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David Colman, University of Manchester,
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Nick Vink, University of Stellenbosch,
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Agricultural biotechnology: implications for food security

Vittorio Santaniello*

Abstract

In 2015 under nourishment and famine will still be at higher levels than the targets set by the World Food Conference. Agricultural biotechnology is the major technological innovation to be made available to farmers after the end of the green revolution. The research activities of the biotech community, to provide solutions to the agricultural production problems, is intense and the results might be far reaching. The development of those technologies has been at times controversial but economic analysis of their impact have shown that producers and consumers, especially in developing countries, can benefit substantially. Although agricultural biotechnology is not a silver bullet to solve food insecurity problems, it can provide a significant help. Those technologies however need to be linked to the real needs of farmers and consumers.

JEL classification:

Keywords: agricultural biotechnology; crop varieties; research and development in agriculture; food security; gene revolution

1. Introduction

It is already generally accepted that the 2015 target—set by the World Food Conference convened by FAO—of reducing by 50% the number of undernourished, from 800 to 400 million, will not be met. The most likely figure is that by that time there will still be 600 million undernourished people in the world.

In the second half of the past century the world has experienced an unprecedented food production increase; in particular in some areas of Asia where food scarcity has traditionally been a source of special concern. Significant results have been obtained in East Asia thanks in large part to the progress made in China. Success stories are also present in some areas of sub-Saharan Africa, especially where the ecology and a favorable policy environment have made this possible. Eight of the best and six of the worst-performing countries in this battle are located in sub-Saharan Africa (Meyers, 2001).

Progress has also been made in the quality of diets, as is evident in the increase in life expectancy at birth and by a decrease in infant mortality in most areas of the underdeveloped world.

In the fight against hunger the best-performing countries have experienced growth in GDP as well as in agricultural production.

This increased aggregate production that has resulted from the first Green Revolution has made possible a substantial decrease in food prices, and has had favorable effects on the food security of those who buy part or their entire food basket. The former are prevalent in the urban areas but are present as well in the rural areas.

A new revolution, a gene revolution, is now on the way. There are, however, fears that the opportunities offered by the gene revolution could worsen the relative position of small farmers, especially those in the developing countries, making them even more threatened by market forces while losing ties with their traditional knowledge.

Advocates of these new technologies, while not completely ignoring the potential adverse effects that they may have on income distribution, maintain that these new seed-based technologies are scale neutral and accessible to farmers even without complementary inputs.

* *University of Rome "Tor Vergata," Italy.*

From a global point of view it is evident that aggregate world food supply could easily satisfy global food demand. This, however, is not a solution to the moral, economic, and political problems posed by the food shortage faced by hundreds of millions of food-insecure people. In some cases, the surplus generated in the well-endowed regions of the world, can even become part of the problem. Poverty in fact is an important component of the food security issue. Food surplus producers in developed areas are obviously often able, more than willing, and ready to supply areas where food shortages are more severe. However, while this may ease acute short-run food security problems, it could delay the implementation of lasting solutions in a more distant future. The objective of sound policy in this area should be to promote production, and efficiency in production, where food is needed the most, i.e., among the poor farmers in disadvantaged areas.

What can biotechnology do to favor this process?

2. The technology and its development

Biotechnology is a basket of tools that have in common the use of DNA manipulation procedures to obtain products or define new processes with desired characteristics. The cadre of processes and products is rather large, although those that have recently received the greatest attention are the genetically modified organisms or varieties.

These genetically engineered varieties are the result of two separate stages in the production process. The first leads to the creation of a receptor variety that has an adequate expression of a character of economic value. The second encompasses the production, starting from the receptor, of marketable varieties of the same species.

The former can be defined more properly as a biotech process, which requires heavy investment and advanced research capabilities, while the latter requires the use of more traditional breeding techniques (Traxler et al., 1999). Those who are involved in the first stage gain a comparative advantage that allows them to be actively present in the second. With a receptor variety on hand the production of a marketable variety can be obtained with a relatively minor effort. This contributes to explaining the importance allocated by biotech companies to intellectual property rights.

It has been suggested that the presence of this two-stage process could offer an opportunity for cooperation between the private and the public sectors, where the former include those private companies that are the leaders in this area of activity, and the latter could be the National Agricultural Research Services (NARS) which, being closer to the needs of local farmers are better apt to select the mix of traits that are most in demand by farmers.

