

TEN REASONS WHY BIOTECHNOLOGY WILL BE IMPORTANT TO THE DEVELOPING WORLD

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The objective in this article is to challenge misconceptions often put forward about the technologies of biotechnology. In particular, I challenge many of the arguments put forward by Altieri and Rosset in their paper published in this issue of *AgBioForum*. My main conclusion is that biotechnology will be very important to the developing world in the next 50 years.

Key words: biotechnology; Green Revolution; benefits; productivity gains; food safety; environmental risk.

Biototechnology companies, national and international organizations, including the Consultative Group on International Agricultural Research (CGIAR), and numerous academics (e.g., Ruttan 1999) have continued to argue for the need to increase agricultural productivity so that sufficient food supplies exist to meet the demand forthcoming from a swelling world population. Despite Altieri and Rosset's (this issue) assertion, population density is hardly the issue. In the absence of significant productivity gains, or expansion of agriculture into marginal lands (e.g., forests), there will be not be sufficient food quantities to feed the projected levels of population. This simple reality is independent of income distribution or the location of the population. And hardly anyone, including Altieri and Rosset, will argue about the pragmatism of population projections. So in the absence of a good alternative – and in the face of a proven slow down in the productivity gains from the Green Revolution – biotechnology is by default our best, and maybe, only, way to increase production to meet future food needs.

My objective in this article is to challenge misconceptions often put forward about biotechnology. Within this context I challenge many of Altieri and Rosset's arguments which are not generally supported by existing scientific evidence. I follow their numbering of arguments to facilitate point-by-point comparisons.

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1. The argument that hunger is a complex socioeconomic phenomenon, tied to lack of resources to grow or buy food, is correct. Equally correct is the argument that existing food supplies could adequately feed the world population. But how food and other resources (e.g., land, capital) are distributed among individuals, regions, or the various nations is determined by the complex interaction of market forces and institutions around the world. Unless our civic societies can come up quickly with an economic system that allocates resources more equitably *and* more efficiently than the present one, 50 years from now we will be faced with an even greater challenge. Calorie for calorie there will not be enough food to feed the projected population of about 9 billion. With the purchasing power and wealth concentrated in the developed countries, and over 90 percent of the projected population growth likely to occur in developing and emerging economies, it is not difficult to predict where food shortages will occur. Unless we are ready to accept starvation, or place parks and the Amazon Basin under the plough, there really is only one good alternative: discover ways to increase food production from existing resources. Bottom line, Altieri and Rosset may want to argue against Western-style capitalism and market institutions if they so choose to -- but their argument is hardly relevant to the issue of biotechnology.

2. The assertion that most innovations in biotechnology are not need driven is incorrect. Here are a few well-documented examples of biotechnology innovations targeting pressing needs:

- Development of a rice strain that has the potential to prevent blindness in millions of children whose diets are deficient in Vitamin A. Vitamin A is a highly essential micronutrient and widespread dietary deficiency of this vitamin in rice-eating Asian countries has tragic undertones: five million children in South East Asia develop an eye disease called xerophthalmia every year, and 250,000 of them eventually become blind. Improved vitamin A nutrition would alleviate this serious health problem and, according to United Nations Children's Fund (UNICEF), could also prevent up to two million infant deaths because vitamin A deficiency predisposes them to diarrhea diseases and measles. A research team led by Ingo Potrykus of the Swiss Federal Institute of Technology in Zurich, in collaboration with scientists from the University of Freiburg in Germany have succeeded in producing the precursor to this vitamin, beta-carotene in rice (Potrykus, 1999).
- Development of rice strains with increased iron content and lowered anti-nutrients. Approximately 30% of the world's population suffers from iron deficiency, especially in less developed countries. Anemia characterized by low hemoglobin is the most widely recognized symptom of iron deficiency, but there are other serious problems such as impaired learning ability in children, increased susceptibility to infection and reduced work capacity. An adequate supply of iron is crucial during the first two years of life because of rapid body growth. Yet the body can use less than 20% of ingested iron. Most iron found in the soil is in the ferric state, an ionic form that can not be utilized until it is converted to the ferrous form. Plants can convert ferric to ferrous iron, however, humans lack the enzyme needed for such conversion. One approach to treating iron deficiency in people is to create plants that contain more iron. The gene for ferritin, an iron-rich soybean storage protein, has been introduced into rice under the control of an endosperm-specific promoter. Grains from transgenic rice plants contained three times more iron than normal rice. The bioavailability of the mineral has been increased also through biotechnology. Seeds store the phosphorous needed for germination in the form of phytate, which is an anti-nutrient because it strongly chelates iron, calcium, zinc and other divalent mineral ions, making them unavailable for uptake. The same Swiss group that created beta-carotene rice has developed a series of transgenic rice lines designed to deal with this problem by introducing a gene that encodes phytase, an enzyme that breaks down phytate. In addition, sulfur containing proteins enhance iron reabsorption so to further promote the reabsorption of iron, a gene for a cystein-rich

