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Genetically modified and organic crops in developing countries: A review of options for food security

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ABSTRACT

Since two decades ago, when the first GM crops were introduced, there have increasingly been hot debates on the applications of gene manipulation. Currently, the development of GM crop varieties has raised a wide range of new legal, ethical and economic questions in agriculture. There is a growing body of literature reflecting the socio-economic and environmental impacts of GM crops which aims to criticize their value for farming systems. While organic crops are promoted as environmentally-friendly products in developed countries, they have provoked great controversy in developing countries facing food security and a low agricultural productivity. Discussion has been especially vigorous when organic farming was introduced as an alternative method. There are in fact, a few tradeoffs in developing countries. On the one hand, farmers are encouraged to accept and implement GM crops because of their higher productivity, while on the other hand, organic farming is encouraged because of socio-economic and environmental considerations. A crucial question facing such countries is therefore, whether GM crops can co-exist with organic farming. This paper aims to review the main considerations and tradeoffs.

Contents

1. Introduction

Biotechnology has been applied as one of the eco-techno-political technologies in the 21st century. Many countries have developed their technological strategies to improve their productivity in different fields. In developing countries where scientific and technological bases are weak and infrastructures are not strong (Hsu et al., 2005), the formation of new biotechnology firms is mostly a strategic response rather than based on a real appreciation of environmental threats. It is maintained that the applications of this technology provide potential contributions to sustainable agricultural productivity and new inputs for resource-poor and small-scale farmers (Huang et al., 2002; Morris and Hoisington, 2000; OECD, 2003; Thirtle et al., 2003; Cohen and Paarlberg, 2004).

Since the second half of the 1980s, when the first genetically modified (GM) organisms were introduced for the industrial production of medicinal products, there has been a heated debate over the applications of gene technology. The discussion has been especially vigorous where the deliberate release of GM crops for agricultural use is concerned. To date, however, the debate has failed

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to clarify an agreed direction of policy, and has instead run into deadlock. Sharply opposed parties of stakeholders and experts characteristically advocate conflicting opinions. Meanwhile, the public is left on the sidelines, while scientists, stakeholders, and other experts are in dispute (Borch and Rasmussen, 2005).

Despite a growing area planted to GM crops worldwide, activist groups in many countries — particularly in Europe — have continued to fight the introduction of GM foods (Paarlberg, 2002). In addition, recent activities in the area of policy development have shown a growing recognition for the potential social and environmental costs imposed by GM crops (Royal Society of Canada, 2001; Canadian Biotechnology Advisory Committee, 2002). In most developing countries, farmers still do not plant any GM crops. Excluding some (e.g. Argentina, Brazil, China, and India), GM food and feed crops have not yet been commercially grown in developing countries. Yet, government authorities in most developing countries have not given farmers official permission to plant any GM crops — because of concerns about biological safety. The new EU regulation calling for strict labeling and traceability on all GM-derived foods and feeds (requiring a costly physical segregation of GM from non-GM all the way up the marketing chain) will further discourage the planting of GM crops in poor countries (Paarlberg, 2002). In response to public fears about genetically modified organisms (GMOs) in food, the European Union adopted in July 2003 two regulations establishing an EU-wide system to trace and label GMOs and to regulate the commercialization and labeling of food derived from GMOs. These new laws came into force in April 2004. On 18 May 2004, the Commission put an end to the 'de facto' moratorium on approving new GM products for the European market, which had been in place since 1998 (EurActiv, 2004).

In reaction to the concerns over agricultural biotechnology, environmentalists have strongly advocated organic farming (OF) (Franks, 1999). Because of the potential risks of GM crops, there is a growing debate which points to farmers to shift their farming method to 'organic' (Delate, 2003). The proponents of OF encourage farmers to stop GM production and implement OF. However, because of certain concerns over OF, mainly its lower productivity and therefore lower income, farmers, especially in developing countries usually do not accept this environmentally-friendly approach. There are thereby, two approaches, so-called GM and OF, which are followed by decision-makers in different countries. In developed countries, one might see the co-existence of both approaches. However, in the developing countries, with a heavier reliance on subsistence agriculture and threats of food insecurity, the co-existence of two approaches is a matter of ample considerations and tradeoffs. This paper aims to discuss these issues. To investigate these challenges, we compare the advantages and disadvantages of both GM crops and OF, and then try to make clear the existing tradeoffs between these two approaches, with particular reference to developing countries.

2. Advantages and disadvantages

2.1. GM crops

The main advantage of GM food crops is their potential promise of future food security, especially for small-scale agriculture in developing countries. The main arguments of GM supporters are safe food security, improved food quality, and extended shelf-life as the reasons why they believe in GM crops which will benefit not only both consumers and farmers, but also the environment (Wisniewski et al., 2002). As Belcher et al. (2005) discuss, a critical question is what impact(s) biotechnology companies should take into their account. For example, in corn, the productivity impact is mainly yield increase, and in soybeans the GM technology allows saving on inputs of chemicals and labor. Moreover, the companies claim that GM technology will promote food security while they are also healthier, cheaper, and more stable. Yet, the nutrients will have more quality and better taste.