In contrast to the first Green Revolution, innovations in the biotech era are mainly in private hands, within a context where public research, extension, and public seed companies are in a perilous state or have been largely dismantled. Moreover, however, while cooperation between the public and the private sectors is often advocated, it is seldom put into practice.

3. What is in the pipeline?

It is not possible to provide a comprehensive overview of the present efforts of the scientific biotech community to address the producer's problems in the developing world, or to show what agricultural biotechnology can do to solve them. This paper in fact has a far more modest and limited scope. Nevertheless, a few examples will be provided with the aim of showing how different and far reaching are the efforts now underway in biotech laboratories and in field experiments.

New fields of agricultural biotechnology research are promising, and are gaining increased support. It might be interesting to note that in November 2004 the Vatican released a document showing open support for agricultural biotechnology in general, and for the developing world specifically. The document will call upon industrialized countries to help the Third World to develop and implement these new technologies to effectively fight food insecurity and poverty.

The Rice Genome projects and the proteomics research that has followed are well known, and need not be discussed here. In addition, however, a large range of other research is being conducted that may not enjoy the same prominence, but that nevertheless will surely produce significant results in the not too distant future. Some examples include:

- CYMMIT and IITA, with the financial support of the Rockefeller Foundation, are mapping the gene resistance to Stringa that infests 21 million hectares of maize in Africa. This map should be available soon, and will allow marker-assisted backcrossing into diverse locally adapted varieties (Mannyong et al., 2003).

- Rice Yellow Mottle Virus (RYMV) is an important disease in African rice production. Endemic in African traditional agriculture, it is also increasingly present in modern irrigated schemes and in experimental fields among Asian exotic varieties. For lowland cultivars RYMV can reduce yields by up to 97%, while with more tolerant upland cultivars damage is more limited, but can be as high as 54%. Control of RYMV is difficult because the virus is highly infectious, and the epidemiology and the role of vectors is not well understood. Natural resistance exists in African rice varieties, but introduction into new varieties is not possible because of fertility barriers, poligenicity of the resistance trait, and its recessive nature. Biotechnologists have apparently been successful in "vaccinating" new varieties by introducing in their genomes fragments of RYMV genome and generating in those transgenic varieties pathogenic-derived resistance (Pinto et al.,1999).
- *Bt* (*Bacillus thurigensis*) technology is presently the most widely employed mean to introduce pest resistance into crop varieties. A considerable amount of research, however, is underway to identify alternative routes, like identification of genes that confer natural plant resistance or enzymes and other inhibitors with pesticide resistance. Virus resistance is already amply used and more is under investigation. (Hilder and Hamilton, 1994; Khush and Brar, 1998; Flasinski et al., 2000).
- *Bt* rice is already available and attempts are now under way to produce *Bt* hybrid rice. Hybrid rice (HR) was introduced commercially for the first time in China in 1976 where it now covers 13 million hectares. Rice heterosys is an important technology that is used in several Asian countries, including India, Thailand, Vietnam, Indonesia, the Philippines, and Malaysia. HR has a yield advantage over inbred varieties of up to 20%, and allowed China to produce an additional 300 million tons of paddy between 1976 and 1994. The increased production of rice obtained in the other Asian countries would have required 6 million hectares of land without the HR varieties. Besides being more productive HR is more responsive to fertilizer and more adaptable to different environments than other varieties. On the negative side, however, HR is more vulnerable to pests and diseases, especially to stem borers. Chemical control of these insects is difficult because their larvae remain in the open for only a short time before penetrating the stem. Until now transgenic HR produced with *nptII* and *bar* genes has indicated poor field performance and therefore limited potential commercial value. New *Bt* HR varieties that are produced with a different set of genes, i.e., the *cry* genes, and that are highly resistant to the larvae of leaf folder and yellow stem borer have been tested. Although introduced transgenes have some effects on yield components (number of panicles, number and weights of filled grains) this does not seem to affect rice yields negatively. In field tests the yield of *Bt* HR have in fact been 29% higher then the non-*Bt* HR control varieties (Tu et al., 2000).
- Efforts to produce transgenic varieties that are effectively resistant to fungal attack have been less successful in controlling crop losses. Moreover, at least until now, transgenic varieties expressing antifungal proteins have had disappointing results in field tests although trials and research are still intensively conducted. A gene, for example, has been isolated in the seed of alfalfa (*Medicago Sativa)* and transplanted into potato plants that produces and antifungal peptide designated as *alfAFP*, which inhibits elongation of pregerminated spores of pathogen such as *Alternaria solani* and *Fusarium culmorum* (Ai Giao Gao et al., 2000). Progress in the area of fungal protection will be highly beneficial for enhancing food security, especially in humid tropical and subtropical agriculture. In those regions of the world ecological conditions are particularly conducive to pre- and post-harvest losses caused by fungal agents.