metallothionein-like protein has also been engineered into rice by Potrykus (Goto *et al.*, 1999; Potrykus, 1999).

- Improvements to hybrid rice by introducing the gene of interest directly into maintainer or restorer lines. Early results at transforming rice with the nodulin gene indicate that this staple can be colonized by bacteria that fix nitrogen from the atmosphere. This would improve productivity in the absence of synthetic fertilizers, which are typically unavailable to resource-poor farmers in less developing countries (LDCs) (Dowling, 1998).
- Edible vaccines, delivered in locally grown crops, could do more to eliminate disease than the Red Cross, missionaries and United Nations (UN) task forces combined, at a fraction of the cost (Arakawa, *et al.*, Tacket *et al.*, Hag, *et al.*).

All these and numerous other technologies are being advanced and directed towards resource-poor farmers and locations.

Biotechnology is being advanced and directed towards resource-poor farmers and locations. Altieri and Rosset ignore the substantial technology pipeline and the efforts of thousands of scientists across the world to safeguard food safety and improve human nutrition and quality of life. They prefer to focus exclusively on the earliest biotechnology products that were broadly commercialized Bt (*Bacillus thuringiensis*) and Roundup Ready technologies. Equally absent in Altieri and Rosset's arguments is an elementary understanding of market-economics and innovation dynamics.

In market-driven economies, need and profit are closely connected. Companies, large and small, profit only when they offer products and services that address needs and induce willingness to pay. Bt and Roundup Ready technologies have been adopted faster than any other agricultural innovation on record (Kalaitzandonakes, 1999). These adoption levels have taken place despite abundant supplies of conventional seed with which farmers can exercise their "age-old right to save and replant." The reason for the quick adoption, of course, is that farmers profit from the use of such technologies through reduced chemical sprays, improved yields, labor savings, shifts to reduced tillage systems and other benefits (Maagd, *et al.* 1999; Abelson & Hines, 1999). Over half of all economic benefits generated by these technologies have gone to farmers, more than what has been appropriated by biotechnology and seed companies combined (Traxler & Falk-Zepeda, 1999; Falk-Zepeda, Traxler, & Nelson, *in press*).

3. The argument that the integration of chemical pesticides and seed-use has led to lower returns for farmers is incorrect. To support their argument Altieri and Rosset reference an obscure manuscript while they ignore several comprehensive studies that point to increased net returns and reduced chemical loads (Rice, 1999; Klotz-Ingram *et al.*, 1999; Falk-Zepeda, Traxler, & Nelson, *in press*; Gianessi, 1999; Abelson & Hines, 1999; USDA/ERS, 1999a; USDA/ERS, 1999b).