The issue is the impact of international regulations on the food situation in the developing countries. In these countries, approximately 800 million people remain seriously malnourished, including at least 250 million children (UNFPA, 2005). One main debate and disagreement has already been made on the claim that biotechnology can potentially help developing countries to go for such advances as higher yields while shorter growing duration, asking for less chemical fertilizers, advanced pest management, higher drought resistance, and increased nutrients quality. Such advantages of GM crops would mitigate public hesitation about GM technology (Sharma, 2003). Some also acknowledged the potential of plant biotechnology to improve plant breeding and crop production in developing countries.

Despite claims to the contrary, as well-evidenced by Third World Network (2009), trade liberalization and globalization are resulting in declining food production and posing a threat to food security, particularly in the countries of the South. The same processes are also wiping out small efficient family farms and replacing them with inefficient and unhealthy industrialized food systems under multi-national agribusiness corporations. Such corporations are supposed to increase production of food, increase efficiency of food production, improve the economic situation of farmers and improve patterns of food consumption. However, the evidences point to the opposite direction. In fact, the beneficiaries of such corporations are neither farmers nor governments of in the South, but making more money for the North, as Senator McGovern of the US Senate had stated, "Food security in private hands is no food security at all" because corporations are in the business of making money, not feeding people.

In their book "Seeds of Contention", Pindstrup-Andersen and Schibler (2001), provide a more balanced view of GM crops in the developing countries (Borch and Rasmussen, 2005). They argue that GM crops may be one element in the solution to poverty and hunger in the developing countries and that people in these countries should have knowledge about benefits and risks and the freedom to make their own decisions about whether or not to grow and consume these crops (Closter et al., 2004). Moreover, GM crops can contribute in designing new foods with specific health protective properties, but given the relatively poor state-of-the-art with respect to knowledge on working mechanisms, joint research in epidemiology, nutrition, and food toxicology is first needed in order to select relevant compounds and to demonstrate their beneficial action (Kuiper et al., 2002). Particularly, in the rapidly emerging economies, such as China, agro-biotechnological innovations in developing economies should be introduced with caution. On the one hand, these countries dispose of the technological and scientific capacity to launch major GM development programmes. However, they often lack the state capacity and civil society forces to effectively consider, monitor and enforce bio-safety policies, on the other hand. In this context, Zhao and Ho (2005) have coined the term "developmental risk society" — a society in which government and science confronted with major development issues, might more easily disregard technological risks due to the absence of sufficient countervailing forces.

While GM crops might create great possibilities to ensure future food security, concern over negative impacts associated with the introduction and proliferation of GM foods are increasing. These concerns have been exacerbated by the rapid proliferation of GM crops and the rapid increase in land area allocated to these productions (Belcher et al., 2005). The international diffusion of these crops dependent on trade linkages (van Meijl and van Tongeren, 2004) mainly held by big companies which have heavily invested in gene technology.

The legal accountability inherent in biotechnology is appearing as a significant consideration in profitability and adoption of GM crops

and asking for the possible co-existence with conventional products in the food chain increases (Globe and Mail, 2004; SCC, 2004). Such legal developments could explain why those farmers who choose GM crops are concerned about taking a risk of litigation mostly from the companies and public institutions (Soregaroli and Wesseler, 2003).

As mentioned by Belcher et al. (2005), the body of research examining the spatial aspects of contamination by GM crops is now growing. A few researchers have currently been busy with the identification of effective and appropriate separation distances, and with developing criteria being used for the separation of GM crops from other sensitive crops to decrease the probability of cross-pollination to below a certain threshold level (Hucl and Matus-Cadiz, 2001, Rieger et al., 2002; Soregaroli and Wesseler, 2003).

Nevertheless, the critics of genetic engineering of foods have concerns, not only for safety, allergenicity, toxicity, carcinogenicity, and altered nutritional quality of foods, but also for the environment. In this context, it would be interesting to note that the recent research has contested the claims of reduced pesticide use by genetically modified cotton (Bt cotton) due to the rise of secondary pests (other than the main cotton pest — the bollworm). The rise of secondary pests also points to unforeseen ecological changes caused by the cultivation of GM crops. Men et al. (2004: 246) noted: "Although insecticides were not applied against the cotton bollworm on transgenic cotton, the total number of insecticide applications was no less than the total applied on non-transgenic cotton, because additional applications were required against sucking pests on transgenic Bt cotton". These results were confirmed in a recent research, based on a survey of 1000 cotton farm households in China. It was then found that farmers have perceived a strong increase in secondary pests after Bt cotton was introduced (Ho and Xue, 2008).

