Chapter 5
Transgenic Crops and Food Security

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Abstract This chapter provides an overview of the potential role of transgenic crops or genetically modified (GM) crops in enhancing food security. This chapter argues that although GM crops are still in their early states of adoption, emerging trends show their potential to contribute to food security. The crops have the potential to increase agricultural productivity on existing arable land; address issues of loss related to pests, disease, and drought; increase access to food through income gains; raise nutrition levels; and promote sustainable agriculture. But realizing the potential needs to be assessed in a non-deterministic, system-wide economic context. A key message is to view the role of GM technology as one of the many factors that influence food security whose contribution should be analyzed on a case-by-case basis.

Keywords Biotechnology • Environment • Food security • Genetic modification • Sustainable agriculture

5.1 Introduction

There is a need to feed a growing population of approximately nine billion by 2050 and address a surge in consumption, including a 70 % increase in the demand for food. Climate change and rising food prices will negatively impact developing countries the most. The challenge of feeding a growing population will include increasing production on existing arable land. One of the ways to combat this is by expanding the agricultural innovation toolkit, which includes genetically modified

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(GM) crops. The aim of this chapter is to review the potential contributions of GM crops to food security, which is defined to include nutrition.

It argues that though GM crops are still in their early states of adoption, emerging trends show their potential to contribute to food security. This potential, however, should be viewed in a non-deterministic, system-wide economic context. Genetic modification is just one of the many technologies that constitute food security systems. Some of the examples in this chapter, especially in nutrition, are being pursued as proof of concept and their long-term impacts cannot be assessed at the moment. The chapter is divided into four sections. The first section summarizes the debate surrounding GM crops. The second section outlines trends in food security and biotechnology. This is followed by a section that examines some of the examples of the role of GM crops in enhancing food security. The final section reviews some of the major regulatory challenges associated with the adoption of GM crops.

5.2 Debating Biotechnology

There are many claims that biotechnology cannot contribute to solving food insecurity or benefit smallholder farmers. Critics argue that biotechnology is a red herring—that food insecurity is simply the result of poor infrastructure, distribution, and income level. GM crops are also criticized for being part of the agro-industrial complex. Critics link GMOs with increased pesticide use, monoculture, and industrialized farming at the expense of smallholder farmers. They argue that large agricultural corporations perpetuate food insecurity by selling expensive, unnecessary technology to poor farmers; preventing farmers from saving seeds; destroying plant diversity; and displacing millions of farmers. Critics claim that GM crops were developed with industrialized countries in mind; that they would never be adopted or accepted by developing countries; and that the technology continues to ignore the plight of smallholders because, for example, no drought-tolerant GM crop is commercially available yet (ISAAA 2013; Belay and Nyambura 2013).

These claims are driven by a wide range of concerns that tend to assert what has not been denied and deny what has not been asserted. GM crops have the potential to increase agricultural productivity on existing arable land; address issues of loss related to pests, disease, and drought; increase access to food through income gains; raise nutrition levels; and promote sustainable agriculture. But realizing the potential needs to be viewed in a wider food security context.

5.3 Food Security and Biotechnology Trends

Food security means different things to different people. At its root, the definition has evolved from the basic "right to food"—as codified in article 25 of the Universal Declaration on Human Rights—to a more complex understanding in 2009 when the FAO convened a World Summit on Food Security and determined that "food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food, which meets their dietary needs and food preferences for an active and healthy life" (FAO 2009, p. 1). Food security also depends on four interrelated factors: quantity of food, which translates into the need for increased agricultural productivity; access to food, which is determined both by income levels and quality of infrastructure; nutrition; and overall stability of the food system, such as resilience to shocks.

GM crops can benefit smallholder farmers in several major ways. First, they help farmers avoid both production and income loss due to pests, disease, and environmental factors such as drought or flooding. This results in greater productivity. Insect-resistant traits are found to have the greatest impact in warm, tropical places where pests are more prevalent and where insecticides and inputs are not widely used—namely in developing countries.

