Plant Biotechnology in the Developing World: The Case of China

by

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A survey of China's plant biotechnologists shows that China is developing the largest plant biotechnology capacity outside of North America. This could affect trade with the United States, since it will increase China's supply and slow down imports. Ê

Private life-science companies in the industrialized world perform most of the world's agricultural biotechnology research and technology development. Farmers in the United States have been the biggest beneficiaries of this work. More than 75 percent of area sown to genetically modified (GM) crops is in the U.S.

However, it is possible that the industrialized world's monopoly on plant biotechnology may no longer exist in the near future. In the past decade China has been accelerating its investments in agricultural biotechnology research and is making breakthroughs on commodities that have been mostly ignored in the laboratories of industrialized countries. Small farmers in China have begun to aggressively adopt GM crops. And this is happening at a time when, because of consumer resistance to GM products and the rising cost of commercializing new products, private research and development on plant biotechnology in the industrialized countries is declining.

This article utilizes data from a survey of 29 of China's plant biotechnology research institutes and interviews with the research directors of the major plant biotechnology programs. The overall goal is to answer the questions: What is China doing in agricultural biotechnology research? Is China's public-sector dominated investment strategy efficient? Can China be a source of plant biotechnology for its own farmers and for farmers in the rest of the world? Will this make China more competitive in the future and/or reduce its needs to import U.S. agricultural commodities?

Plant Biotechnology Research and Achievements in China

Since the mid-1980s, scientists in China – mostly on their own, using technologies that they have developed themselves – have been applying advanced biotechnology tools to the field of plant science. The effort of the research community in China has generated an impressive array of new breakthroughs. From 353 applications between 1996 and 2000, China's Office of Genetic Engineering Safety Administration approved 251 cases of GM plants, animals and recombined microorganisms for field trials, environmental releases or commercialization (Table 1, rows 1 and 2). Of these approvals, regulators approved 45 applications for field trials of GM plant varieties, 65 for environmental release, and 31 for commercialization (rows 3 to 5).

Table 2 (on page 4) summarizes breakthroughs in China on food crops that have received little attention elsewhere. This commitment demonstrates the government of China's concern for food security. Transgenic rice resistant to three of China's major rice pests – stem borer (using Bt and CpTI genes),

Table 1. Agricultural Biotechnology Testing in China, 1997-2000

	1997	1998	1999	July 2000	Total
Total (plants, microorganisms and animals)					
Submitted	57	68	126	102	353
Approved	46	52	94	59	251
Approved for Plants					
Field Trials	29	8	28	na	45
Environmental release	6	9	30	na	65
Commercialization	4	2	24	1	31

Table 2. Genetically Modified Plants (commercialized and in trials) in China, 1999

Crop	Induced Trait
1. Cotton	Insect resistance [a] Disease resistance
2. Rice	Insect resistance Disease resistance Herbicide resistance Salt Tolerance BADH
3. Wheat	BYDV resistance and quality improvement
4. Maize	Insect resistance (Bt) & Quality improvement
5. Soybean	Herbicide resistance
6. Potato	Disease resistance
7. Rape Seed	Herbicide resistance
8. Peanut	Virus resistance
9. Tobacco	Insect resistance
10. Cabbage	Virus resistance
11. Tomato	Virus resistance [a] Shelf-life altered [a] Cold tolerance
12. Melon	Virus resistance
13. Sweet Pepper	Virus resistance [a]
14. Chili	Virus resistance
15. Petunia	Color altered [a]
16. Papaya	Virus resistance

Source: Authors' survey

[a] *Approved for commercialization; all others waiting for commercialization or environmental release*

planthopper and bacterial leaf blight (using the Xa21 gene)–have already been through at least two years of successful environmental release trials. Researchers have moved GM wheat with BYDV resistance to field and environmental release trials. China's scientists also are experimenting with GM potatoes and peanuts. They also have begun experimenting with an array of horticultural and floral crops although work is still at a very early stage.

The nation's public-dominated research system has given China's researchers a strong incentive to produce GM crops that increase yields and prevent pest outbreaks. In industrialized countries, 45 percent of all field trials are for herbicide tolerance and improving product quality; only 19 percent are for insect resistance. In China, more than 90 percent of the field trials target insect and disease resistance.

