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COMMENTARY

SCIENCE, TECHNOLOGY AND THE FUTURE OF FOOD IN AFRICA

Paul Thompson*[1]

Prof. Paul Thompson

*Corresponding author Email: p.thompson@utoronto.ca

[1]University of Toronto, Institute for the History and Philosophy of Science, and Department of Ecology and Evolutionary Biology, 91 Charles Street West, Toronto, Ontario, Canada M5S 1K7.

ABSTRACT

Genetically modified (GM) crops and the food products derived from them have been in widespread use in North America since 1995. A wide range of food products in North America and elsewhere contain GM derived products. With a slightly longer timeframe, and almost no public rejection or even debate, medical products throughout the developed world, including EU countries, have been produced using GM bacteria (especially *E coli*) and GM animals, such as goats. The next generation of GM crops will be drought tolerant, require less nitrogen and have enhanced nutritional profiles. During the almost 15 years of widespread use in North America and a number of other countries, no new risks have emerged. Nonetheless, Sub-Saharan African countries, with the exception of South Africa, continue to resist the use of GM crops. Given, the safety record of these crops, the mitigation of environmental degradation they achieve compared to traditional crops and the farming practices they require, and the higher yields of GM crops, this resistance and rejection is, on the surface, baffling. A full explanation will certainly be complex but a significant role is played by the post-colonial influence of developed nations – their governments and their non-governmental organisations. Today in all developed nations, medical applications of GM are moving forward at a rapid pace and in many countries outside Europe GM crop development and planting is advancing rapidly. In the developing world, China, India, South Africa and many countries in South America are moving forward with the use of GM crops. Once again because of the influences of old colonial powers, Sub-Saharan African countries are being left behind. It is time for African countries to take control of their destinies; it is time for them to turn their gaze and allegiance away from the developed world –especially Europe - towards their natural partners in development: China, India and South Africa. These countries are pointing the way forward, the way out of poverty, hunger and dependency.

I. A HISTORICAL LESSON

Thomas Malthus (1766-1834) in his famous *An Essay on the Principle of Population* [1] connected population growth and means of subsistence (principally food and shelter). Malthus contended that without constraints population would increase exponentially whereas the means of subsistence would increase only arithmetically. As a result, the population would at some point exceed the means of subsistence required to sustain it. Once that point is reached, there will be a struggle for existence among the members of the population. Further population growth will be constrained; population size will oscillate around this equilibrium point. Malthus, in this case, offered a two variable mathematical model of population dynamics. The lesson from the subsequent two centuries is that Malthus' model was too simple. A number of other factors turned out to be important. One significant factor is the affect of affluence on population increases; the other is advances in technology which resulted in a quasi-exponential expansion of resources. This made food, for example, plentiful and inexpensive.

On the matter of population growth, there are numerous factors that Malthus did not anticipate and, hence, did not include in his model. First, there is a fundamental and inverse relationship between affluence and population growth. This was known in the 19th century and was a concern in, for example, Victorian Britain. The concern was that the poor, who had far more children on average than the rich, would increase in numbers faster than the rich and dilute the quality of the population (in today's terms, diminish the quality of the gene pool). The relationship is now well documented; affluence (A) is inversely proportional to reproductive rates (R) ($A \propto 1/R_r$ or $A = c(1/R_r)$). Although for the next few pages, I will concentrate on the impact of increases in affluence in developed nations, it should be clear that poverty (the inverse of affluence) entails a high rate of population growth. I return later in the discussion to the nature and impact of poverty.

There are a number of secondary relationships that underlie the inverse relationship ($A \propto 1/R_r$). First, methods of birth control have become more and more sophisticated and reliable, and more readily available. This is largely a technology driven factor. This provides the means for fertility control but other factors provide the motivation to employ it. One motivation, and another secondary factor, is the cost (financially, emotionally and personally) of bearing and rearing large numbers of children. Unlike the poor who depend on children for labour and care and support in later life, the affluent have other ways of obtaining these and they also find their affluence allows more leisure activities with which caring for numerous children over extended periods of their lives interferes. A third factor, which diminishes further the need for large families, is the decrease in infant mortality. In affluent countries, vastly more children live to age 5 than a century ago. Also, because of substantially better nutrition, individuals live longer, healthier and more productive lives. Another important factor is the age at which women bear their first child; in affluent countries this had declined dramatically. In 1850, women, on average, bore their first child around 16 years of age; in 2007 that had risen to 29.