Because of their improved production economics, the introduction of Bt- and herbicide resistant crops have forced tremendous competition in herbicide and insecticide markets. Prices of many herbicides and insecticides have been slashed by over 50% in these markets in order to compete with the improved economics of biotechnology seed/chemical solutions. Such price reductions have led to significant discounting of weed and insect control programs and have benefited even farmers who have not adopted biotechnology crops. Because of lower prices and reduced volumes synthetic pesticides from the use of biotechnology crops, the agrichemicals sector has experienced significant financial losses over the last two-three years.

There is ample evidence to suggest that Altieri and Rosset's assertion that "the integration of seed and chemical industries appears destined to (deliver) lower returns" is incorrect. What is surprising, however, is the lack of rudimentary understanding of farm economics and decision making. Why would thousands of farmers adopt technologies that lead them to losses year after year while conventional seed and pesticide solutions are readily available and cheaper than before the introduction of biotechnology crops?

4. The assertion that "genetically engineered seeds do not increase the yield of crops" is misleading. Generally, Bt-type technologies are expected to increase yields while herbicide-resistant technologies are expected to reduce costs and input use. Conventional weed control programs applied on conventional seed may be as effective in controlling weeds as herbicide resistant plants and are expected to yield similarly. However, conventional weed treatment programs are expected, on average, to cost more and involve larger amounts of synthetic pesticides. In addition herbicide tolerant crops eliminate the need for pre-emergent spraying with far less benign herbicides. On the other hand, Bt-crops enjoy greater protection from hard to control insect pests relative to conventional plants that are applied to chemical insecticides. As a result, when insect pests exceed certain thresholds, Bt-crops are expected to yield better. Such effects will tend to vary from one region to another and from one year to another as insect pest pressures and weed infestations tend to be variable.

To effectively measure the yield and cost impacts of biotechnologies, one must control for all other variation (e.g., year-to-year weather and pest infestation variation, variability in seeding rates, differences in farming systems, and so on). Currently, a small number of studies have measured the yield impacts under proper statistical controls. In these few cases, adoption of herbicide resistance and insect resistance were generally associated with increases in yields and variable profits (Klotz, *et al.*, 1999; Falk-Zepeda, Traxler, & Nelson, *in press*; Maagd, *et al.*, 1999; Abelson & Hines, 1999).

5. The assertion that "there are potential risks of eating (bioengineered) foods" is alarmist. Citing unspecified "recent evidence" Altieri and Rosset fail to acknowledge the extensive scientific evidence that consistently finds that the use of biotechnology methods and biotechnology products pose risks no different from those of other genetic methods and products.

The Food and Drug Administration (FDA) has evaluated technical evidence on all proteins produced through biotechnology and which are currently in commercial food products. All of the proteins that have been placed into foods through the use of biotechnology and are currently in the market are non-toxic, sensitive to heat, acid and enzymatic digestion, and hence rapidly digestible, and have no structural similarities with proteins known to cause allergies (Thompson, 2000). Under their oversight structure, the FDA does not routinely subject foods from new plant varieties to pre-market review or to extensive scientific safety tests, although there are exceptions. The agency has judged that the usual safety and quality control practices used by plant breeders, such as chemical and visual analyses and taste testing, are generally adequate for ensuring food safety. Additional tests are performed, however, when suggested by the product's history of use, composition, or characteristics.

Similarly, the argument that insertion of new DNA can alter the metabolism of plants or animals causing them to produce new allergens and toxins is deceptive. For one thing, these kinds of changes can happen through natural mutations or with any type of plant transformation (e.g., through traditional breeding or bioengineering). For another, newly developed plants (resulting from traditional breeding or bioengineering) are subjected to extensive testing that demonstrates that such plants look and grow normally, and have the expected levels of nutrients and toxins. Extensive scientific evidence suggests that there are no food safety issues with bioengineered plants (*ibid.*). Presence of a substance that is completely new to the food supply or of an allergen presented in an

unusual or unexpected way (for example, a peanut protein transferred to a potato) invokes greater scrutiny by the agency. This focus by the FDA on safety-related characteristics, rather than on the method by which the plant was genetically modified, reflects the scientific consensus that "the same physical and biological laws govern the response of organisms modified by modern molecular and cellular methods and those produced by classical methods," and, therefore, "no conceptual distinction exists" (National Research Council, 1989).