Furthermore, in areas where farmers face a variety of problems and extension agents are scarce, biotechnology can be successful at filling the void, as it can make farming less complex, "suggesting that farmers with less human capital may benefit the most" (Sexton and Zilberman 2011, p. 13). Most important, GM crops help farmers increase their income, which in turn provides them with increased ability to consume more nutritious food. Essentially, food security is about expanding ecologically sustainable agricultural practices as well as increasing access to nutritious food. The rest of this paper seeks to address how biotechnology can play a role in increasing agricultural productivity, income levels, nutrition, and stability and resilience of the food system to various shocks, thereby helping to increase food security at the global level but especially in developing countries.

Agricultural biotechnology, which was commercialized in 1996, refers to the application of scientific information and methods such as genetic modification of crops or animals to select certain traits that are more productive or desirable. Plant breeders have long sought to improve crops through traditional methods such as cross-breeding and hybridization, a time-consuming process that results in the presence of undesirable traits mixed in with desirable ones. Genetic modification is a significantly faster, more precise technology that is designed to achieve similar results as conventional plant breeding techniques by allowing the transfer of one specific gene to another plant. It has the potential to address a host of agricultural problems.

The major types of GM crops commercially available are herbicide-tolerant (HT) crops that are resistant to broad-spectrum herbicides such as glyphosate and gluphosinates; insect-resistant (IR) crops that include a specific bacterium, *Bacillus thuringiensis* (*Bt*), which is poisonous to certain insects; and/or crops with a combination of both (stacked trait). HT and IR traits help make weed and pest control more efficient, as crops need fewer applications of herbicides and/or eliminate the need for pesticides. HT crops are the most common, comprising more than half of the 175 million hectares of GM crops grown globally in 2013, followed by stacked-trait crops at 27 %, and IR crops at around 16 % (James 2014a, b).

Both first- and second-generation GM crops are produced commercially. First-generation crops typically have a single trait introduced. Newcomers, such as Burkina Faso, benefit most from adopting second-generation GM seeds, which contain two or more genes to resist specific pests or weeds. Monsanto's Genuity™ Bollgard II® cotton, for example, "work[s] against leaf-eating species such as armyworms, budworms, bollworms, and loopers . . . [and] cotton leaf perforators and saltmarsh caterpillars" (Juma 2011a, p. 37). Second-generation cotton is a superior technology because it takes longer for pests to develop resistance. First-generation GM technology is still beneficial but will break down sooner in terms of pest resistance.

Developing countries have seen clearly the potential of GM crops to increase agricultural productivity, income, and food security. Since their commercial introduction in 1996, GM crops have been one of the "fastest adopted crop technologies in recent history" (James 2014a). In 2013, "a record 175.2 million hectares of biotech crops were grown globally . . . at an annual growth rate of 3 %." (James 2014a). This is a 100-fold increase from 1996, when 1.7 million hectares were planted. Of the 28 countries that plant GM crops, 20 are developing countries. Finally, 90 % of those who grew biotech crops—that is, more than 16 million—were resource-poor smallholder farmers in developing countries (Ibid.). The impact of GM crops at the farm level has been significant. In 2011 alone, net economic benefits were $19.8 billion, and cumulative economic benefits amounted to $98.6 billion since 1996. The key point is that the "majority of these gains (51.2 %) went to farmers in developing countries" (Brookes and Barfoot 2013, p. 74).

Yet developing countries could benefit even more from adapting biotechnology to address local problems. The technology used to delay the ripening of tomatoes, for example, could be applied to tropical fruits, which ripen too quickly and end up going to waste due to lack of proper storage or transportation infrastructure. Another problem that is prevalent in tropical countries is soil acidity. "Acidic soils comprise about 3.95 billion ha . . . about 68 % of tropical America, 38 % of tropical Asia, and 27 % of tropical Africa. In spite of its global importance . . . problems that affect acid soils are investigated by only a handful of scientists in developed countries" (Herrera-Estrella 2000, p. 924). This problem is not limited to soil acidity. In fact, there is much scope for developing countries to invest in their own science and technology research institutes, which would allow local scientists to come up with solutions specific to local contexts.