Plant Biotechnology Research Resources

Unlike the rest of the world, in which most plant biotechnology research is financed privately, China's government funds almost all of the country's plant biotechnology research. The Ministry of Science and Technology has increased investment in plant biotechnology from 16 million yuan in 1986 to 92.8 million yuan in 1999. After a number of adjustments, China's total investment in plant biotechnology in 1999 was estimated to be U.S. $112 million in Purchasing Price Parity (PPP) terms, more than 80 percent of which was directed at scientists in research academies.

Expenditures of this level, as well as future investment plans, demonstrate the seriousness of China's commitment to plant biotechnology, especially when compared to that of other developing countries. The two other large biotechnology programs in the developing world, in Brazil and India, fall short of China's. The Brazilian central agricultural research system, EMBRAPA, spends $2 million annually on genetic engineering. The Indian government allocates $15 million in PPP terms. Even after adding the investment of private firms (estimated to be $10 million), plant biotechnology research expenditures in India are still only around 20 percent of China's. Given these levels of spending, China accounts for more than half of the developing world's expenditures on plant biotechnology

Compared to the industrialized world, including the U.S., China's spending has been relatively small, less than 5 percent of the $2 - 3 billion expended in industrialized countries. Such an assessment changes, however, when comparing China to the public research spending of other countries and when considering its future plans. Globally, the public sector makes about 45 percent of the research expenditures on plant biotechnology. China currently accounts for about 10 percent of this amount. In early 2001, however, China's officials announced that they plan to raise research budgets for plant biotechnology by 400 percent over the

Table 3. Yields, Costs and Pesticide Use by Cotton Varieties in the Sampled Households, 1999

Variety	Yield kg/ha	Total Production Costs per kg cotton (yuan/kg)	Pesticide use per Hectare No. of Applications	Quantity (kg)	Cost (yuan)
Bt cotton	3371	3.10	6.6	11.8	261
Non-bt	3186	4.28	19.8	60.7	1465

next five years. If this plan is carried out, China could account for nearly one-third of the world's public spending on plant biotechnology. China's agricultural biotechnology research staff has become one of the largest in the developing world.

The Case of Bt Cotton

In response to rising pesticide use and the emergence of a pesticide-resistant bollworm population in the late 1980s, China's scientists began research on GM cotton, launching the nation's most successful experience with GM crops. Embarking on their own method for genetically modifying crops, China's scientists started with a gene isolated from the bacteria, *Bacillus thuringiensis* (Bt) and modified the cotton plant using an artificially synthesized gene that was identified with sequencing techniques. Greenhouse and field testing began in the early 1990s. When cotton yields and sown area decreased due to pest losses in the mid-1990s, in 1997 China's Office of Genetic Engineering Safety Administration approved the commercial use of GM cotton. During the same year, Bt cotton varieties from publicly funded research institutes and from a Monsanto joint venture (with the U.S. seed company Delta and Pineland and the Hebei Provincial Seed company) became available to farmers. Although officials had previously approved the commercial release of tomatoes, sweet peppers and petunias into circumscribed regions around certain cities in China, the release of Bt cotton began China's first large-scale commercial experience with a product of the nation's biotechnology research program.

Response by China's poor cotton farmers to the introduction of Bt cotton eliminates any doubt that GM crops can play a positive role in poor countries. From only 2,000 hectares in 1997, the sown area of Bt cotton grew to around 700,000 hectares in 2000. By 2000, farmers planted Bt varieties on 20 percent of China's cotton acreage. The average cotton farm in the survey sample was less than one hectare. Currently, Bt cotton in China is the world's most widespread transgenic crop program for small farmers.

Farmers are receiving the greatest benefit from Bt cotton's reduced need for pesticides. According to our producer survey, Bt cotton farmers reduced their use of pesticides by an average of 13 sprayings, or 49.9 kg, per hectare per season (Table 3). This reduced costs by 1204 yuan per hectare per season. Farmers also significantly reduced labor for pest control.