Finally, Altieri and Rosset assert that Roundup Ready soybeans are nutritionally inferior due to reduced quantities of isoflavons, known anti-cancer agents. Yet, to-date there exist no studies that properly control for variations in the supply of water, light, minerals, pests and even germplasm, all of which are known to affect the amounts of isoflavons in soybeans, as they assess the effect of transgenes on such amounts (e.g., Taylor & Hefle, 1999).

Over the years, scientists working on bioengineered crops have used strict scientific principles and thorough analyses to confirm for themselves and the public that the genes and techniques used are safe for the consumer and the environment. The most we can ask is that all foods produced by whatever method receive the same level of evaluation. Millions of people have already consumed the products of genetic engineering and no adverse effects have been reported or demonstrated. Scientists are confident in the validity of the system that regulates and oversees the food supply.

6. The argument that the new bioengineered varieties will fail, as pests develop resistance to the natural Bt-toxins produced by these varieties because they violate the basic principles of integrated pest management (IPM), is misleading. Pests tend to overcome any control mechanism, including those introduced through biotechnology, synthetic pesticides, or even the broader integrated approaches suggested by Altieri and Rosset. In biology no solutions are permanent. Once selection pressure is applied on a population, that population is effectively enriched for resistant organisms. That is why it is imperative to develop a multi-pronged approach. Integrating crop rotation and ecology with biotechnology is not only feasible but also the logical way to progress. Indeed biotechnology companies like Ecogen and AgraQuest use biotechnology to identify and enrich natural predators of damaging pests.

However, biotechnology supplies yet one more mode of defense. For instance, many variations and combinations of Bt genes are currently being produced to minimize pest selection pressure. Indeed, Altieri and Rosset are incorrect when they drive a parallel with the "one pest-one pesticide" paradigm. Biotechnology is striving for a "one pest-many genes" paradigm. Molecular biologists recognize the need to study and apply multiple and diverse mechanisms for controlling pests and pathogens to reduce selection pressure. Simultaneous or sequential deployment of different resistance genes has the same rationale as crop rotation. Pathogen evolution is less able to overcome a changing environment or an environment made inhospitable by an array of resistance genes.

There are many sources of resistance genes in addition to those found in nature. Combinations and re-combinations of genes may be used or completely synthetic genes can be developed. By having a range of gene products with subtle variations produced for example through directed evolution (a technology that mimics the natural process of evolution and brings together advances in molecular biology and classical breeding), or, by creating suites of synthetic genes which the target pest would never encounter in nature, the selection for resistance is greatly reduced. Diverse mechanisms of action of gene products can also be employed to reduce selection pressure through a technique called gene pyramiding whereby genes with very different modes of action such as chitinases, feeding inhibitors, maturation inhibitors, and so on, are used in combination. The probability of any single organism overcoming all of these diverse strategies is vanishingly small. Finally, use of refuges where conventional crops are planted along side of bioengineered ones can further reduce pest

selection. The recent refuge regulation introduced by the Environmental Protection Agency (EPA) targets long-term protection from selection and development of resistance among pests. In conclusion, not only can biotechnology be integrated with ecological and other pest management methods it also supplies several new modes of action thereby enriching IPM.

7. The argument that biotechnology crops have been commercialized without proper testing while posing risks to human health and the environment is incorrect. Biotechnology crops and foods have been massively tested over the years both in the laboratory and in controlled natural environments under the oversight of the EPA, the FDA and the Animal & Plant Health Inspection Service / United States Department of Agriculture (APHIS-USDA). Over 4,000 field tests have been performed in some 18,000 sites throughout the United States over the last 15 years for efficacy, performance and suitability for release in the environment. Thousands of similar field tests have been performed in other countries around the world. Volumes of data have been generated on the food safety of bioengineered foods as well, with no evidence of safety risks as indicated above.