5.4 Biotechnology's Contributions to Food Security

5.4.1 Agricultural Productivity

Technology played an important role in generating significant increases in agricultural productivity during the Green Revolution. The combination of new, high-yielding crop varieties, agro-chemicals, and better irrigation techniques helped "raise food production to levels that no one would have dared predict . . . .farmers in the developing and developed countries nearly doubled their per-hectare output of cereal production, increasing yields during this time by 3.16 % annually" (Huang et al. 2002, p. 678). This led to a significant decline in poverty and hunger throughout much of Asia, because food levels rose, prices fell, and food trade and consumption increased.

However, the favorable conditions that led to the success of the Green Revolution have changed. Staple crops will be most affected by the "exhaustion of some past sources of growth [making] future yield expansion as great a challenge as in the past" (Ibid., p. 678). Overuse of fertilizers and chemical pesticides has led to pest and weed resistance and has contributed to environmental degradation; availability of arable land is declining; water resources are scarce; and climate change is causing significant changes in weather patterns, making it necessary to find alternatives to current production methods. Finally, the Green Revolution never addressed conditions specific to African agricultural productivity, such as soil depletion, lack of inputs, drought, and disease.

GM crops offer one alternative to addressing these challenges, as they are specifically designed to increase production while decreasing the use of pesticides and herbicides and addressing disease control. Increased production is necessary to feed a growing population and meet an ever-increasing demand for food. The genetically modified soybean enabled double-cropping in Argentina, which specifically helped to meet the huge increase in soy demand, driven primarily by an increased desire for meat in Asia, with only a limited effect on prices (Zilberman et al. 2010).

Although studies that examine production increases of GM crops have produced varying estimates, recent cotton studies in India and China confirmed earlier results: GM cotton production per hectare is demonstrably higher than non-GM cotton, especially in India. Other benefits include decreased pesticide use especially in China, and health benefits in both countries (Pray et al. 2011). Cotton was the most-adopted genetically engineered crop globally and saw the highest production increase, and the global price effects of planting *Bt* cotton are estimated at 10 % (Zilberman et al. 2010).

India had one of the lowest rates of cotton production in 2001–2002 (308 kg/ha). Aggregate levels of cotton increased substantially after the introduction of *Bt* cotton post-2002 (560 kg/ha) (Pray et al. 2011, p. 98). *Bt* cotton was adopted at a rate of 90 %, leading to "a 24 % increase in cotton yield per acre through reduced pest damage and a 50 % gain in cotton profit among smallholders. These benefits are stable; there are even indications that they have increased over time" (Kathage and Qaim 2012). Indian smallholder farmers who planted *Bt* cotton earned 50 % more from higher production due to reduced pest damage. With the extra income, farmers' consumption levels increased 18 % from 2006 to 2008 (Juma et al. 2014; Kathage and Qaim 2012).

In China, where surveys were conducted from 1999 to 2007, mean production of *Bt* cotton was higher than conventional cotton. One concern is that *Bt* cotton production levels will decline over time due to the development of bollworm resistance or as a result of being "backcrossed into more varieties by public- and private-sector plant breeders" (Pray et al. 2011, p. 93). Yet the data do not support these concerns. Indeed, "aggregate cotton yields continue to rise in China suggesting that *Bt* cotton also continues to do well" (Ibid.).

In developing countries more generally, where smallholder farmers use significantly fewer inputs than in developed countries, IR crops could have the greatest impact on production. By adapting the technology to local conditions, developing countries could also address the issue of yield drag, which occurs because companies typically modify generic seeds that are unspecific to a particular region. Developing countries could increase the production potential of GM crops by applying the technology to high-quality, local germplasm.