The decrease in pesticide use has increased production efficiency. Although per hectare yields and the price of Bt and non-Bt varieties were the same, the costs savings and reduction in labor enjoyed by Bt cotton users reduced the cost of producing a kilogram of cotton by 28 percent from 4.28 yuan to 3.1 yuan (Table 3). If this case is generalizable to the case of farmers that plant other crops in China (and other developing countries), plant biotechnology will certainly have an impact on world production, consumption, nutrition and trade.

Assessing the Impact of China's Plant Biotechnology Program

China's experience with Bt cotton demonstrates the direct and indirect benefits of its investment in plant biotechnology research and product development. According to our research, the total benefits from the adoption of Bt technology in 1999 were 650 million yuan. Ignoring the benefits created by foreign life science firms, the benefit from the varieties created and extended by China's publicly funded research institutes were 375 million yuan. Farmers captured almost all of these benefits since government procurement prevented cotton prices from declining (which would have shifted some of the benefits to consumers). The social benefits from research on one crop, cotton, in only the second year of its adoption were enough to fund all of the government's crop biotechnology research in 1999. As Bt cotton spreads, the social benefits from this crop will easily pay for China's past biotech expenditures on *all* crops. Clearly, the high returns are one reason China is pushing ahead with plans to expand its biotechnology research agenda.

The survey also showed that farmers reduced the use of the most toxic pesticides, organophosphates and organochlorines, by more than 80 percent, and that this reduction appears to have improved farmer health. The survey asked farmers if they had suffered from headaches, nausea, skin pain or digestive problems after applying pesticides. If the answer was "yes," it was registered as an incidence of "poisoning." Only 4.7 percent of the Bt cotton growers reported poisonings; 11 percent of the farmers who used both Bt and non-varieties reported poisonings; and 22 percent of those who used only non-Bt varieties reported poisonings.

China is still struggling with issues of consumer safety and acceptance, and it still has not approved the commercial use of GM varieties for a major food crop. Nonetheless, the needs of China's producers and consumers, the size of China's research investment in plant biotechnology, the rise of its research capacity, and its success in developing biotechnology tools and GM plants suggest that products from its plant biotechnology industry will one day become widespread inside China. If so, China's farmers will almost certainly become more productive. And the rise in productivity will directly affect China's production and will either directly or indirectly affect its trade in agricultural products. With China's accession to the World Trade Organization, the rest of the world (including farmers in the U.S.) expects to increase exports to China, and as new imports flow into the country, farm gate prices will certainly fall and reduce the income of some farm households. While we do not think that the increase in productivity will change China's long–run role as a major importer of the world's grains and other land intensive staple crops, aggressive adoption of cost reducing GM technology will slow down the flow of imports into China and reduce the decline in income that its grain farmers will experience.

China also could become an exporter of biotechnology research methods and commodities. Opportunities for contract research selling genes, markers and other tools, and exporting GM varieties are expanding in both industrialized and developing countries. China has the advantages of a large group of well-trained scientists, low cost research and large collections of germplasm.

For further information on this subject, the authors suggest the following resources:

C. James, Global Status of Commercialized Trangenic Crops, ISAAA Briefs 17, 65 (2000).

C. E. Pray, "Corporate Structure: Status of Research in a Chastened Agbiotech Sector," Paper Presented at the 2001 American Agricultural Economics Association Annual Meetings, Chicago (2001).

J. Huang, R. Hu, L. Zhang, S. Rozelle, *China's Agricultural Research Investment*, China Agricultural Press, p. 105 (2000).

Z. Xu, Biological Engineering Progress 20, 20 (2000).

R. L. Paarlberg, Governing the GM Crop Revolution: Policy Choices for Developing Countries, 2020 Vision Discussion Paper 16 (2001).

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

J. Huang, Q. Wang, Y. Zhang. "Agricultural Biotechnology Development and Research Capacity," Working Paper, Center for Chinese Agricultural Policy, Chinese Academy of Sciences (2001).

J. Huang, R. Hu, C. Pray, F. Qiao, S. Rozelle, "Biotechnology as an Alternative to Chemical Pesticides: A Case Study of Bt Cotton in China," Working Paper, Department of Agricultural Economics, University of California, Davis (2001).

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