Genetically Modified Rice in China: Effects on Farmers—in China and California

by

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China is likely to soon commercialize a genetically modified (GM) major food grain. In this report, we track not only the implications for producers in China, but also discuss how the release of GM rice might affect the rest of the world, including California's rice growers. Ê

China has not commercialized genetically modified (GM) rice, but they are close and many observers believe the time is near when national leaders will "pull the trigger." After examining the state of biotechnology research on rice in the world, in general, we examine the implications for producers in China, the world's largest rice economy. To do so, we draw on our work that has appeared in *Science* and other media. While we come to the conclusion that China's producers will benefit, the consequences of the decision to commercialize GM rice, however, likely will be felt by millions, perhaps even billions, of people outside of China. Indeed, China's decision may start a domino effect that could cascade around the globe. It also could have direct consequences for California rice growers—both positive and negative. In the second part of the article, we will speculate on some of the far-reaching consequences of the commercialization of GM rice, especially considering how it might affect California's rice industry.

Stalled Out: The Record of GM Rice during the Past Decade

One of the early promises by the supporters of agricultural biotechnology was that it could make a major contribution to the reduction of world hunger. It is now 25 years since some of those early promises were made and a decade since genetically modified (GM) crops were first grown commercially. Unfortunately, the only way that biotechnology has contributed to the well-being of small, semi-subsistent producers is through higher incomes from the production of GM cotton. There arguably has been no benefit for poor, hungry consumers. However, China is currently on the threshold of starting to fulfill the promise of more food for the poor through the introduction of rice varieties that can resist important insect pests and diseases. One important question is if GM rice were to be released, could it begin to deliver on its promise?

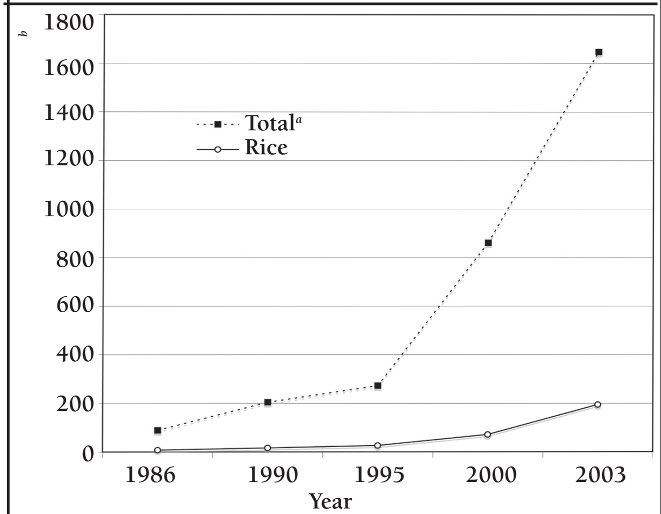
While most scientists believe that agricultural biotechnology can provide new sources of productivity growth and address some of the negative effects of conventional agronomic techniques for producers of rice and other basic food crops in China and other developing countries, at present GM varieties are primarily used for industrial crops, such as cotton, and feed crops for animals, such as yellow maize and soybeans. In the late 1980s and 1990s, government research in many developing nations—including China, often funded by the Rockefeller Foundation, began ambitious rice biotechnology research programs to develop new rice varieties that would increase yields and nutrition, reduce input use and make the rice plant, as well as other food plants, more tolerant to both biotic and abiotic stresses. This research led to a major increase in knowledge about the rice plant and rice genetics. Scientists in many of those countries—China, India, Costa Rica, to name a few—are currently conducting field trials for new GM varieties of insect and disease-resistant rice. However, due to government indecision, evolving biosafety regulatory systems, and a perceived resistance of consumers and traders, no country has yet approved GM rice for commercial use.

The difficulties of commercializing GM rice appear to be affecting the amount and direction of public and private biotech research. For example, government scientists in India are faced with increasing complications in finding locations for the trials of GM rice because of regulatory issues and pressure by anti-biotechnology groups on state governments. The private sector also is cutting back because of consumer resistance to GM products and the rising cost of commercializing new products. For example, Monsanto in the United States discontinued work on rice in the late 1990s and other companies, such as Syngenta and Bayer, have cut back on their rice research programs. California, too, has made it clear that it is not interested in trying to move forward on commercializing GM rice.