Higher production is not the only positive impact of GM crops. They also help reduce loss due to pests, weeds, and diseases. The potential of this technology lies in how it is adapted to meet specific, local needs in developing countries, which can range from combating diseases to improving indigenous crops.

Researchers in Uganda, for example, are using biotechnology to reverse the trend of *Xanthomonas* wilt, a bacterial disease that causes discoloration and early ripening of bananas and costs the Great Lakes region approximately $500 million annually. There is currently no treatment for the disease, and given its status as a staple crop in this region, solving this problem would directly increase food security and income (Juma et al. 2014; Juma 2011b). The most efficient method of containing the disease is by growing transgenic bananas instead of more labor-intensive methods. By transferring two genes from green peppers, scientists were able to grow highly resistant bananas.

In Nigeria the insect *Maruca vitrata* destroys nearly US$300 million worth of blackeyed peas—a major staple crop—and forces farmers to import pesticides worth US$500 million annually. To solve the problem, scientists at the Institute for Agricultural Research at Nigeria's Ahmadu Bello University have developed a pest-resistant, transgenic blackeyed pea variety using insecticide genes from the *Bacillus thuringiensis* bacterium.

These techniques have the potential to address a wide range of agricultural, health, and environmental issues in developing countries, leading to increased productivity and therefore contributing to increased food security.

5.4.2 Agricultural Incomes

Increasing production, reducing loss, and encouraging higher agricultural productivity among smallholder farmers has a significant effect on income and poverty. For one thing, growth in the agricultural sector is more effective at reducing poverty and increasing access to food than growth in any other sector. Since smallholder farmers comprise the majority of the workforce in sub-Saharan Africa, boosting their income levels through agricultural productivity would go a long way toward increasing food security.

The evidence from several long-term studies suggests that biotechnology is successful at helping smallholder farmers increase their income through costs savings. The last section showed how GM crops improve production and reduce loss. This translates into higher incomes at the farm level; indeed the income effect can be significant. A recent study explains how planting GM crops results in cost-savings up front, specifically with IR crops, which "require little capital and can substitute for chemical applications altogether" (Zilberman et al. 2010, p. 5). Not only were farmers able to reduce pesticide use, but they were also able to limit the related health risks.

Similarly, both IR and HT crops can reduce input expenses associated with pesticide use, such as machinery costs, fuel costs, and water use. Although seed prices for GM cotton were higher than for conventional seeds in India, these costs were "offset by reductions in expenditures on pesticides and labor, due in large part to reductions in number of required sprays" (Pray et al. 2011, p. 94). Overall production costs decreased, and net revenue increased. In fact, revenue from *Bt* cotton exceeded that of conventional cotton in every household surveyed in China (Ibid.). Results of *Bt* cotton studies in India also indicated that cost savings related to pesticide use, as well as higher production, offset the higher seed costs.[1]

When faced with less costs upfront, a reduction in crop loss, and more time available to pursue other income-generating activities, farmers have more income at their disposal, which also leads to greater consumption. So far, *Bt* cotton—which is the most widely adopted GM crop worldwide—has had the most impact on income. Approximately 15 million smallholder farmers in Burkina Faso, China, India, Pakistan, and a few other developing countries are growing *Bt* cotton. Several studies in India demonstrate the positive effects of *Bt* cotton on income, nutrition, and food security among poor farmers. Specifically, "*Bt* cotton adoption has raised consumption expenditures, a common measure of household living standard, by 18 % during the 2006–2008 period" (Kathage and Qaim 2012). In Burkina Faso, which grew 125,000 ha of Bt cotton in 2009, rural households saw production increases of approximately 18.2 % over those that grew conventional cotton; earning $39 per ha in profit. Although the seeds were more expensive, farmers saved money on inputs and labor (Vitale 2010).