As a result of these factors, and others, population size has not grown exponentially; population growth in the developed world has not unfolded as Mathus predicted. But, neither has the expected trajectory of the second variable in Mathus' model: rate of growth in the means of subsistence. He predicted an arithmetic growth. The major element of subsistence is food. Food in the developed world has increased at a quasi-exponential rate and, for the most part, has increased individual access to high nutrition foods. Since, over the last 200 years, the rate of growth in food supply has been quasi-exponential and the rate of population growth has diminished and in many countries is soon expected to be negative, the supply of food per person has increased significantly. As a supply to demand model implies, the cost per unit of food has declined significantly.

So, what actually occurred over the last 200 years is virtually the opposite of what Malthus predicted. What is the core explanation for this divergence? I, along with many others, have suggested affluence is the proximate cause of the decline in the rate of population growth. Increased affluence, however, is, in large part, a function of advances in science and technology. Similarly, the quasi-exponential growth of the

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quantity and quality of food is a direct function of science and technology. Jeffery Sachs [2] eloquently makes this point in his book *The End of Poverty*:

> *I believe that the single most important reason why prosperity spread, and why it continues to spread, is the transmission of* ***technologies*** *and the ideas underlying them. Even more important than having specific resources in the ground, such as coal, was the ability to use modern science-based ideas to organize production. The beauty of ideas is that they can be used over and over again, without ever being depleted. Economists call ideas nonrival in the sense that one person's use of an idea does not diminish the ability of others to use it as well. This is why we can envision a world in which everyone achieves prosperity. The essence of the first industrial revolution was not the coal; it was how to use the coal. Even more generally, it was about how to use a new form of energy. The lessons of coal eventually became the basis for many other energy systems as well, from hydropower, oil and gas, and nuclear power to new forms of renewable energy such as wind and solar power converted to electricity.*

Science and technology have been at the core of the success of developed countries in thwarting the Malthusian dynamic. For most of the 20th century, agricultural technology has exploited millennia-old breeding knowledge and contemporary population genetics. Animal and plant agriculture relied on selecting organisms with desirable traits as a breeding stock. As a new advantageous trait is identified or emerges, organisms with the trait become the new breeding stock. As scientific knowledge advanced, the understanding of hybridisation became more sophisticated (beginning with Gregor Mendel [3], through the development of population genetics in the 1920s to molecular and population level knowledge of hybridisation). In the latter part of the 20th century, based on advances in molecular biology, biotechnological manipulation of the genome of organism became possible [4]. Medical, environmental and agricultural applications were approved by regulators in many developed countries during the 1990s. Of these three applications, for reasons I will explore later, agriculture – especially plant agriculture – became the target of intense criticism. These criticisms resulted in a virtual ban on genetically modified crops in Europe with, I contend, devastating effects on sub-Saharan Africa. The exception is South Africa which has embraced these agricultural products. Food products comprised in whole or in part from materials derived from genetically modified crops entered the North American market in 1995 (14 years ago).

II. THE CONTEMPORARY SITUATION

Malthus concentrated on rates of population growth and means of subsistence. As described above, in developed countries both rates differed from his dire prediction. In other countries, however, the Malthusian dynamic has been realised. In most developing countries population growth has outstripped the means of subsistence, and individuals live in various states of poverty, starvation, inadequate nutrition and poor health. Some developing countries (e.g., China and India) have made significant advances in ameliorating poverty in some segments of the population. As developing countries increase the affluence of their citizens, however, the demand on food supplies increases. Even modest increases in affluence in these countries allow some portion of their citizens to expand the quantity and variety of food consumed. In effect, as the poor become more affluent, the effective population size, with respect to demand on food resources, increases. Although no new individuals are added to the world population, many new individuals are added as consumers of food. Those who could barely find the resources for a bowl of rice each day will, with a very modest increase in affluence, be able to afford three bowls a day and perhaps a chicken and such on many days of the year. Given the features of this increase in population demand, the solution at work in developed countries over the last 200 years – that is, decreasing the rate of population increase – will not work. Even if world population numbers were held constant at 2008 levels (6.7 billion), the demand for food (driven by increasing affluence in the developing world) will rapidly outstrip current world production. Of the 6.7 billion in 2008 about 1 billion are in developed countries. The other 5.7 billion are in developing countries. Hence, even assuming no future growth in world population, as a significant portion of this 5.7 billion becomes more affluent there will be, at a minimum, a doubling of demand for food. And, not even the most optimistic demographic projections envisage a stabilisation at 6.7 billion. The Population Reference Bureau projection [5][6] has the world population at 9.3 billion by 2050 with virtually all of that increase occurring in developing countries.