As a result, GM rice has not been commercialized anywhere in the world and little is in the pipeline in most countries. In fact, no GM staple-food crop is grown in developing countries except for Bt white maize in South Africa, where it is primarily grown by large, relatively wealthy farmers. Even in China, a country that aggressively commercialized Bt cotton and invested heavily into research on GM food crops, has not commercialized any major food crops despite the fact GM food crops have been in field trials since 1997.

One reason that commercialization may not have proceeded, especially in developing countries such as China, is that there has been little independent evidence on whether GM food crops would really improve the income and well-being of small, poor farmers. Often regulators and policymakers have to take the word of the government scientists and companies who developed and are promoting these GM products. In this article, we attempt to answer two questions: Does GM rice help reduce pesticides in the fields of farmers? Do the new varieties of GM rice increase the yields of farmers?

Figure 1. Public Research Expenditures on Agricultural Biotechnology in China: 1986 to 2003



[a] Total agricultural biotechnology spending includes spending on animals, plants and microorganisms.
[b] The official RMB-U.S. dollar exchange rate in 2003 was 8.277.
Source: Authors' survey.

China's GM Rice Research Program

China's modern biotechnology program, begun in the 1980s, has grown into the largest initiative in the developing world. A recent survey, by the authors, of agricultural biotechnology research investment in 2004 shows that the government's spending on agricultural biotechnology was US$199 million (at current exchange rates) and almost US$1 billion in purchasing power parity terms. (PPP is a method of calculating value figures that can make them comparable to those in other countries.) Rice scientists also have been provided with increasing financial resources. Although estimates of world spending on rice biotechnology are not available, given the low priority accorded by funding agencies to rice in nations with the largest biotechnology programs (such as the U.S. and the UK), it is almost a certainty that China's public investment into rice biotechnology exceeds that of any other nation.

Rice Technologies from China's GM Research Program

China's rice biotechnology research program has generated a wide array of new technologies that are at all stages of the R&D process. For example, many types of transgenic rice varieties have entered and passed field and environmental release trials and four varieties currently are in pre-production trials. Transgenic Bt rice varieties that are resistant to rice stem borer and leaf roller were approved for environmental release trials in 1997 and 1998. In experimental fields in Central China in 1999, a Bt rice hybrid yielded 28.9 percent more than its non-Bt counterpart in the presence of natural attacks of leaf roller and natural and induced attacks of yellow stem borer; scientists did not apply any pesticide on either variety. Two insect-resistant hybrids that contain the stem borer-resistant Bt genes entered pre-production trials in 2001.

Other scientists introduced the CPTi gene into rice, creating rice varieties with another type of resistance to rice stem borer and this product was approved for environmental release trials in 1999. One hybrid containing the CPTi gene, entered pre-production trials in 2001. Transgenic rice with Xa21 and Xa7 genes for resistance to bacterial blight were approved for environmental release trials in 1997 and one variety (with the Xa7 gene) entered pre-production trials in 2001. Experimental results from trials of an IRRI variety (IR72) that was transformed to express the Xa21 gene have shown that the new varieties give high levels of protection against bacterial blight. Interviews also found that although environmental release trials have not begun, field trials in China have been underway since 1998 for transgenic plants with herbicide tolerance and for varieties expressing drought and salinity tolerance in rice.

Table 1. Statistics of GM and Non-GM Rice Producers in Pre-Production Trials in China, 2002-03

	Mean	
	GM Rice[a]	Non-GM Rice
Pesticide Spray (times)	0.5	3.7
Cost of Pesticide (yuan/ha)	31	243
Pesticide Use (kg/ha)	2.0	21.2
Pesticide Spray Labor (days/ha)	0.73	9.1
Yield (kg/ha)	6364	6151

[a] GM rice includes 2 varieties: GM Xianyou 63 and GM II-Youming 86. *Source: Authors' survey*

Instead of moving ahead to commercialization, pre-production trials for the three insect-resistant rice hybrids have been expanded and, since 2001, have been carried out in at least 13 sites. According to regulations, the area for each pre-production trial should not exceed 1000 mu (or 66.7 hectares). Pre-production trials occur in both experimental station fields (and are run by technicians) and in farmer fields. Farmers in the pre-production trial sites are only provided seed and are cultivating GM rice without the assistance of technicians. The survey results in the next section come from a randomly selected sample of farmers who were enrolled in the pre-production trials.