Although *Bt* cotton does not directly contribute to better nutrition, it does indirectly contribute to food security by increasing household income levels and improving access to more nutritious food. This in turn increases the "purchasing power of farmers (and thus their exchange entitlements) and their access to food" (Juma et al. 2014). A recent study analyzes the impact of *Bt* cotton on caloric consumption and nutrition at the household level in four cotton-producing Indian states from 2003 to 2009. The authors find that households growing *Bt* cotton leads

[1]Different studies used different methods for calculating income gain from Bt cotton, but all indicated significantly higher profit margins for Bt cotton farmers (Pray et al. 2011, pp. 99–100).

them to consume significantly more calories—specifically, "each ha of Bt cotton has increased total calorie consumption by 74 kcal per AE [adult equivalent] a day" (Qaim and Kouser 2013, p. 6).

Furthermore, a smaller proportion of households are food insecure (7.93 % of adopting *Bt* cotton households vs. 19.94 % of non-adopting households) (Ibid., table 2). The results also show that *Bt* adoption has led to consumption of more nutritious foods such as fruits, vegetables, and animal products. The authors estimate that if the households that do not currently grow *Bt* cotton switched, "the proportion of food insecure households would drop by 15–20 %" (Ibid., p. 6).

These findings indicate that increased income among smallholder farmer households that grow *Bt* cotton lead to greater food security and consumption of more nutritious food. But the results also demonstrate that farmers are the main beneficiaries of *Bt* cotton, rather than seed companies or biotechnology companies. This reinforces how plant biotechnology can be one important tool in addressing food insecurity.

Finally, farmers have seen their insurance costs decline as production risks stabilize. As a result, they will also gain access to better risk-management products. Given the increased production and income associated with *Bt* cotton, it can be extrapolated that further development of IR crops could "serve as an engine of rural economic growth that can contribute to the alleviation of poverty for the world's small and resource-poor farmers" (James 2013).

5.4.3 Nutrition

Biotechnology is also a useful technique for enhancing the nutrition in staple crops, specifically targeting low-income families. There are several bio-fortified crops that are currently available or being tested in developing countries. These include "Golden Rice," which contains more beta carotene or Vitamin A, under evaluation in the Philippines and Bangladesh; and "Golden Bananas," bio-fortified with Vitamin A and iron and developed by Ugandan researchers (Wamboga 2011). Nearly 15 million people either rely on bananas for their income or consumption, making it one of the most important crops in Uganda. It is estimated that the per capita consumption of bananas in Uganda is 0.7 kg per day. Scientists applied the pro-Vitamin A genes used in golden rice to a popular local crop to help solve a regional health issue. Addressing vitamin deficiencies would lead to lower healthcare costs and higher economic performance.

Drawbacks to bio-fortification include a long development process, enhancing micronutrient density at the expense of other traits such as drought or pest tolerance, and a lack of both biodiversity and competition because of a limited number of enhanced crop varieties produced by only a few companies. Realizing the potential of bio-fortification can be achieved through extensive collaboration between farmers, researchers, governments, NGOs, and nutritionists (Juma et al. 2014).

Nutritional enhancements through genetic modification are still in their infancy. Examples such as Golden Rice are important because they represent proof of concept. When confirmed, they will open a wide range of opportunities for related modifications in other crops as well as the use of new techniques to improve human nutrition.

5.4.4 Sustainability and Resilience

It is well established that climate change will adversely affect agricultural productivity primarily in developing countries. Many regions are expected to suffer production loss due to "drought, flood, storms, rising sea levels, and warmer temperatures" (Goering 2012). In the past, these events were rare, and it was possible for farmers and regions to recover during the next growing season. Now it is imperative to determine ways of increasing the resilience and stability of food systems so that productivity is less affected by drought, flood, or both in the same season. Challenges include increasing productivity on existing land to conserve biodiversity and protect vulnerable land, as well as reducing agriculture's traditionally large environmental footprint.

GM crops, for example, are one of the better land-saving technologies available, as they are designed to increase production on existing plots, avoiding slash and burn agriculture often practiced in developing countries. Indeed, "if the 377 million tons of additional food, feed and fiber produced by biotech crops during the period 1996–2012 had been grown conventionally, it is estimated that an additional 123 million hectares . . . of conventional crops would have been required to produce the same tonnage" (James 2014a).