There is no completely reliable data on world poverty. Perhaps the best data are found in the World Bank's 2005 *World Development Indicators* [7]. Globally in 2001, 2.7 billion people lived on less than $2 per day. This means 50% of those in developing countries are very poor and, as a result, are usually malnourished. Recently, China and India have experienced declines in the proportion of very poor people. Tragically, Sub-Saharan Africa has experienced an increase. The challenge set by the United Nations Millennium Development Goals is to reduce by half the proportion of people who suffer from hunger, measured by malnutrition, by 2015. To achieve this goal means increasing the food resources consumed by 2 billion people, at a minimum. Although the Organisation for Economic Co-operation and Development (OECD) continues to forecast an increase in world agricultural output [8], the increases fall far short of what will be needed to halve the number of malnourished individuals by 2015.

There are two broad concerns about increasing agricultural output on the scale required: an environmental concern and a distributive justice concern (ensuring as broad as possible participation across nations, cultures and socioeconomic demographics). The environmental concerns focus on the environmental impact of current agricultural practices. According to The World Wildlife Fund [9] current agriculture uses about 50% of habitable land, 69% of all water use by humans (municipal uses comprise 8% and the total industrial use is 23%), and is a significant contributor to greenhouse gases (citing the Food and Agriculture Organization of the United Nations, WWF reports that livestock agriculture alone is responsible for 18% of all greenhouse gas production and rice production is the largest single producer of methane). Agriculture is also the largest user of chemicals – more than any industrial use. Although WWF is quick to point out that agriculture provides many benefits and

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opportunities for environmental protection, the picture that emerges is that current agricultural practices are environmentally unsustainable.

Faced with this environmental concern, many have advocated a move away from current practices and an embracing of organic farming; this has become a common mantra in the EU. Organic farming, it is claimed, avoids chemicals and involves responsible land management. It is not clear just how far these claims can be pressed but, even assuming them to be incontrovertible, organic farming will not change many of the unsustainable features cited above – methane from livestock agriculture, water consumption and the like. Moreover, based on current data, a move to organic agriculture can be expected to lower agricultural output, not increase it – unless even more land is cleared and placed into agricultural production. Notwithstanding these factors, there is clearly a place for organic farming in the overall solution to the environmental concerns but it will remain a boutique part of agriculture. Many EU countries have promoted organic farming and provided significant subsidies; nonetheless the organic sector has remained very small. In France, organic farming occurs on about 2% of its agricultural land; Austria is one of the highest at 3.9%. In the U.S., it is .5%. There are clear demand-for-food and economic reasons for these very small percentages.

As has been the case over the last 200 or so years, science and technology will be a significant element in increasing the supply of food; as we move forward, however, science and technology will also have to be part of the framework for decreasing the environmental impact of agriculture. This will include continued use of selective breeding and hybridisation but must include molecular genetic technologies. Indeed, the benefits of currently available genetically modified plants are now well documented. Before highlighting the most significant and indicating what the next generation of GM plants promise, let me be clear that employment of science and technology, in any of its forms, has an attendant potential risk of harm. This is true of science and technology in medicine, in the home and in the workplace just as much as in agriculture. Rejecting science and technology, however, also has significant attendant potential risks of harm. To the extent that the precautionary principle is used – as it often has been – as a way of thwarting the use of science and technology, it is an unhelpful, indeed deeply flawed, approach. Acceptance or refusal to employ science and technology introduces risks of harm. The challenge, in all aspects of life is to identify potential benefits and harms, to capture the benefits while mitigating the harms and to ensure a reasonable benefit to harm ratio.