Effective procedures of field testing and food safety assessment have been developed after careful consideration and subject to scientific standards (for example see National Research Council, 1989; Report of a Joint Food & Agriculture Organization / World Health Organization (FAO/WHO) Consultation, 1991; Organization for Economic and Cooperation on Development (OECD), 1993). Altieri and Rosset fail to explain precisely how the FDA, EPA, APHIS-USDA and the vast majority of the scientific community, in undertaking more than 20 years of extensive assessment of biosafety claims, have been negligent. More importantly they should provide stronger scientific evidence in support of their arguments. Specifically:

- The argument that adoption of biotechnology crops is "creating genetic uniformity" inducing vulnerability to new matching strains of pathogens is incorrect. Transgenes are added to existing locally adopted germplasm and have no inherent influence on the genetic variation of the varieties planted. For example, there are over one thousand Roundup Ready varieties of soybeans cultivated in the United States alone. Hence, adoption of biotechnology has not increased the vulnerability of germplasm to homogeneous or other strains of pathogens and has not led to genetic erosion. Quite the opposite. Biotechnology tools are allowing traditional varieties to be revived and safeguarded (see for example Woodward *et al.*, in this issue) or develop new genetic variation.
- The argument that herbicide resistant crops "reduce agrobiodiversity" is incorrect. While minimal restrictions are put on specific rotations (e.g., following Roundup Ready corn with Round-Ready soybeans), equally minimal planning can easily by-pass such restrictions. Indeed, herbicide resistant plants improve agrobiodiversity by encouraging minimum tillage and no-tillage cultivation systems.

Unlike conventional tillage, which controls weed growth by plowing and cultivating, no-till agriculture depends on selective herbicides to kill weeds. The resulting vegetation detritus protects seedlings when they are most vulnerable. Soil erosion is reduced. Beneficial insects in the debris are protected. And the till-less technique reduces equipment, fuel, and fertilizer needs and, significantly, the time required for tending crops. It also improves soil-aggregate formation, microbial activity in the soil, and water infiltration and storage.

- Assertions that cultivation of herbicide resistant plants will result in "superweeds" through gene flow are misleading and alarmist. Gene flow is the exchange of genetic information between crops and wild relatives. The movement of genes via pollen dispersal provides, in principle, a mechanism for foreign genes to "escape" from a genetically engineered crop and spread to weedy

relatives growing nearby. Gene flow becomes an environmental issue when the associated trait confers some kind of ecological advantage. This is a particular concern in the case of herbicide resistance genes, for example, where transfer of the resistance trait to weedy relatives that are more difficult to control.

The risk of gene flow is not specific to biotechnology. It applies equally well to herbicide resistant plants that have been developed through traditional breeding techniques (e.g., STS soybeans). Moreover, gene flow is a constant concern of plant breeders who worry about unwanted genes flowing into their fields. It is widely recognized that the "superweed" concept is exaggerated. Resistance to a particular herbicide, if and when developed, implies that use of other herbicides may be necessary for effective control. Currently, there exist effectual alternative chemistries for most economically relevant weeds.

These arguments aside, gene flow is possible and could deem certain chemistries ineffective. The questions then become how possible is such gene flow and what are some alternative strategies that may be used to address the potential risk.

It is important to remember that for any transgene to spread (nuclear or plastomic), there must be successful hybrid formation between a sexually compatible crop plant and recipient species. The two species must flower at the same time, share the same insect pollinator (if insect-pollinated), and be close enough in space to allow for the transfer of viable pollen. Thus, the transfer of transgenes will depend on the sexual fertility of the hybrid progeny, their vigor and sexual fertility in subsequent generations, and the selection pressure on the host of the resident transgene.