Uzogara (2000) already introduced the main GM crops' critics who are mostly politicians, environmentalists and concerned scientists, but also organic farmers, consumer and health advocacy groups, public interest groups, trade protectionists, grain importers, religious rights groups, and ethicists. The critics warn the adverse consequences which can be driven from applying GM techniques to human food production. For these critics, safety, ethical, religious, and environmental concerns are more important than the interest in improved food taste, increased food production, and having a modern agriculture through GM techniques. Uzogara believes that bioscience touches agriculture on some important concerns such as: (1) the right of consumers to know what exactly they eat; (2) the right of individual countries to set up some standards and monitoring rules as they deem fit; (3) the relationship between multinational companies, scientists, farmers, and government regulators; (4) the impact of GM crops on biological diversity; (5) the possible negative impacts of GM crops on the food security and safety; (6) the possible risk of spreading antibiotic resistance to human and livestock; (7) the possible risk of insects' resistance to GM plant toxins; (8) the ecological impact of spreading GM crops. However, the total list appears to be more of a critique of intensive, industrialized capitalist farming practices than a criticism of GM foods. Table 1 shows the main (dis) advantages of GM crops and their cited references.

Regarding the right to know, not only consumer awareness, but more importantly, also their understanding of GM technology is critical. In this regard, there is a major concern that in the developing countries, access to information might be significantly more difficult than in the developed. A recent survey testing Chinese consumers' understanding of GM food is a case in point. In the survey, it was found that less than one fifth (18%) of the sample could give correct answers to the questions: "is it false to say that non-GM soybeans do not have genes?" and "is it false to say that eating GM food may change one's genes?" Most respondents (68%) were also unable to name any GM crop. Among those who could, one half could mention only one GM crop. Lastly, a majority did not believe that GM crops could cause damage to other crops or the ecology: 38% answered they did not, 29% "maybe, but nothing important", and only 13% said they did (Ho et al., 2006).

Table 1
Main (dis)advantages of GM crops and their cited reference(s).

Main advantages	Reference(s)
High yield productions	Wisniewski et al., 2002; van Meijl and van Tongeren, 2004; Egelyng, 2000; Kuiper et al., 2002; Uzogara, 2000
Cheaper products	van Meijl and van Tongeren, 2004
Greater drought resistance	Sharma, 2003
Main disadvantages	**Reference(s)**
Less quality of foods	Phillips, 1994; Young and Lewis, 1995; Hobbs and Plunkett, 2000; Knoppers and Mathios, 1998
Antibiotic resistance	Hileman, 1999a; Phillips, 1994; AgResearch, 2001; Malarkey, 2003
Potential toxicity from GM foods	Phillips, 1994; Malarkey, 2003
Possible creation of allergenicity	Billings, 1999; Coleman, 1996; Nordlee et al., 1996; Malarkey, 2003; AgResearch, 2001
Unintentional gene transfer from GM to non-GM crops or to wild plants	Hileman, 1999a; Kaiser, 1996; Rissler and Mellon, 1993, 1996; AgResearch, 2001; Downey and Beckie, 2002; Haslberger, 2001; Rieger et al., 2002; Gilligan et al., 2003; Hucl and Matus-Cadiz, 2001, Soregaroli and Wesseler, 2003
Possible creation of new viruses and toxins	Phillips, 1994; AgResearch, 2001; Malarkey, 2003; Patterson and Painter, 1999; Weihl and Roos, 1999
Limited access to seeds through patenting of GM food plants	Lustgarden, 1994; Koch, 1998
Threat to crop genetic diversity	Koch, 1998; Phillips, 1994; AgResearch, 2001
Religious/cultural/ethical concerns	Crist, 1996; Robinson, 1997; Thompson, 1997; Dyer, 1996; Wilmut et al., 1997; Woodard and Underwood, 1997; Schardt, 1994; Share, 1994
Concerns for lack of labeling	Federal Register, 1992; Hoef et al., 1998; Cummins, 1997; Weiss, 1998
Concerns of animal rights group	Kaiser, 1996; Koenig, 1999; Dyer, 1996; Wilmut et al., 1997
Concerns of organic and traditional farmers	Koch, 1998; AgResearch, 2001
Fear of the unknown impacts	Koch, 1998; Longman, 1999; AgResearch, 2001
The risk of the GM plant itself becoming a weed	AgResearch, 2001
Concerns over the wider ecosystem because of direct and indirect effects on no target species	ACRE, 1997; Mantegazzini, 1986; Diamond, 1997
Environmental concerns	Longman, 1999; OECD, 1993; Raybould and Gray, 1993; Ellstrand, 1992; Ellstrand and Hoffman, 1990