Plant agriculture in North America that involves genetic modification is currently dominated by two traits: glyphosate resistance and Bt δ endotoxin expression. Glyphosate is a broad spectrum (non-specific)herbicide; almost all plants will be negatively affected by contact with it, most being killed. Through genetic modification, certain crops are resistant to glyphosate. Hence, a farmer can plant these GM crops, spray the field with glyphosate and kill the weeds (not crop plant life) while not harming the crop plants. Glyphosate was until recently under patent by Monsanto with the trademark Roundup™ and the crops were designated as "Roundup™ ready". Glyphosate compares favourably with alternatives such as

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atrazine (widely use on non-GM corn fields) and 2, 4-D amine (commonly used in non-GM soybean fields) with respect to environmental and health impacts, such as leaching into groundwater. The United States Environmental Protection Agency in its Consumer Factsheets claims [10]:

> *"Glyphosate is strongly absorbed to soil, with little potential for leaching to ground water. Microbes in the soil readily and completely degrade it even under low temperature conditions. It tends to adhere to sediments when released to water. Glyphosate does not tend to accumulate in aquatic life."*

> *"Microbial activity and other chemicals may break down atrazine in soil and water, particularly in alkaline conditions. Sunlight and evaporation do not reduce its presence. It may bind to some soils, but generally tends to leach to ground water. Atrazine is not likely to be taken up in the tissues of plants or animals."*

> *"2,4-D is readily degraded by microbes in soil and water. Leaching to ground water may occur in coarse-grained sandy soils with low organic content or with very basic soils. In general little runoff occurs with 2,4-D or its amine salts. There is no evidence that bioconcentration of 2,4-D occurs through the food chain. This has been known from large-scale monitoring studies of soils, foods, feedstuffs, wildlife, human beings, and from other environmental cycling studies."*

So it is reasonable to consider glyphosate to have a somewhat better overall profile than its alternatives with respect to environmental and health issues. Moreover, fewer applications of glyphosate are required on GM-crop fields. This lessens the environmental herbicide load and decreases fuel consumption. Additionally, a field can be planted with "Roundup™ ready" crops without tilling the soil (zero tillage). This avoids exposing the soil to wind and water erosion (loss of top soil from erosion due to farming practices is a major environmental concern) and, again, reduces fuel consumption. These environmental gains are realised while at the same time increasing per acre yields. The following GM "Roundup™ ready" crops are in use in North America: soybean, canola, corn (maize) tobacco and cotton.

The obvious environmental benefits of pest resistant crops are that **no** pesticides are applied, which eliminate numerous environmental impacts including hydrocarbon emission from tractor use. These crops have been genetically modified to express a δ-endotoxins (cry toxins) which are toxic to moths, butterflies, flies, mosquitoes and beetles. The toxicity is highly specific to these organisms and in the case of corn and cotton kills the larvae of the pest (boll weevil, corn rootworm bore and corn bore). These δ-endotoxins are naturally expressed by the bacterium *Bacillus thuringiensis* , a bacterium that is found in soils. *Bt*, usually as a spray, has been used for more than 50 years as an insecticide – including controlling mosquitoes – and has an impeccable safety record; that record has led to its being widely used in organic farming and to the U.S. EPA not imposing any requirements on it with respect to food residue tolerances, groundwater, animal or human toxicity labelling or special reviews.

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Researchers at the University of California, San Diego [11] claim the following about *Bacillus thuringiensis* (drawing on Glare, and O'Callaghan [12]:

> Bt products are found to be safe for use in the environment and with mammals. The EPA (environmental protection agency) has not found any human health hazards related to using Bt. In fact the EPA has found Bt safe enough that it has exempted Bt from food residue tolerances, groundwater restrictions, endangered species labeling and special review requirements. Bt is often used near lakes, rivers and dwellings, and has no known effect on wildlife such as mammals, birds, and fish.
>
> Humans exposed orally to 1000 mg/day for 3-5 days of Bt have showed no ill effects. Many tests have been conducted on test animals using different types of exposures. The results of the tests showed that the use of Bt causes few if any negative effects. Bt does not persist in the digestive systems of mammals.
>
> Bt is found to be an eye irritant on test rabbits. There is very slight irritation from inhalation in test animals which may be caused by the physical rather than the biological properties of the Bt formulation tested.
>
> Bt has not been shown to have any chronic toxicity or any carcinogenic effects. There are also no indications that Bt causes reproductive effects or birth defects in mammals.
>
> Bt breaks down readily in the environment. Because of this Bt poses no threat to groundwater. Bt also breaks down under the ultraviolet (UV) light of the sun.
>
> Even with such widespread use of Bt-based products in the past 50 years, only two incidents of allergic reaction have been reported to the EPA. In the first incident, it was concluded that the exposed individual was suffering from a previously diagnosed disease. The second involved a person that had a history of life-threatening food allergies. Upon investigation, it was found that the formulation of Bt also contained carbohydrates and preservatives which have been implicated in food allergy.