Finally, mention should be made of the efforts made to produce drought, salinity, and acid resistance or nutrient-enriched varieties with vitamins, iron, and amino acids.

4. Benefits and beneficiaries of agricultural biotechnologies

Only a relatively small number of developing countries have introduced genetically modified crops.

Actual open field experience and data on the performance of these crops in developing countries are, therefore, limited and often refer to trial plots. Several studies on the effects of biotech in developing countries are, therefore, of an *ex ante* nature and tend to estimate what would be the effects of those crops if they were introduced.

Biotechnology often has been a controversial development, and this has limited its diffusion in the developing world. Some developing countries fear that its adoption would act as a further barrier to access to lucrative markets in Europe and Japan. This attitude can, however, backfire and make the situation unmanageable, especially where such countries are not able to police a ban. The introduction of genetically modified (GM) varieties can in fact take place in an uncontrolled fashion, as has been the case in Brazil, where it is estimated that 3 million hectares of soybean are GM herbicide resistant (Sampaio, 2002).

There is a substantial difference between the effect of new traits embodied in biotech varieties for farmers in developed and developing countries. In a developed country a *Bt* variety decreases the number of treatments that a farmer has to apply to a crop. In a developing country a *Bt* crop, in a low input agriculture, can make the difference between a reasonable harvest and a significantly reduced harvest. Most of the available data on the effects of biotech varieties in developed countries in fact tend to show that the yield effects are negligible and in some cases even negative. On the contrary, a different scenario may instead prevail in developing countries where the ecology and the techniques presently in use often cause severe yield losses.

As will be seen later, this could result in dualism even within developing countries themselves, between large and modern farmers on the one hand and poor and backward small holders on the other.

From a more general point of view the sharing of the benefits of any technological improvement in agriculture depends upon several factors. De Janvry et al. (1999) showed that sharing of benefits between rural and urban poor depends critically on the type of crop and on the nature of the technological improvement. Notwithstanding, the rural poor are always the greater beneficiaries. However, their share is still larger if the crop is not traded and/or the technological improvement is scale neutral. In the case of a cash crop technological improvements tend to lower the market price and therefore the value of the farmer's marketable surplus. In the latter case the largest benefits for the rural poor come from an increase in family consumption.

Qaim and Zilberman, (2003) report the results of a 2001 study on *Bt* cotton, conducted in seven Indian States. This experiment, which was carried out on experimental stations and that tried to duplicate the technology adopted by farmers, demonstrated a reduction of losses of 80–87% of produce. It should be considered, however, that the 2001 crop season was exceptionally severe for bollworm in India. Those results are in line with other information gathered from entomologists that indicate that losses of 50–60% are to be considered common.

An *ex ante* evaluation of the introduction of the combined resistance to three tuber-borne diseases, which affect the potato in Mexico and often cause an estimated 25% yield loss, reports that the resistance has been genetically engineered into two modern and into one traditional variety (Qaim, 1999). Consumer and producer both benefit from the new technology. However, benefits for farmers are more limited because the combinations of price and quantity variations are such that profit increases but slightly. More significant, instead, are benefits to consumers who are able to buy this produce at a lower price. Yield increases will be higher for small traditional farmers than for larger farmers. The latter in fact already have access to modern varieties and production techniques. Yield increases for traditional, medium, and large farmers were estimated to be in the range of 45%, 28%, and 15%, respectively, while per unit cost was reduced by 32%, 22%, and 13%. However, the overall benefits to small farmers were adversely influenced by the constraints in the distribution network of the GM traditional variety. The introduction of the new technology *ceteris paribus*— will, therefore, improve the condition of those small farmers who are adopters, but worsen the income distribution within the sector.

Pachico et al. (2002) have analyzed the economic and employment implications of the adoption of one of three technological innovations aimed at improving cassava production in Colombia. In their exercise they simulated the release and adoption of a transgenic herbicide-resistant variety (HRV), a traditional breeding high-yielding variety (HYV), and the mechanization of the planting and harvesting of this crop.