2.2. Organic farming

Among many benefits of OF, the most obvious advantage that might mostly be considered for small-scale farmers is their traditional knowledge of the natural environment that can be well-matched with OF (Closter et al., 2004). Concurrently, OF avoids chemical inputs (Laird, 2001; Nijhoff and Andersson, 2001; Benbrook, 1999), which are generally expensive for small-scale farmers who have a livelihood farming system and earn normally much less than large-scale farmers who can afford expensive technologies. Additionally, small farmers cannot easily eliminate the harmful effects of chemicals which normally need big funds to deal with. Yet, there is a fair amount of debate on whether or not OF is a lower-cost technology (Yelm Earthworm & Castings Farm, 2003; Cacek and Langner, 1986; Foley, 2006), and promotes biodiversity (Meacher, 2000; Randerson, 2004; Nutiva, 2002). Another matter of debate is production costs which can potentially be increased by the adoption of OF, more specially, if major

soil protection or restoration activities are needed. For instance, if farmers need to control weeds mechanically, they may need bigger funds to buy or rent such vehicles than chemical ways. Although in other cases, they might be able to reduce the costs through biological ways of control (Closter et al., 2004).

Also, the wider community could appreciate the advantages of OF as it controls soil erosion (Das, 2004; Rai, 2006; Geherman et al., 2003; Nijhoff and Andersson, 2001), soil fertility (Greenthumb, 2002; Lampkin and Midmore, 1999; Cacek and Langner, 1986), promotes green coverage (Closter et al., 2004), and reduces toxic chemicals (Foley, 2006; Benbrook, 1999). Therefore, it creates a healthier life for downstream communities with (e.g.) a cleaner, healthier and more-abundant water supply while neighboring communities with all the advantages of a healthier and less-polluted environment (Lampkin and Midmore, 1999; Cacek and Langner, 1986; ESRC, 1999; ESRC, 1999; Laird, 2001; Foley, 2006). It is often presumed that OF is the most 'environmentally friendly' farming system, but in fact, on anything but on a local scale, it cannot be judged in terms of sustainability because the regional and national demands for food involve more nutrients than are available to OF (EFMA, 2005).

There are some constraints which inherently exist in small-scale farmers' adoption of organic agriculture: few in-farm scientific research on organic methods; their hard access to organic plant, plant-protection inputs and animal breeds; their poor knowledge and ability to react to unpredicted external factors, such as drought, the sudden arrival of new diseases or pests (Foley, 2006; Benbrook, 1999); the high certification cost; their little bargaining power with buyers; their hard access to organic markets; and the bias of most legal structures in favor of conventional agriculture (Closter et al., 2004).

The main hurdle for transition from conventional agriculture to organic is the major costs often involved in such a transition as it unavoidably increases the prices of the products, especially in developing countries where the agricultural sector is not independent in terms of producing the strategic products (mainly, wheat and cereals), farmer organizations (e.g. cooperatives) are weak; and lack of those organizations which can set up main organic standards with regard to quality control of the products and existing realities in farming systems (Organic Farming Research Foundation, 2006; Benbrook, 1999).

There are also some concerns regarding the inability of organic agriculture in sustaining soil-fertility and nutrient levels (Greenthumb, 2002; Lampkin and Midmore, 1999; Cacek and Langner, 1986). However, using purchased organic matters, spraying organic nutrients and green manure/cover crops, as well as appreciating some traditional techniques (e.g. crop residues and compost), farmers can deal with such a problem (Peters, 2003; Closter et al., 2004).

Another important critique is the price of organic crops which are more expensive, and therefore, low-income families and people, in developing countries, despite their desire, cannot afford it (Organic Farming Research Foundation, 2006; Foodaware, 2002). While organic foods have a price premium, the difference of the price can

Table 2
Comparison the main (dis)advantages of OF and their cited references.