GM Rice Adoption and Effects on Producers

In our analysis of producers who adopted GM rice, we found that the characteristics of rice producers and the prices in the markets received and paid for by households using GM rice and non-GM rice are nearly identical, and the main difference between the households is in the level of pesticide use. Specifically, when comparing GM rice and non-GM rice producers, there is no statistical difference between the size of the farm/plot, the share of rice in the household's cropping pattern, or the age or education level of the household head.

In contrast, there is a large difference between GM rice and non-GM rice production in the use of pesticides (Table 1). GM rice farmers apply pesticide less than once per season (0.5 times) compared to 3.7 times per season by non-GM rice farmers (a level which is statistically significant). On a per hectare basis, the pesticide use of non-GM rice production is more than eight to ten times higher than GM rice in terms of quantity and expenditures. GM rice farmers spend only 31 yuan per season per hectare on only 2.0 kilograms of pesticide for spraying for pests while non-GM rice users spend 243 yuan for 21.2 kilograms. Because of the reduction of pesticide application in GM rice, GM rice farmers reduced their labor use (less than 1 day/ha) compared to non-GM rice farmers (9.1 days). Although the pattern of pesticide reduction for those who adopt GM rice is similar to the reductions in the case of those who adopt Bt cotton, there is one important difference. While Bt cotton producers all continue to apply pesticides to control for a number of non-targeted pests, in the case of 64 percent of the sample GM rice plots, farmers did not apply pesticides at all. The results held up when we used more sophisticated statistical analyses.

In addition, statistical analysis also showed that GM rice outyielded non-GM varieties. As a result, the simultaneous rises in output and reductions of inputs mean that GM rice varieties have led to absolute rises in productivity. Profitability, at least for the initial adopters, is about 15 percent higher. Although there is still only a small set of farmers on which the studies are based, should the gains be similar elsewhere in China, the potential gains to China's economy could be as large as US$4 billion annually if GM rice were adopted by only 40 percent of China's rice producers. The benefit-to-cost ratio for investment into GM rice, assuming China ultimately commercializes it, will be extremely high.

Finally, the impact on farmers goes beyond productivity. In the same way that research on Bt cotton adoption showed that the productivity effects of Bt cotton were supplemented by positive health effects, according to our survey data, similar effects occur within the sample households. Among the sample farmers, there were no farmers who used all GM varieties who reported being affected adversely by pesticide use in either 2002 or 2003. Among those who cultivated both GM and non-GM plots, 7.7 percent of households in 2002 and 10.9 percent of households in 2003 reported adverse health affects from pesticide use; none, however, reported being affected after working on the GM plots. Among those who used only non-GM varieties, the health of 8.3 percent households in 2002 and three percent in 2003 was affected adversely. Although the study did not examine the effect on drinking water quality, interviews of farmers showed that many believe if pesticide use were reduced due to the adoption of GM rice, the quality of the local sources of drinking water would improve.

To Commercialize or Not: The Implications for California and Others

Although China is still struggling with issues of biosafety and considering the issues of international and domestic acceptance, many competing factors are putting pressure on policymakers to decide whether they should approve commercializing GM rice or not, and the results in this study provide evidence that should encourage commercialization. The nation has already invested several billion U.S. dollars in biotechnology research and the development of a stock of GM technologies. Many of the new events have already been through several years of environmental and pre-production trials.

