapted variety. By contrast, illegal seeds have reduced the private returns to MMB's R&D. Illegal GM seeds are not unique to India; they are rampant in Brazil and China as well. Even with IPRs and biosafety laws, weak enforcement in developing countries will reduce the ability of private innovators to appropriate the gains, which in turn affects the incentives of biotech firms to develop products for these countries. The arguments of Kremer and Zwane (2005) suggest that governments could rectify this somewhat through pull programmes of research. This implies that the Indian government should stop worrying about the diffusion of illegal seeds (which are as safe and as proven in farmers' fields as the legal varieties) and compensate MMB in relation to the social gains from such diffusion.

The release of the *Bt* technology in India was accompanied by refuge policies whereby farmers were required to plant non-*Bt* cotton around *Bt* cotton. The need for such policies has been questioned where mixed cropping could provide alternative hosts for pests. However, assuming some kind of refuge restriction is desirable to manage resistance to the *Bt* toxin, how could compliance be ensured when it is not in the interest of the individual grower? This is an issue in any society; even in the US, compliance has been imperfect (Buttel et al, 2005). The problem cannot be easier in India where potential offenders are poor and numerous and enforcement capacity is weak. Finally, externalities in agriculture are not due to GM technologies alone. They frequently arise in many other contexts, including groundwater depletion and pest management. In the din of GM politics, however, such issues have been pushed to the background.

Notes

1 For valuable comments, we thank Sakiko Fukuda-Parr and participants at the seminar, Making GM Crops Work for Human Development: Socio-Economic Issues and Institutional Challenges, Bellagio, Italy, June 2005.

2 These estimates are obtained by comparing household expenditures with official poverty lines. Because of a change in survey design, poverty estimates of 1999 are not strictly comparable to earlier poverty estimates. Various researchers have produced 'adjusted' estimates – the number reported in the text is on the higher side of these estimates (Kijima and Lanjouw, 2005).

3 In the 1980s, associated with the diffusion of high yielding seeds, crop output grew at more than 3 per cent per annum compared to about 2.3 per cent earlier. In the period since, growth rates have slumped back to 2.2 per cent per annum.

4 See Herring (2005) for an analysis of how opposition to GM crops has been constructed and how it has played out in politics.

5 The involvement of the Ministry of Health has been marginal. This could

change with the debate about labelling norms and laws for GM foods.

6 The experience of JK Seeds and Nath Seeds – domestic private seed companies that are developing *Bt* cotton hybrids with non-Monsanto genes – will be instructive in this regard.

7 A packet consists of 450 grams of seed.

8 Although India now allows patents to biotechnology innovations, it may well keep in public domain the key elements of genomics and the basic biotech tools. It is not clear, therefore, that patents will hamper public sector research.

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