Given this environmental and health impact-profile, *Bt* is a dream insecticide which is why, in spray form, it is widely used by **organic** farmers. One challenge – probably the only one - that *Bt* shares with all other pesticides is the potential for resistance to evolve in the target organism. The development of resistance is a function of selection acting on the high level of variability (genetic and phenotypic) in populations of organisms. Resistance to the toxin may exist in some organisms in the population or a mutation may arise which confers resistance on the mutant. Resistance is usually dose dependent such that large quantities of the toxin applied over an extended period will affect all but the most resistant organisms. Leaving aside GM crops with the *Bt* endotoxin expression for a moment, an application of *Bt* spray in an organic field will kill the target organism unless there are organisms

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resistant to that level of the toxin. If there are resistant organisms, they will be the only ones left to reproduce. If only resistant organisms survive the *Bt* spraying, there will be complete resistance to that dosage after a single generation. In actual cases of the development of resistance, it takes several (but not very many) generations to fully develop; this occurs for a variety of reasons such as differential spatial density of the sprayed toxin (some areas will receive more than others due to factors such as wind-caused drifting) and the scalar nature of resistance (some organisms will have minimal resistance to the toxin, others a high resistance, i.e., tolerance).

Clearly, it is not in anyone's interest – except for the target organism – to have resistance develop to an initially effective pesticide: and, especially not to a pesticide that after 50 years of use, has no known negative environmental, wildlife or human health impacts. Two key biological elements used to delay the development of resistance are toxicity dynamics and population genetic dynamics. Research to determine the toxicity level of different levels of exposure is essential. *Bt* ideally needs to be applied at rates (quantitatively and temporally) sufficient to kill all of the target organisms. Unfortunately, even with excellent toxicological data, application can be uneven and, more importantly, mutants can develop that have resistance to the prescribed application rates. GM crops engineered to express the *Bt* δ-endotoxin resolve the consistency of application issue because all the plants express the endotoxin. To resolve the other causes of potential resistance, in the case of GM crops, toxicological approaches have been supplemented by population genetic approaches.

Although population genetic modelling is complex involving many variables, the essence of this method of delaying the development of resistance can be set out quite simply. Farmers are required to plant a refuge crop (a non-GM crop); the refuge crop must be 20% of the total hectares planted. This ensures that any larvae that survive the *Bt* δ-endotoxin will breed with a large population of larvae not exposed to the *Bt* δ-endotoxin. The most widely used GM crops with the *Bt* δ-endotoxin expression are maize and cotton; tomatoes and potatoes have been engineered and approved but are not widely used. Bourguet, *et al* [13] provide an excellent account of insect resistance management.

Two additional traits have been engineered into plants and are in the research, development and/or approval stages: drought tolerance and reduced nitrogen requirement.

The current traits reduce the environmental impact of agriculture and increase yields. The traits undergoing research and development, when marketed, will multiply these benefits. This is precisely what is needed in order to expand the food supply to more individuals in as environmentally friendly a way as possible.

III. REJECTION IN AFRICAN COUNTRIES OF GM CROPS

For the most part, sub-Saharan African countries – except for South Africa – have rejected or at least resisted, the use of GM crops. In light of the benefits described above, the almost 15 years of widespread use of GM crops and foods in North America – with no new risks having emerged – and the critical, urgent need in African countries for increases in the quantity and quality of food, this resistance, to put it mildly, is troubling. There are, of course, many non-African individuals, organisations and governments that also advocate rejection of, or resistance to, GM crops and foods. Some of the proffered reasons for their positions are patently disingenuous and serve only to alarm Africans with tales of horror; claims, for example, that these foods will make men sterile and GM crops are a disaster waiting to happen. Most who make these claims are from rich developed nations (a majority are Europeans) who would never hold the advances in medical biotechnology or even environmental remediation biotechnology in such contempt – a point to which I will return later. These people usually have reliable access to abundant, inexpensive and high quality foods. Starvation and malnutrition are, for them, exceptionally rare.