Estimates of production changes were based upon the judgment of cassava scientists and the analysis was conducted for six regions in northern Colombia, where cassava producers are among the poorest people, and are usually located in the most disadvantaged areas. Any improvement in their economic condition will, therefore, surely affect their capacity to access a more convenient source of nutrition. The HRV ranked first in all six regions in terms of reduction in production costs, thanks mainly to the reduced requirement for labor for weeding. The position of the other technologies varied depending upon the prevailing ecological conditions. The HYV performed better in the more favored regions, while in the less favored regions mechanization offered a better potential opportunity.

In addition to this cost analysis the authors estimated the effects on economic surplus brought about by the supply-shifting effects of the new technologies, and therefore the effects upon consumer and producer welfare. In all cases HRV produced the largest economic surplus effects, while HYV and mechanization ranked second and third, respectively. In all cases the simulation allocated 40% of the increased surpluses to consumers and 60% to producers. However, all the technologies led to a lower level of employment. This is true also for the introduction of the HYV, regardless of the fact that its adoption would require more labor per hectare. Given an inelastic demand for cassava, the increased production per hectare lowers the area needed to satisfy the quantity demanded and therefore the labor requirements at the aggregated level.

The authors do not speculate on how all these changes would be influenced by the introduction of a technology fee. However, it is clear that in a situation were weeding is performed with the help of landless labor, as is often the case; these new technologies are bound to worsen the economic condition of this social group. The effect will be more pronounced in the case of the HRV, as its introduction has the greater effect on the demand for labor.

One of the few studies available on the effects of the introduction of the *Bt* cotton in a smallholder area in a developing country has been conducted by Ismael et al. (2000) in the Makhatini Flats in the KwaZulu-Natal province in South Africa. This is one of the lesser well-endowed cotton-producing areas in South Africa, and producers face uncertain tenure. Moreover, the area is characterized by labor shortages as many men migrate to town. *Bt* cotton was introduced for the first time in this area in 1998, and since then the percentage of small holders growing *Bt* cotton has been growing constantly. Preliminary data indicate that for 2002, i.e., after 4 years, 90% of the 3,000 smallholders that grow cotton were employing the *Bt* variety. A panel made up of a random sample of 100 farmers, and including both *Bt* adopters and nonadopters, has been studied to identify the yield effects, the factors that have influenced the adoption and the economic impact on the adopters. A fraction of the farmers in the panel were already *Bt* adopters in the first year, and there were more in the second year. None of the adopters in the first year dropped the *Bt* variety in the second year. This is a first indication of the farmer's acceptance of the new variety.

Farmers in the panel belonged to an association that gave them the opportunity to exchange experiences and information in organized meetings. A private company provided credit, seeds, and other farm inputs, and bought the cotton from farmers. In the first year the yields of the *Bt* adopters were 39% higher than those achieved by the nonadopters, even though the adopters used 20% less seed due to the higher cost of the seed. The *Bt* variety also performed better in the wet crop year, producing yields that were 33% higher, because the rains wash off the chemicals used to fight pests and makes treatment more difficult to apply. The *Bt* variety was still accountable for increased production even when due consideration is given to the fact that first adopters usually are the better-off farmers who would have better results even with traditional technology.

In a later paper Thirtle et al. (2003) revisited the data, employing a stochastic efficiency frontier and the DEA model to better account for differences in farm size and labor use. This second analysis allowed the authors to estimate total, technical, and scale efficiency separately, and confirmed that the *Bt* variety was responsible for the better performance of the cotton crop in the smallholders' fields.

A sample of 299 Argentinean farmers was analyzed by Qaim and de Janvry (2003) to determine the income and environmental effects of the introduction of *Bt* cotton in the major cotton-growing regions of Chaco and Santiago del Estero. Farmers were either *Bt* adopters or nonadopters, and were divided into small (less than 90 ha) and large (more than 90 ha) categories. It was found that *Bt* had a positive effect on yields, leading to an average increase of 32%, while chemical use declined by 50%. However, small farmers usually cultivated cotton with low inputs, while large farmers employed a more sophisticated technology. In both groups of farmers the introduction of *Bt* varieties resulted in a yield increase and a reduction in the use of chemicals, but not uniformly. Yield increases were more pronounced for small farmers, who had lower yields to start with, and who hardly used chemicals. In contrast, the benefits for the larger and more advanced farmers were mostly in the form of less intense applications of chemicals.