GM crops have succeeded in reducing the environmental impact of agriculture by reducing pesticide use (by an estimated 8.5 % in 2011 alone); and reducing fossil fuels and CO_2 emissions through less ploughing and less chemical spraying (saving approximately 1.9 billion kg of CO_2—the equivalent of removing 0.8 million cars from the road). The adoption of HT crops allows farmer to use a single broad-spectrum herbicide.

Limiting the practice of tilling, which is the use of mechanization for planting, weed control, and harvesting, is an important trend in sustainable agriculture. It refers to "direct planting into previous crop stubble without further soil disturbance" (Dill et al. 2008, p. 329). Farmers who practice conservation tillage aim to leave 30 % residue on the surface of the soil, which can help reduce soil erosion by 70 %.

Finally, several biotechnology tools, including tissue culture, diagnostics, genomics, and marker-assisted selection can be used collectively to isolate new traits such as drought or flood tolerance that can help mitigate the effects of climate change.

In 2012, drought wrecked havoc on maize production in the United States, highlighting what farmers in developing countries, especially in Africa, already know: drought is, "by far, the single most important constraint to increased productivity for crops worldwide." The development of drought-tolerant crops is arguably the most important GM trait that will occur in the next decade of commercialization (Edmeades 2013). The gene in question was isolated from a common soil bacterium known as *Bacillus subtilis*. It helps the plant cope better with stress caused by water shortages, allowing the plant to focus on filling the grains. The first drought-tolerant maize crop was set for commercial release in the United States in 2013, and it is hoped that it will be commercially available in sub-Saharan Africa by 2017.

In March 2008, a public-private partnership called 'Water Efficient Maize for Africa' (WEMA) was formed between Monsanto, which developed the drought-resistant technology; the African Agricultural Technology Foundation, which directs the partnership; the International Maize and Wheat Improvement Center; and five national agricultural research systems in East and Southern Africa (including Kenya, Mozambique, South Africa, Tanzania, and Uganda). WEMA is working to make the drought-resistant technology available to smallholder farmers through local and regional seed companies. The crop is being developed using conventional breeding, marker-assisted selection, and genetic modification to find the optimal crop for local conditions. Confined field trials thus far show 20–30 % higher production than conventional hybrids. Sites were selected specifically for their dry conditions. The five national research systems are coordinating the field trials. WEMA hopes to offer at least five "farmer-preferred" IR maize hybrids with and without the drought-tolerant gene by 2017, pending field trials and regulatory approval.

The 2008 food crisis demonstrated the effect of an increase in demand and a tightening of supply on the price of rice. After severe flooding in 2007 and 2008 decimated rice production in Southeast Asia, 12 countries including India and China responded by initiating export restrictions. Riots broke out in Haiti, Bangladesh, and Egypt. Although the food crisis affected all grains, a shortage of rice would prove disastrous. According to the International Rice Research Institute (IRRI), in 2005, rice comprised 20 % of global calories consumed; in Asia, 30 %. In addition, "two-thirds of the world's poor . . . subsist primarily on rice." With consumption and prices rising, production declining, and climate change effects expected to grow (e.g., Asia currently loses approximately $1 billion from flooding), IRRI estimates that "by 2015 the world must grow 50 million tons more rice per year than the 631.5 million tons grown in 2005. This will require boosting global average yields by more than 1.2 % per year, or about 12 % over the decade" (Normile 2008).

Furthermore, 25 % of the global rice supply comes from flood-prone regions. One solution has been to isolate the gene present in a variety of Indian rice that allows plants to survive after up to 3 weeks underwater. In collaboration with IRRI, researchers at the University of California at Davis used marker-assisted selection to breed this gene into locally important varieties. The result is a variety of rice that can tolerate flooding but which also retains the capability of high production. IRRI partnered with PhilRice, a nonprofit organization in the Philippines, to distribute the rice free of charge to seed growers and certain farmers who can disseminate further to other farmers. In 2011, over one million farmers in the Philippines, Bangladesh, and India planted the rice (Clayton 2009; Ronald n.d.).[2] So far, it has led to production increases of 1–3 tons after 10–15 days of flooding. Other varieties are also being studied, including drought tolerance, heat and cold tolerance, and salt tolerance. In Africa, IRRI is partnering with the Africa Rice Center (AfriRice) to develop rice that can tolerate poor soils.