Notwithstanding the large number of unsupportable and disingenuous claims, there are, of course, legitimate concerns. Regrettably, even these are amplified, by some opponents, to distortion. These unwarranted distortions should be avoided since the concerns deserve careful, non-ideologically-based attention. Among the more important concerns have been:

1. GM seed companies are large multinationals with too much control (concentration of control over seed production and distribution),
2. Farmers cannot keep their GM seeds and, hence, become dependent on the seed companies,
3. Impact on small-hold (small-scale) farmers
4. Adventitious presence
5. Development of resistance
6. Effects on species (monarch butterfly)
7. Loss of heritage stock
8. Human health effects (e.g., food toxicity, allergic reactions)

These concerns, and others like them, can be grouped into three broad categories: socio-economic concerns, environmental concerns and human health concerns. The human health concerns seem less significant now that we have almost 15 years of experience with widespread consumer consumption in North America (population of U.S. and Canada: approx. 350 million) of products containing GM plant material (e.g., soybean oil and canola oil); **no new health risks have emerged**. Of course, one must, nonetheless, be constantly monitoring and researching the issue, as with any product – even conventional foods such as meat and dairy. The same is true for environmental concerns. The potential risks identified prior to 1995 related to horizontal gene transfer, effects on non-target species and so on have not materialised. Vigilance, of course, is necessary in this area as well. The loss of heritage stock warrants some specific comment. Such loss is indeed problematic for a variety of

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reasons but this is not a GM crop specific problem. The loss of heritage stock was identified as a serious problem related to conventional farming prior to 1950. As a result, important steps have been taken to develop seed banks with the responsibility to preserve the variety and vitality of heritage seeds; seed companies for whom maintaining heritage stock has special scientific and business importance support this initiative vigorously.

Of the three categories of expressed concern, the socio-economic ones attract considerable attention and provoke strong expressions of apprehension and angst. This collection of concerns also has the most relevance to African countries. Although I share many of the apprehensions frequently expressed, I hold that they are far from specific, or of greater relevance, to GM crops and foods. As it turns out, large multinational seed companies such as Monsanto are relatively small compared to many other large multinational companies such Bayer, Coca Cola, Unilever and Toyota. Unilever, which has an extensive food manufacturing and distribution arm, is vastly larger than Monsanto or Pioneer or Syngenta. In 2007, it employed 174,000 people in 100 countries and had a worldwide turnover of €40 billion (≅U.S.$52 billion) [14]. Also, in 2007, Unilever spent €5.2 billion (≅U.S.$6.8 billion) solely in advertising and promotions. The worldwide revenue for Monsanto in 2007 was U.S.$8.6 billion; hence, Monsanto's total revenues are only 25% more than the €5.2 billion (≅U.S.$6.8 billion) that, in 2007, Unilever spent solely in advertising and promotions . Unilever claims, "Every day, 160 million people choose our brands to feed their families and to clean themselves and their homes." [14]

The reality is that Monsanto (and other seed companies) are relatively small multinationals and the control they can exert over socioeconomic factors pales by comparison with companies like Unilever. The point, however, is not that Monsanto's large multinational status doesn't matter just because it is relatively small, but that the issue of multinational socioeconomic power and control is much larger than GM seed companies and any meaningful attempt to tackle the potential negative socioeconomic consequences of the actions of multinational companies will require attention to issues that are unrelated for the most part to the specific products involved. I say "potential" because, again for the most part, multinational companies have a vested business interest in not being seen to produce negative socioeconomic consequences; and, most such companies equal or exceed the level of corporate responsibility found in national and community-based businesses. Of course, sometimes there are concerns about a company's product – regardless of whether the company is multinational or much smaller in scope. It should be obvious, however, that where there are issues with the products, those issues need to be the focus; the scale of the particular company should only be included where the issues themselves justify it.

In my view, large multinational corporations are with us for the long haul – indeed are unavoidable, probably essential, in a sustainable global economy. The need for national and international legal frameworks, regulations, and enforcement mechanisms is beyond dispute. There is no reason, however, to single out GM seed companies, and GM crop and food companies as needing special attention.