Finally Traxler et al. (2003) report the successful introduction of *Bt* cotton in Camarca Lagunera in Mexico. Here benefits, as has also been found elsewhere, depended upon the level of lepidoptera infestation.

5. Some institutional aspects of the introduction of biotechnology in developing countries

Intellectual property rights, appropriate biosafety regulations together with the capacity of effectively implement them, and the promotion of local research capacity and cooperation between the private and the public sectors are some of the institutional issues that are most often raised and considered as essential preconditions for the effective promotion of agricultural biotechnology in developing countries.

Experience with the Green Revolution shows how the lack of local quality traits or traits adapted for local climate conditions are critical to farmers' acceptance of new varieties, and therefore to their level of adoption (Santaniello, 2002). In Thailand, for example, the rate of adoption of MV rice has been constrained because breeders have been not been able to produce varieties that are comparable to Jasmine rice from a quality perspective. HYVs that last more than 110 days and are intolerant to drought cannot be grown in eastern India, where the rainy season is short and the monsoon erratic. In regions of deep flooding (basins of Bangladesh and Cambodia, part of Uttar Pradesh) semi-dwarf varieties cannot be grown because of the risk of submergence. In Brazil only 25% of rice is under modern varieties because of the lack of suitable drought-tolerant varieties for the uplands (Hossain et al. (2003).

A national agricultural research capacity, a sound science base, and experience in traditional breeding are necessary preconditions for the development of a national biotech capacity. Evenson and Gollin (1997) in a recent, well-documented book on the Green Revolution, show that four decades of agricultural innovations have made evident the importance of the National Agricultural Research Systems (NARS) and the pivotal role that the International Agricultural Research System (IARS) has played in stimulating their growth and feeding their research activities.

For the still large number of countries where NARS have not yet developed or grown to maturity, the role of the IARS is still vital. As in the Green Revolution, the role of the IARS can be of pivotal importance in promoting agricultural biotechnology in the developing world, especially if they can adapt their policy and structure to the needs of the gene revolution. Here cooperation between private and public sectors needs to be seriously explored.

The number of "orphan" countries where neither the public nor the private sectors are active is large, probably close to 50. Here the public sector is inactive because of a lack of funds, and the private sector because the size of the market is too small and IPR protection is probably not effective. As food insecurity problems are most acute in these countries, innovative ways of promoting this partnership are urgently required.

Kremer (2003) and Master (2003) address the problem of market failure in the African research market and propose two alternative systems of public/private cooperation to stimulate scientific innovation and adoption among farmers. These schemes aim at promoting the acquisition by the public sectors of innovations, produced by the private sector, at a price based upon their estimated social value.

The Mexican experience (Traxler et al., 2003) provides clear evidence that the presence of a large national agricultural research system, the size of the agricultural area, the capacity of a university-based research establishment, and the availability of credit and technical assistance to smallholders have all been crucial to the successful introduction of *Bt* cotton in that country. In the specific case of the *Comarca Lagunera*, the capacity of the seed company to recoup the benefits of its research investments was made easier by the control that the marketing structure could exercise over producers. In another situation, however, where producers are less vertically integrated such control by the seed companies would be more problematic and therefore those companied less willing to make improved seed available to farmers.

The relevance of a well-functioning IPR system to local production, and the transfer and the adaptation of technological innovations have been questioned. Here it may be interesting to note that biotechnology innovators have ways of enforcing appropriability that are unknown in other more traditional fields such as mechanics, physics, and chemistry. These means could lower the cost of enforcing the ownership of proprietary knowledge and open *de facto* markets that, due to limited size or institutional factors, are at present neglected by the private sector.

It is well known that hybrid seeds are protected because the benefits of heterosys are limited only to the first generation. Breeders that produce hybrids can enforce their proprietary rights by limiting control to the parental lines; hence the enforcement of IPR is limited to the parental lines.

Maize is the best known case of a hybrid crop whose seeds are widely used in developing countries, although with large variation between regions. Three quarters of the total maize area in developing countries is seeded with modern varieties. Some 90% of the more than half a million tons of maize seeds that are sold annually by the seed industry in the developing countries are hybrids developed and sold by the private sector (Morris et al., 2003).