5.5 Policy Implications and Future Directions

The claim that GM crops cannot benefit developing countries is clearly false. As population growth, climate change, and rising food prices become more important, it is imperative to consider all options for increasing agricultural productivity. GM crops offer one option in the agricultural innovation toolbox and must be considered as such. To be sure, GM crops are not without criticism. However, biotechnology is an important tool developing countries can use to address food security. Risks should be taken into account and the technology strengthened, but to deny farmers the right to grow GM crops would be irresponsible.

To fulfill the African Union's commitment to agricultural development, reforms are needed in country-level biotechnology R&D and risk analysis programs. To be successful, biotechnology must be embedded within a wider socioeconomic system. The policies needed to advance biotechnology are much broader than the implementation of biosafety laws. An overall policy framework is needed that promotes capacity building in local research institutes and universities (and links the two); promotes international technology cooperation; enhances knowledge management practices including intellectual property rights; and finally, addresses the safety aspect of biotechnology. For biotechnology to play a role in addressing food security, countries must not only set their priorities regarding agricultural innovation. They must also decide how science, technology, and innovation will be used in improving existing crops and agricultural productivity (Juma et al. 2014).

Developing countries must overcome strong regulatory barriers to adoption of GM crops. One of the biggest barriers to adoption is the controversy over the safety of GM crops, both in terms of human consumption and their effect on the environment. This is especially true in Africa. However, recent studies tend to support the safety of GM crops. For example, the European Commission funded more than 50 studies to evaluate this issue and found that "the use of biotechnology and of GE plants per se does not imply higher risks than classical breeding methods or production technologies" (Nicolia et al. 2013, p. 2). A literature review covering the last 10 years of GM crop safety and effects on biodiversity and human health concludes that "the scientific research conducted thus far has not detected any significant hazard directly connected with the use of GM crops" (Ibid.).

[2]The three varieties planted in India, Bangladesh, and the Philippines include Swarna Sub1, Samba Mahsuri, and IR64-Sub1, respectively (IRRI n.d.)

Despite the growing body of scientific evidence, sub-Saharan Africa in particular follows a strict interpretation of the European regulatory model, which uses the precautionary principle to evaluate GM crops (as opposed to the United States, which evaluates the crop itself). Given the differences between U.S. and European regulatory systems, there is a lack of harmonization that hinders the adoption process. A final barrier to adoption is that farmers in sub-Saharan Africa have little political power and cannot make the case for adoption, despite comprising such a large percentage of the population. This is not always the case, however. South Africa, for example, has produced GM crops for the past 18 years and has a particularly effective biosafety regulatory framework and R&D investment. South Africa also trained farmers and scientists and embarked on a substantive public awareness campaign. In addition, farmers groups (including both large-scale and smallholder farmers) were supportive of the adoption of GM crops (Adenle et al. 2013).

5.6 Conclusions

This chapter has provided an overview of the potential role of GM in food security. The examples provided are indicative of emerging trends. A key message of the chapter is to view the role of GM technology as one of the many factors that influence food security. That it is only one factor does not mean its role is insignificant. To the contrary, genetic modification has also already demonstrated its transformative power and will continue to play an important role in food security.

The future of the role of GM crops in food security will be influenced greatly by advances in science and technology. New development in genomics, molecular biology, and other allied fields will expand technological options in ways that will address some of the current uncertainties. The growth in technological abundance will also play an important role in democratizing biotechnology and bringing more players into the field. This will go a long way in helping to spread the gains of biotechnology.

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