Main advantages	Reference(s)
Reducing health risks	Organic Farming Research Foundation, 2006; Sustainable Enterprises, 2002; Nutiva, 2002; Yelm Earthworm & Castings Farm, 2003; Foodaware, 2002; Foley, 2006; Benbrook, 1999
Better quality	Organic Farming Research Foundation, 2006
Promoting biodiversity	Meacher, 2000; Randerson, 2004; Nutiva, 2002; Greenthumb, 2002; Foodaware, 2002; Lampkin and Midmore, 1999; Cacek and Langner, 1986; Science News, 2002; Das, 2004
Implementing farmers' knowledge	Closter et al., 2004
Serving water resources	Sustainable Enterprises, 2002; Nutiva, 2002; Yelm Earthworm & Castings Farm, 2003; ESRC, 1999; Laird, 2001; Foley, 2006
Strong commitment of farmers to their land	Sustainable Enterprises, 2002; Nutiva, 2002; Foodaware, 2002
Working with nature in harmony	Nutiva, 2002; EFMA, 2005; Trewavas, 2004
No pesticide, herbicide, fungicide residues on food	Sustainable Enterprises, 2002; Yelm Earthworm & Castings Farm, 2003; Foley, 2006; Benbrook, 1999
Less chlorine chemistry into our environment	Sustainable Enterprises, 2002
No synthetic fertilizer residuals built into plants	Sustainable Enterprises, 2002; Greenthumb, 2002; Laird, 2001; Nijhoff and Andersson, 2001
Intense, realistic taste and flavors	Nutiva, 2002; Sustainable Enterprises, 2002; Yelm Earthworm & Castings Farm, 2003; Foodaware, 2002; Foley, 2006
Higher vitamin content	Sustainable Enterprises, 2002
Higher mineral content and greater mineral variety	Sustainable Enterprises, 2002; Yelm Earthworm & Castings Farm, 2003; Science News, 2002; Bryan and Newcombe, 2005
No pesticide residues on foods	Sustainable Enterprises, 2002; Yelm Earthworm & Castings Farm, 2003; Bryan and Newcombe, 2005; Holden, 2004; Laird, 2001
Reducing pollution	Lampkin and Midmore, 1999; Cacek and Langner, 1986; ESRC, 1999
Conserving energy	Lampkin and Midmore, 1999; Cacek and Langner, 1986; Science News, 2002; Holden, 2004
Making balance	Balfour, 2003
Conserving insects	Greenthumb, 2002; Nutiva, 2002
Less cost	Yelm Earthworm & Castings Farm, 2003; Cacek and Langner, 1986; Foley, 2006
Creating job	Holden, 2004
Enhancing soil fertility	Greenthumb, 2002; Lampkin and Midmore, 1999; Cacek and Langner, 1986, Science News, 2002; ESRC, 1999; Das, 2004, Kirchmann and Ryan, 2004
Minimizing soil erosion	Sustainable Enterprises, 2002; Yelm Earthworm & Castings Farm, 2003; Greenthumb, 2002; Lampkin and Midmore, 1999; Cacek and Langner, 1986; Science News, 2002; Das, 2004; Rai, 2006; Geherman et al., 2003; Nijhoff and Andersson, 2001
Improving animal welfare	Foodaware, 2002; Holden, 2004
Conserving fauna & flora	Balfour, 2003; Lampkin and Midmore, 1999; ESRC, 1999
Serving wildlife	Yelm Earthworm & Castings Farm, 2003; Cacek and Langner, 1986; Holden, 2004; Foley, 2006
Less disease (plants & animals)	Yelm Earthworm & Castings Farm, 2003
Main disadvantages	**Reference(s)**
Lower yield	Organic Farming Research Foundation, 2006; Peters, 2003; MacKerron et al., 2000; Nyam News, 2004
Higher cost/price	Organic Farming Research Foundation, 2006; Foodaware, 2002
Need to a huge rate of manure	Peters, 2003
Pro-till intensive	Peters, 2003
More management required	Quinn and Sandy, 2002

result from the higher demand for organic foods, and essentially does not reflect a higher cost of production (Vasilikiotis, 2001). Apart from the fact that the demand for 'organic' foods is unlikely ever to be more than a niche market, the production of such foods on any more than a very modest scale is not possible. The main reason is land unavailability as the extra land required (due to reduced productivity per unit of area) is not available. Also, valued wild ecosystems cannot be considered for this purpose as sufficient approved nutrient sources which should help maintaining the soil do not exist in such ecosystems (EFMA, 2005). Most of those farmers who deal with organic methods believe that GM is the complete opposite of what the OF movement is all about (AFIC, 2004). Overall, as IFAD (2003) believes, organic agriculture could certainly be beneficial for small-scale farmers, albeit under a number of conditions. Table 2 shows the main (dis)advantages of OF crops and their cited references.

3. The dilemma of food security

3.1. GM technologies and food security

There are both potentials and constraints in introducing GM technology in relation to improving the agricultural outcome for small-scale subsistence farmers in the developing countries. As discussed, one potential is that GM technology enables the development of new crop varieties, which have beneficial characteristics for farming. This could be resistance to drought, pests or diseases. In situations of unstable food security, due to bad harvests caused by climate or crop-diseases, GM crops open up opportunities in order to stabilize and ensure food supply for poor subsistence farmers (Egelyng, 2000). Another potential is that some types of GM crops can reduce the use of chemical pesticides and fertilizers, because of their pest resistance with transgenic pesticides. Some crops are made resistant to stress from drought, salt and low pH. This is an important consideration, because chemical inputs are often not available for the subsistence farmers, as the farmers often can afford to none of these inputs (Egelyng, 2000). GM allows crops to be bred by selectively inserting one or more genes into a plant to confer specific advantages. Plants that are resistant to pests and diseases can be produced this way thereby reducing the amount of required insecticide (AFIC, 2004).