Genetic Use Restriction Technologies (GURTS) are biotechnology-based techniques that prevent unauthorized use of genetically improved varieties could fulfill the same role in this regard. GURT technologies can operate through a mechanism that makes the second-generation seed sterile (V-GURT) or which requires the application of a chemical inducer for the expression of the desired trait (T-GURT). In the latter case farmers can still use their own duplicated seed, but need to buy the inducer, which is patent protected, to activate the specific trait (FAO, 2002). The V-GURT technology operates through the activation or deactivation of a gene by an inducer to impede the embryo formation in a second-generation seed, or to block the growth of a vegetatively reproduced plant. In all cases the crop varieties do not necessarily need to be protected by patents or other IPR. The protection operates at the level of techniques needed to generate the V-GURT varieties or upon the molecule of the T-GURT inducer.

The GURT technologies can therefore be used to protect biologically improved varieties produced either transgenically or with traditional breeding, as they are, in fact, not limited to transgenic varieties, although several technical problems have yet to be solved. It is, therefore, not infeasible that the V-GURT technologies may supplant other types of protections in the future, notwithstanding negative public perceptions. The marketing of GURT varieties will not, therefore, require the elaborate institutional framework needed to implement other types of IPR for crops. However, the use of these technologies still lies in the future. Five to ten years are required for the V-GURT varieties to come to market, while the T-GURT varieties are much closer to the market.

There have been concerns (Swanson and Goeschl, 2002) that the GURT varieties might disrupt the seed improvement activities of farmers that operate in low-input farming systems, although it can be assumed that the effect on farmers that are already using modern varieties would be minimal. The detrimental effects on low-input farmers are, however, a possible side effect of the spreading of those technologies. The mere fact that those farming systems have limited links with input markets, however, makes this possibility rather unlikely. The success of these techniques might cause a widening of the gap between those who have access to them and those who do not, contributing to the worsening of the income distribution that is usually the negative side effect of many technological innovations.

GURT technologies could provide an incentive to private research to enter in the markets for inbred crops or for species where hybrid technologies have not been successful, and in seed markets where it is not now financially attractive to invest due to their limited size. GURT technologies will lower the transaction costs of IPR protection, but will increase the production costs of those varieties. The overall effect will depend, among others, on the compensatory effects of those cost variations. The International Union for the Protection of New Varieties of Plants (UPOV) system will be most influenced because the farmers' privilege and the existing research exemption will be directly affected, unless reverse engineering becomes acceptable. If the GURT technologies limit the flow of elite lines between developing countries they may also negatively influence the rate of growth of crop genetic improvement.

On the other hand, the rate of growth of crop improvements might improve because these technologies will offer innovators a better chance of recouping a share of the benefits generated by their work, especially because the time coverage of the GURT is not limited, and this is unlike patents whose protection has a limited timespan. Moreover in the case of the latter the economic life of a protected variety is often shorter than the legal protection, because of the introduction of improved and more effective competing varieties.

A well-functioning seed market is considered essential to the adoption of the new improved varieties. This is certainly true. Dalton and Guei (2003) note that the low adoption rate of new upland rice varieties in Nigeria is often attributed to weakness in the extension service and in the seed distribution service. However, this explanation must be seen against the fact that the varieties adapted to the local needs of farmers have been widely adopted in this case. These farmers, have, instead, resisted the introduction of modern varieties that were not able to outperform traditional seeds. The role of the informal seed market should not be undervalued, even in situations where public-produced varieties play an important role.

6. Summary and conclusions

This paper presents some indications of how agricultural biotechnology can help in assuring a better chance of obtaining a higher food security for the rural poor. A significant research effort is now underway to help solve production problems in developing countries. Contrary to many technological innovations of the past, biotech innovations are scale neutral, and therefore well able to help small farmers. These benefits will, however, will reach poor farmers only if the innovations are closely linked to the farmers' needs and if a national research system is properly developed.

Agricultural biotechnology can increase yields, improve the environment by decreasing the use of chemical inputs, cooperate in reducing soil erosion, and decrease the need for new land to respond to the increase in food demand. However, it is not wise to raise unreasonable expectations about what agricultural biotechnology can do. Agricultural biotechnologies are not the magic silver bullet that will eliminate food insecurity and poverty. The spread of a message that is unrealistically optimistic would be ethically wrong, economically erroneous, and politically counterproductive. Nevertheless, agricultural biotechnology can support to the efforts aimed at increasing the life expectancy and quality of many in the developing world in much the same way that the high-yielding varieties did in the Green Revolution.

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