I turn now to the second socioeconomic concern, namely, creating a dependency on seed companies for annual seed inputs. This concern is considerably less significant than often claimed. In the more developed countries, almost all farmers who buy **non-GM** seeds from a company are doing so to obtain a beneficial trait. Since the vast majority of those traits result from hybridisation, seeds that are collected from one season and planted the next will result, on average, in 25% of the second crop not having the trait. This is an elementary fact of population genetics – the great achievement of Gregor Mendel's work on hybrids. As a result, almost all farmers in more developed countries will continue to buy hybrid seeds from a company that guarantees the presence of the trait in every seed. Why would a farmer endure a situation where in every season 25% of her crop lacks the trait from which she hopes to benefit, especially when, on that 25%, she will incur all the costs of planting, fertilising, and dealing with weeds and pests? To add to the complications and costs, the 25% will not be neatly confined to a 1/4 section of the field; it will be entirely mixed with the plants manifesting the trait. I have a small (1/2 acre) vegetable garden at my home. I always buy new seeds every year, even for the heritage crops I grow, because keeping seed in those cases results in yearly diminution of the quality of the germ-plasm (reproductive cell – gamete – DNA). I, along with virtually all developed-world farmers, buy quality tested and guaranteed seeds because I can and I want to avoid the risk of planting seeds of inferior quality.

While increasingly farmers in developing countries like China and India are obtaining seeds from companies on a yearly basis and for the same reason those in developed countries do so, many farmers in other developing countries are not well positioned to do this. By default, they retain seeds from one season to plant in the next. This is the case in sub-Saharan African countries – except for South Africa. However, to raise this **necessity** to a **virtue** (as some have done) would be simply a bad joke were it not for the fact that the lives and quality of life of millions of Africans are at stake. What African farmers need is access to quality controlled and guaranteed seeds on a yearly basis. To suggest that the appropriate solution to their plight is to stop seed companies from directly or indirectly encouraging farmers not to keep seeds season to season is entirely counterproductive. The solution actually involves finding ways to enable poor African farmers to obtain high quality seed with traits beneficial in their context. There is no shortage of innovative and exciting ideas such as initially providing seeds and other appropriate inputs like fertiliser free; as a farmer begins to realise a profit above a defensible threshold, a contribution to the purchasing of seed begins. The contribution will be well below market rates for a long time. If the farmer becomes as successful as farmers in developed countries, as many in China and India are becoming, the contribution will rise to market rates. Many companies are exploring, or are in fact working with local governments on implementing, schemes such as this. Malawi is an excellent case study [15].

For some opponents, these kinds of initiatives will be unsatisfactory because at the core of their opposition is a hankering after a new world economic order. A world in which commodities such as pharmaceuticals and seeds, to pick the two most frequently targeted, are not subject to intellectual property protection; a world in which research and development (R&D) is funded by governments resulting in commodities that are "owned" by the public, whose tax dollars presumably funded the R&D; they would be "public goods". Given the performance record of governments around the globe on systems such as this, I am definitely not hankering after it. More to the point, debates about the benefits, likelihood of success and so on of such an economic structure misses a fundamental reality. We do not have such an economic order – not even in communist China - and are unlikely to have one any time soon. The majority of medical, agricultural, environmental and consumer product advances have been funded by private investors and undertaken by private companies. If their ability to realise an appropriate return on their investment and efforts is curtailed, a great deal of research and development on which we all depend will grind to a halt. This, of course, is not to say that there should be no public scrutiny and control over profits. Nor is it to say, that where governments do make R&D investments (and most developed-nation governments do make such investments) that the outcomes should not be public rather than private. Nor also is it to say that there are no challenges to be faced in the current economic order; there are many. To think, however, that these can or will be met by a new economic order in which public resources fund R&D and the results are entirely a public good is at best naïve.

So far, the discussion of socio-economic concerns has focussed on conventional seed technology, of which hybridisation is a major part. Concerns specific to GM seeds and crops differ very little from those discussed with respect to conventional seeds. Patents do play a more significant role, largely because the R&D costs for GM crop production are considerably larger but this does not seem to change the socio-economic dynamics discussed above.

The summary of the picture sketched so far is that: (1) GM crops increase yields while mitigating environmental degradation (Kalaitzandonakes [16] provides some excellent analyses of economic and environmental impacts), (2) in almost 15 years of widespread use in the U.S. and Canada, no new health risks or environmental risks have emerged, and (3) the socio-economic challenges can, and must, be managed in the same way as for large multinational and national companies that have no involvement in seed production and sales. It would be naïve to believe that everything about GM seeds and crops is rosy but there is nothing that stands out as different from the challenges faced with every aspect of commerce and, likely, every human activity – from use of fossil fuels to disposing of human organic waste. Indeed, GM seeds and crops present a more positive profile than most. For these reasons GM seeds and crops are increasing in use in the Americas and in emerging economies such as China, India and South Africa. **Given all of this, why have sub-Saharan African countries, except South Africa, been so resistant to GM crops? Why are these African countries yet again falling behind?**