In spite of all strong claims from some biotech industry and scholars, there is indeed no indication that biotechnology could and will compensate for shortcomings of industrial agriculture. Compared to high-tech untested in-farm solutions as the unique solution to food security problems that biotech companies are pushing the farmers to apply, OF has many advantages. The majority of GM crops do not make higher yields' sense and necessarily need some optimal circumstances which cannot be found in the conditions of small-scale farmers. For example, a study by Benbrook (1999), the former director of the Board on Agriculture at the National Academy of Sciences, indicates that genetically engineered Roundup Ready soybeans do not increase yields. The study reported a broad review over 8200 university trials in 1998 regarding R.R.S. (Roundup Ready soybeans yield). The result showed that the yield was 7–10% less than similar conventional varieties. The study also found that the farmers used herbicide on R.R.S. even 5–10 times more than on conventional ones. The only reason that the farmers preferred this manipulated variety was because of the simple management of their large chemically-intensive farms.

Yet, as explained by Paarlberg (2002), the most significant factor for keeping GM crops out of the developing world, is the politicization and blockage of national biosafety screening processes. He believes that screening GM crops is not only a routine policy function throughout the industrial world, but also it has now become an institutionalized practice in most large developing countries. Due to Paarlberg, most of developing countries now have some biosafety regulations and guidelines to with GM crops. Most of them have also constituted national biosafety committees to review GM crop applications for environmental and commercial release though a few approvals have been given to date. In his previous study in some developing countries, Paarlberg (2001) showed that international constraints on the use of intellectual property have not been a principle reason for the slow spread of GM crops to the developing countries. He believes, GM crop critics in the developing world have an easy time blocking this technology when it is brought in from abroad by widely mistrusted foreign multinational corporations. He supposes that if the technology were seen emerging instead from scientists working for national development purposes within publicly financed national laboratories, local political resistance could diminish.

Nevertheless, there are some problems and constraints with the GM technology. One constraint is that the technology might not reach the poor farmers, because of the privatization in the rights of implementing and using the technologies. The worldwide Intellectual Property Right regime has already been extended to cover plants and animals, including their genes, making the technology expensive and thus, inaccessible for the subsistence farmers who already have limited opportunities for using the GM technology (Egelyng, 2000). As well, many of developing countries do not have the capacity required to undertake the needed assessments and control on whether they would benefit from the GM crops and whether they can comply with the safety regulation.

Finally, the GM technology may require adequate education and training as well. The farmers, especially in the developing countries, have to be willing to adopt the technique and GM crops. The GM technology thus, has great potential in securing food supply for small-scale subsistence farmers, however, the technology cannot be transferred to the farmers, without carefully considering the above-mentioned aspects (Closter et al., 2004).

3.2. OF and food security

With the huge population reaching 7 billion, the dispute over the ability of OF to feed the world is heating up. Often large biotechnological corporations, particularly those who profit from the use of pesticides and GM seeds raise the questions of whether or not OF can feed the world.

According to the FAO, the applicability of OF on production depends on the previous farming systems. An over-simplification of the impact of transition to OF on yields indicates that (Clean Production Action, 2005):

- In developed countries, organic systems decrease yields; the range depends on the intensity of external input use before conversion;
- In the so-called Green Revolution areas (irrigated lands), conversion to organic agriculture usually leads to almost identical yields;
- In traditional rain-fed agriculture (with low-input external inputs), organic agriculture has the potential to increase yields.

In a study by Pretty et al. (2002), it has been observed that implementing OF in some developing countries causes higher yield of productions. This suggests that OF can secure the food supply in these countries where a greater knowledge in farming techniques has been introduced. Parrott (2004) stresses that avoiding the risk of failure, instead of increasing the production, provides better food security. OF has some potential to do so, as the diversity of crops grown in OF reduces the risk of crop failure from particular pests and diseases. By educating the South farmers about OF, they may attain the capability of self-sufficiency and thus a more secure and stable supply of food (Closter et al., 2004).

In fact, on one hand and not surprisingly, agribusiness companies and their supporters reject OF, claiming it cannot feed growing

population and secure the world's hunger though they may take some advantage of OF as niche product lines. “If overnight all our food supply were suddenly organic, to feed today's population we'd have plowed down half of the world's land area not under ice to get organic food ... because organic farmers waste so much land. They have to, because they lose so much of their crop to weeds and insects.” Said Dennis Avery, an economist at the Hudson Institute — funded by Monsanto, to ABC News' 20/20 broadcast (Vasilikiotis, 2001).

On the other hand, due to the other studies, OF can potentially produce higher yields than conventional methods if the farmer knows how to “manage” his farming system. Furthermore, a global transition to organic may not only have the potential to promote food production levels but also conserve agricultural soils and improve soil fertility and health.

The critical question would therefore be: is it not too risky for our food security to ask politicians, especially in the third world, to solve the environmental constraints caused by GM farming by this transition? On the contrary, is it not too risky for our environment to ask the politicians, to solve the food security constraint by spreading GM more globally? Are there any other alternatives?