GM Rice (dark) grown in a checker-board pattern with non-GM Rice (light) in experimental fields that were infested with plant-hoppers without treatment of any pesticides, China, 2002

Photo Courtesy of Authors' Research Staff

As competitive pressures inside build in agriculture from the nation's accession to the World Trade Organization in 2001, and as leaders search for ways to increase rural incomes, there will be a continuing demand by producers for productivity-enhancing technology. The past success in developing technologies and high projected rates of return suggest that products from China's plant biotechnology industry could be an effective way to both increase competitiveness internationally and increase rural incomes domestically. Our analysis shows that in the pre-production sites, the costs of those farmers who adopt insect-resistant GM rice fall and their yields rise. Given that the farmers in the sample are small and relatively poor (the average per capita income of the households in the sample was US$0.74 per day at official exchange rates), leaders concerned with agricultural productivity and farmer income likely will back any decision to commercialize GM rice.

The implications of the commercialization of GM rice, should China decide to proceed, could far exceed the effect on its own producers and consumers. Robert Paarlberg, political scientist at Wellesley College, suggests that if China were to commercialize a major crop such as rice, it is possible that it would influence the decisions about the commercialization of GM crops in the rest of the world. For example, if China were to commercialize GM rice, it possibly would clear the way for the extension to GM wheat, maize and other crops inside China. If China, a large export market in future years, proceeded in this direction, this could encourage the large grain exporting nations, such as Canada, the U.S. and Australia, to recommit themselves to expand their programs in GM wheat and other export crops, since China is a likely target for their exports in the future. More importantly, the commercialization of rice and other crops may induce other developing countries, such as India or Vietnam, to expand their plant biotechnology programs. On the one hand, other developing countries might follow China in an effort to remain competitive. On the other hand, with a clear precedent, other leaders might be willing to adopt GM food crops to increase the income of their farmers as well as to improve their health. It is in this very real sense that the future of GM rice in China may have an important influence on the future of GM crops in the world.

The rice industry in California also is likely to be affected. Although speaking off the record, officials in South Korea have stated that they likely would not allow imports of rice from China if the nation were to commercialize GM rice. Japan could do the same. Interestingly, such an action has been hypothesized even though currently all GM technologies to date have been introduced into long-grain rice varieties, the type of rice that is produced in the southern region of the United States. There are no field trials of genetically modified varieties that include the use of short/medium-grain rice. So why would East Asian consumers (and importers), who only consume (import) short/medium-grain rice, not welcome China's non-GM short/medium-grain rice? In part, it could be that those in charge of importing would fear contamination of non-GM varieties by GM varieties. It could also be in anticipation that China would eventually move to introduce GM technology into all of their varieties. Finally, South Korea and Japan may also want to use this as an excuse for reducing imports.

So who would benefit? At least in the short run, California rice growers might be expected to gain. Throughout the world, there are only two nations that are able to produce significant volumes of short/medium-grain rice for world markets. If East Asian importers refused to import GM rice from China, they would have to rely almost entirely on exports from California. From this point of view, given the high likelihood of China's eventual commercialization of GM rice, California's reluctance to extend or commercialize GM rice may be the right move. California also might be able to capitalize on the (so far) small fraction of China's consuming population that would prefer to eat non-GM rice. Of course, California rice growers can easily understand that it does not take a very large share of China's population to make a large market for GM-free California short/medium-grain rice.

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However, the decision to produce GM rice is potentially more complicated. It is possible that other factors could undermine or even offset any advantage that California might be expecting to gain. For example, if China could convince its East Asian neighbors (and its own wary consumers) that it could segregate the GM rice crop from the non-GM rice crop, China could ultimately have an advantage. With higher productivity in the long-grain rice-producing region of the country, growers in parts of the country that are able to produce either type of rice (that is, either long - grain rice or short/medium-grain rice) could move into short/medium varieties (which command a higher price premium in China's domestic market). With higher supplies of short/medium-grain rice, the price in China's domestic market could fall, allowing China to sell more competitively into export markets. In addition, it is possible that in the future the reluctance of consumers to buy GM food products could disappear. In this case, China's rice economy ultimately could be stronger since it would be a leader in GM technologies.

The current GM technologies are only scratching the surface of what biotechnology may be able to do for agriculture in the long run. At the very least, this means that even if in the short run California rice growers will not be using biotechnology, research in public and private research institutes should be encouraged.

For additional information, the authors suggest the following reading:

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