Robert Paarlberg in his recent book, *Starved for Science: How Biotechnology is Being Kept Out of Africa* [17] develops a compelling case that these African countries are victims of a rich world indulgence. To crystallise his point, he compares attitudes

Published by Rural Outreach Program
KARI-NARL Complex, Westlands, off Waiyaki Way
P.O. Box 29086-00625 TEL: +254-20-4444030 FAX: +254-20-4444030
Nairobi, KENYA
Email: oniango@iconnect.co.ke OR info@ajfand.net www.ropkenya.org

about medical biotechnology and agricultural biotechnology in rich nations. There is very little protest in rich countries directed against the genetic modification of *E coli* or goats to produce recombinant insulin and other medical and industrial products but there is considerable protest directed against GM crops and foods derived from them. His explanation of this apparent inconsistency is that in rich countries quality food currently is abundant and cheap; few will die or be malnourished because GM crops and food are resisted[1]. People in rich nations, however, do get sick and do die of disorders and diseases; to reject medical biotechnology will have an immediate and dramatic negative effect on the well-being of those in rich nations. In short, rich nations can afford to engage in esoteric debates about GM food because, for the present, little depends on the outcome; they cannot, and do not and will not, engage in debates about GM organisms in medicine because their lives will be significantly negatively affected by a slowing of GMO-R&D and production of recombinant medical products. If he is correct, and I along with a host of others believe he is, “hypocrisy” and “turpitude” are about the only words that are appropriate to describe the current debates about GM crops and the very harmful spill over of those debates to some of the most vulnerable individuals on the planet – the extreme poor in sub-Saharan African countries.

Paarlberg may have identified the influence of the rich world debate on the rejection by most African counties of GM crops but that gives rise to a different question: why have African countries allowed themselves to be so influenced when China, India, South Africa and South American countries – all emerging economies - have not? The complete answer is no doubt extremely complex but some quickly identifiable elements are certainly a part of the answer. The legacy of the colonial period cannot be ignored, nor can the current influence, through its NGOs, of the EU and its stance on GM foods – a rich nations’ stance, I hasten to add, and one driven, in significant part, by trade protectionism and massive agricultural subsidies. Part of the answer, however, will rest with the African nations themselves: the tremendous challenges of disease (malaria and HIV/AIDS), exceptionally high rates of extreme poverty – both resulting in an unhealthy, and ultimately unsustainable, dependence on foreign aid, foreign views and foreign priorities – and a relatively short period of experience with governance and economic dynamics. Many African nations are embroiled in violence, which grinds all hope of a better future into dust. Even those with some semblance of peace and stability have high levels of political and administrative corruption, tribalism, and electoral fraud.

This is a rather depressing picture which focuses on the past and present. Important as it is to understand where we are and how we got here, it is vastly more important, and urgent, to focus on where to go from here. Whatever prescriptions are offered – and these will be many and divergent – all should rest firmly on the recognition of the sovereignty of African nations. Non-Africans may be useful in assisting with the crafting of solutions but those solutions must be freely adopted by Africans and shaped to their own needs; they must provide tangible, sustainable, long-term benefits

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[1] It is worth underscoring that, except in the EU, this resistance has not affected the dramatic increase in the planting of GM crops and the production and marketing of foods containing GM plant material.

to them. In that spirit, African nations must insist, and rich nations acquiesce, that biotechnological R&D, and production and distribution be part of the fabric of their economies - with R&D being done in their universities and industrial laboratories, and products being produced in their manufacturing plants. Much will have to change in developed nations and in African nations for this to happen.

As a first step, African nations should turn their gaze from Europe, and even North America, and explore the use of GM crops in China, India and South Africa. The picture they present is far from a utopia – there are still many challenges – but they are making progress. My advice is to start by investigating GM cotton in India; cotton is not a food, so a number of apprehensions relating to food (misapprehension in my view, as argued above) can be set aside. There are lessons to be learned (negative and positive) about market forces, incentives, regulations, legal frameworks and taxation. There are lessons to be learned about dramatic increases in profitability, about the transformation of the quality and quantity of cotton by using GM seeds - even on smallholder farms of three or so acres. This is an exploration that African nations can begin now and by so doing they will be taking hold of their destiny and shedding the continuing post-colonial influences of developed nations.

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