There are also strategies to reduce the, however small, risk of gene flow from transgenic crops. One possibility is the use of male sterile plants, which works well but is limited to a few species. For the many crops in which chloroplasts are strictly maternally inherited, which is to say not transmitted through pollen, transformation of the chloroplast genome should provide an effective way to contain foreign genes. Henry Daniell and colleagues at Auburn University introduced a gene for herbicide resistance into tobacco, showed that it was stably integrated into the chloroplast genome, and demonstrated that transgenic plants contained only transformed chloroplasts. This result advances the potential for chloroplast transformation to be an effective strategy to manage the risk of gene flow (Daniel *et al.*, 1998).

To test the theory of gene flow for herbicide tolerant genes introduced through chloroplast transformation, Scott and Wilkinson (1999) studied a 34-km region near the Thames River, United Kingdom where oilseed rape is cultivated in the vicinity of a native weed, wild rapeseed. Oilseed rape, the cultivated form of *Brassica napus*, and the wild rapeseed (*B. rapa*) are capable of exchanging pollen to produce viable hybrids. The study was designed to determine whether oilseed chloroplasts could be transferred to wild rapeseed, and how long the hybrids and maternal oilseed plants would survive in the wild. To identify chloroplasts, the authors created primers specific to chloroplast DNA non-coding regions. In PCR experiments, oilseed chloroplasts produced a single amplification product of 600 bp, whereas wild rapeseed produced a 650 bp product. In all cases, the chloroplasts from hybrid plants contained the PCR product of the maternal line demonstrating that they are not transferred in pollen.

The authors studied the frequency of hybrid formation and viability of oilseed and hybrids in non-cultivated areas over a three-year period. Their studies show that oilseed has a very low survival rate outside cultivated fields. On average, only 12-19% of oilseed survived each growing season. At the same time, a very low level of natural hybridization was observed (0.4-

1.5%). Taken together, the results indicate that there is a very low possibility of transgene movement into feral populations of maternal lineage. However, the persistence of the maternal line in the wild will be of limited duration.

- Assertions about the impacts of Bt-crops on non-target insects are misleading. Reports of the potential for effects from these Bt corn hybrids on Monarch butterflies or other lepidoptera are not new. They have been reported in the scientific literature and regulatory review documents since at least 1986. The environmental protection agency has been provided data on the potential for impacts on non-target species from Bt pollen for years. Their analyses indicated that, when compared with the numerous other relevant factors, the impacts from such pollen were likely to be negligible. Despite popular belief, Losey, *et al.* (1999) demonstrated nothing new other than that force feeding monarch caterpillars is still not as hazardous as using chemical insecticides.

Indeed, the use of Bt-crops may have a positive impact on biodiversity. Ongoing monitoring by companies of Bt-corn fields since their introduction shows that insect biodiversity and population densities in Bt-corn fields is significantly higher than in fields treated with chemical pesticide sprays. Bt-corn may help enhance beneficial insect populations that would otherwise be threatened by the use of pesticidal sprays. This could lead to benefits for, among others, insect eating birds and small mammals.

Strategies to minimize impact on non-target insects are also being developed. For example, the current generation of Bt corn is aimed at reducing crop losses to an imported pest from Europe, the European corn borer. This pest eats corn stalks. Varieties of corn are already under development that could express Bt or other genes of similar effect only in corn stalks, and not in other parts of the crop (e.g., leaf, pollen). Likewise chloroplast transformation described above will eliminate expression in pollen. Such corn varieties would also eliminate entirely any risks to non-target organisms that might come from Bt containing pollen.

The issue of vector recombination and creation of new viruses has been considered by scientists independently and in specific forums. For example, the USDA-APHIS and the American Institute of Biological Sciences convened a workshop in 1995, to address risk issues associated with the possible generation of new plant viruses in transgenic plants expressing viral genes that confer virus resistance. Most workshop participants believed that current data obtained from laboratory and field research indicate the risk associated with the generation of new plant viruses through recombination is minimal and should not be a limiting factor to large-scale field tests or commercialization of transgenic plants expressing viral transgenes. Genomic viral RNA transcapsidated with coat protein produced by a transgenic plant should not have long-term effects, since the genome of the infecting virus is not modified. Similarly, synergistic interactions between an infecting virus and a viral transgene should not have long-term impacts on the agricultural production. The weight of opinion, though, was that, given time and opportunity, all viral recombinations are possible. With or without the use of transgenic plants, new plant viruses will develop that will require attention. Hence, this is an area where additional research is needed.