4. Main considerations and tradeoffs

Consequently, as discussed in the previous sections, there are some main considerations and tradeoffs when comparing GM crops and OF. Here, we discussed the main issues. Considering GM crops, it makes clear that the nutritional and health benefits of genetic engineering are so many and will be useful to the growing world population which is currently estimated over than six billion (Henkel, 1995; Rudnitsky, 1996), and will probably double by the year 2050, according to the UNFPA (2005). As a result, genetic engineering might be considered as the logical way of feeding and medicating an overpopulated world (Lesney, 1999). As Uzogara (2000) discussed, GM has also the potential to improve the quality and nutritional value as well as increase the variety of food available for human consumption, and waste management. Biotechnology could also create raw materials for industrial uses and new crop varieties that have not only higher yield in the field but also less need to inputs. As well, genes injection/manipulation can create stronger biological defense against pests and diseases, thus reducing the need for expensive treatments for small-scale farmers such as chemical fertilizers and pesticides. Such manipulations could also create the stronger drought, pH, frost and salt resistance. Gene manipulation can therefore be used for different treatments (e.g. tolerance, resistance, slow ripening, etc.) and solve major problems of farmers (Thayer, 1999).

However, the uncertainty in the environmental effects is a major problem concerning the GM technology, especially in relation to the pest resistant GM crops. There are also some concerns related to the loss of biodiversity and other environmental risks effecting the ecosystems, agriculture and health because the natural plants have become extinct (Darkoh, 2003). It is very difficult to comprehend and predict these effects.

In some sense, there is little or no significant difference between genetically foods and organic foods. It is easier to control products of genetic engineering than those resulted organically. GM foods can be safe. Careful application of genetic engineering will make life better, improve human health and welfare, and save time and money (Uzogara, 2000). However, before any intervention in farming systems, antibiotic resistance genes used in GM crops must be scrutinized to see whether or not they can be substituted for with other similar effective selection methods to care both human and animal health and avoid any potential risks (Hileman, 1999b). Overall, many researchers believe that the benefits of GM foods are more than their negative consequences. Therefore, before any interventions in the complicated third world's farming systems, risks of producing and consuming new GM foods should be evaluated against potential benefits, and when benefits are much bigger than the risks, such foods can be introduced and adopted (Uzogara, 2000).

Many farmers in the developing countries are farming without the use of any chemical inputs fertilizer and pesticides. This type of farmers could be considered as organic farmers, however, they are not organic farmers while they do not benefit from the OF techniques. On the other hand, there are also a few organic farmers in the North countries which have focused their crop production on the international market. Subsistence farmers in the South, have therefore, different circumstances than farmers in the North, because the South farmers do not have profit to focus on national and international market. The farmers, so-called small-scale farmers/holders, are mainly focusing on the survival of the family. The chemical inputs used, such as fertilizer and pesticides, are often limited, and in some cases non-existent, because of insecure financial markets, lack of knowledge to use chemicals or do not assume that these inputs fit with their way of farming (Parrott, 2004). The problems with the agriculture in many African and some Asian countries have been due to different issues such as ‘high illiteracy rates’ resulting in farmers being unable to read and follow instructions on how to use chemical inputs, climatic and soil conditions, particularly the poor soils, when the soils have been exploited. Many farmers have continued using the traditional agriculture practices, and have not been able or willing to adopt or adapt new farming techniques. (Parrott, 2004; Pretty et al., 2002).

The most of Africa might not be developed enough to sustain OF, and most aid should be focused on increasing production and international trade rather than OF methods. The reason for not focusing on production with OF is that there are some major problems with low soil fertility in several African countries (Jensen, 2004). One of the principles of OF is to maintain the soil fertility, but a major problem with encouraging OF in some African countries is that they have very poor soils, fast breakdown of organic matter which is rarely returned to fields (Closter et al., 2004). While soil fertility depletion has been identified as the fundamental biophysical root cause for hunger in Africa, one of the most sensible ways of replenishing soil fertility, as shown in Peter van Straaten's work (2002) in 48 countries of sub-Sahara Africa, is the use of available natural resources, and phosphate rocks as one attractive alternative for replenishing phosphorus in soils that have been depleted of this nutrient.

Farmers are possibly willing to adopt new ways of farming, and might be willing to implement OF or use GM crops. According to these results, the local farmers would be willing to change the way they normally farm. However, they might be reluctant to use new technology because they cannot see the immediate benefits, but have to wait for example, five to ten years for an increased output in crop production. Small-scale mixed farming may require fewer changes in farming techniques, and according to Parrott (2004), OF is shown to involve many different practices, for instance, farming on extensive grassland may require only few changes in the management practice. On the other hand, the organic production of crops, which are likely to have been intensively grown in mono-cultures, may require significant changes in agricultural practice to achieve acceptable yields and returns and prevent infestations. However, to prepare this type of farming for international markets, it requires significant organizational changes in order to comply with the international standard for certified OF (Parrott, 2004). Additionally, as Parrott (2004) argues, the majority of the African farmers would use fertilizer if they had a choice. Financial issues are the major reason that the local farmers are not using inorganic inputs, and lack of availability is the second most important reason. It is also discussed by Harris et al. (1998), that two-thirds of the African farmers that are using organic methods said that they did so, because they could not afford fertilizer or pesticides (Parrott, 2004), but if they could, they probably would change to farming using chemical inputs. Regarding the Asian farmers the reason for not using chemical inputs are more mixed, as the farmers

are not using chemical inputs due to tradition, availability and financial reasons (Closter et al., 2004).

In sum, the population in both Asia and Africa may recognize the advantages of OF, but only few of the farmers believe that there are no advantages with OF. The greatest advantage is prevention of pollution of both the water and soil from not using chemicals when farming. While, there is a great potential for OF in South-East Asia, East Europe and the countries around the Baltic Sea, little exits in Africa, even if organic principles and techniques may be useful. On the other hand, as Egelyng (2000) stated, some countries might be more affluent if the agriculture is organic. However, the demand market for organic crops is very small in Africa, and if the OF became certified with a possibility to sell to Europe or North America, it would only be a few products in a small scale (Closter et al., 2004).

The disadvantages of OF for both African and Asian countries are mainly lower yield, more labor intensive, increased costs and decreased income. The OF is difficult to implement if the farmers cannot see the immediate benefits. Other constraints and problems with implementing OF for subsistence farmers are lack of knowledge or information, lack of money to start farming and low fertility. At the same time as GM crops have potential to help farmers in the developing countries only if the crops are suited to the agricultural problems that the developing countries are dealing with, e.g. more drought resistant crops or better ability to take up phosphorus. In fact, GM crops should be introduced with the guarantee that it will not create new problems in these countries. Similarly, as Closter et al. (2004) discussed, there is potential in using GM crops if it can be proven that it is safe to other plants (avoiding loss of biodiversity) and human health, though their findings in Africa show that GM technology is too expensive. They believe, in general, the reasons to use GM crops in the developing countries are mainly higher yield and increased income. Other reasons are resistance to diseases and pests, drought resistance, early maturing varieties and less labor. Despite these benefits, some farmers do not adopt GM crops because of their lack of knowledge about its use, safety, or where to buy them. In these countries, the GM crops are often not tested adequately, while the countries need to assess the impact of the GM crops in relation to risk and make their own implementation policies (Egelyng, 2000).

Farmers, especially those who are poor, usually feel a great risk of food insecurity (Parrott, 2004), and OF can be held at a considerably high risk so this issue of risk would be an important reason why subsistence farmers are not willing to adopt the OF. Nevertheless, another problem with the OF is that it takes a long time before the benefits become apparent Finally, OF should provide (more or less) the same income as GM crops (Closter et al., 2004).

5. Conclusion

It is indeed hard to give a straight answer or simple solution on how food insecurity is being solved. Due to the possibilities offered by GM technology in this new century, societies will need to make some important choices about the type of world that they wish to build up. The politicians in the developing countries are recently faced by a crucial question on how GM technology should be viewed in relation to OF. This study identified and scrutinized this issue in the agricultural sector of these countries where many factors are involved with food insecurity.

Although GM food is important and beneficial, it should be adopted under conditions that avoid potential risks. Time and effort must be devoted to on-farm trials before any interventions in this regard. Policy makers and researchers in developing countries should carefully assess environmental risks (such as the major risks to biodiversity, the prospects of insufficient out-crossing distances, the relative absence of clear labeling and other threats to seed purity, adjacent traditional food production) before farmers change their conventional farming methods to GM. Government should restore public confidence in their ability to regulate GM foods by setting up special commissions to advise politicians on long-term impacts of GM crops to human health, agriculture and the environment. In sum, GM technology has advantages in increasing food supply, due to the resistant crops, and reduced chemical inputs as well. The disadvantages are mainly fear of food safety and consequently, health and environmental impacts.

On the other hand, while some believe that OF in developing countries is basically not a very good alternative for securing food supply because of generally poor soil conditions, lack of organic matter, labor intensive, increased cost, invisibility results in short-term and virtually no access to international markets, the advantages of OF are perceived to be reduced water and soil pollution, as well as reduced use of chemical inputs in the farming practices. One may put in the lack of farmers' knowledge and information when implementing OF; followed by financial constraints, then low productivity, as the other disadvantages.

Finally, the public understanding should be sufficiently promoted on both GM and OF methods to recognize the health foods. Private and public sector leaders should also understand the level of consumer's awareness and acceptability of new products. This will enable them to plan a strategy for improvement the quality and quantity of agricultural products.

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