8. Many of Altieri and Rosset's "unanswered ecological questions regarding the impact of transgenic crops" are not unanswered. Indeed, there is a substantial body of knowledge and volumes of data on both the environmental and food safety of biotechnology crops and foods demonstrating their overall suitability. This is not to say that environmental and other impact assessment of biotechnology crops should not be expanded. Indeed, more impact assessment studies are needed to augment and expand the existing empirical evidence, answer any unanswered questions and put risks and benefits of biotechnology crops and foods in a proper perspective. This need is explicitly recognized in a recent

report of a Task Force reporting to the Land Grant University and Extension Service administrators which placed high priority on assessment studies (ESCOP/ECOP Report, 2000).

9. Altieri and Rosset misrepresent the position of CGIAR and their research direction. Indeed Ismail Serageldin, Chairman of the CGIAR noted that, *a priori*, biotechnology could contribute to food security by helping to promote sustainable agriculture centered on smallholder farmers in developing countries. Furthermore, they misrepresent the potential of "rotations, inter-cropping and biological control agents" as singular solutions for environmentally sound and productive agriculture. Despite Altieri and Rosset's indirect references to scientific evidence which they report has confirmed repeatedly the dramatic effects of such methods, the evidence in the published literature remains scant.

Crop rotation has been with us since the manor system of medieval times. And although there are no regulatory or technological barriers to its use, it has had only modest adoption by producers because of the limitations it places on resource management and because of its economics. In and of itself crop rotation has not proven to be the singular solution to our increasing food demand problem.

Use and commercialization of biological agents in crop production has also been limited despite decades of research both in the private and public sector. Companies like Ciba, DuPont, American Cyanamid and various startups like Mycogen invested millions of dollars in research of biopesticides and biological agents and, ultimately, disposed them as uneconomical. Even companies that specialize in biological agents and biopesticides, like Ecogen and Agraquest, have focused primarily on high value markets with few chemical pesticide alternatives.

The most misleading aspect of Altieri and Rosset's argument, however, is the artificial dichotomy they draw between biotechnology versus agroecology. As amply described above, biotechnology and agroecological approaches are synergistic and should be combined to improve the sustainability of our agriculture and food systems. Altieri and Rosset use an artificial dichotomy to mask an underlying issue: that there is "an urgent need to challenge the patent system and intellectual property rights intrinsic to the WTO." Ultimately, Altieri and Rosset are after market and political institutions that are unrelated to biotechnology.

10. Altieri and Rosset extend their artificial dichotomy further to pass judgement on what kind of agriculture we should have. "Small farmers using agroecological approaches and low input practices," who are presumably discovering better ways to yield more in environmentally benign and socially responsible ways, is the way to go. Again, there is nothing inherent in biotechnology that justifies the small versus large farm dichotomy. Biotechnologies are size neutral and can benefit small holders and large commercial farmers alike. As Florence Wambugu director of the International Service for the Acquisition of Agri-Biotech Applications (ISAAA) in Kenya notes, the great potential of biotechnology to increase agriculture in Africa lies in its "packaged technology in the seed", which ensures technology benefits without changing local cultural practices. In the broader context, one must also question the wisdom of Altieri and Rosset's argument. In the presence of social, environmental and economic advantages they describe, why are small holder agroecological production systems not quickly dominating?

While laudable in its intent to reduce environmental impact, much of Altieri and Rosset's philosophy is founded on a fallacy. They support a form of farming in which average crop yields on a variety of soils are about half those of intensive farming (Avery, 1999; Evans, 1998; Tillman, 1998). As populations rise, inefficient farming will destroy a much greater quantity of wilderness and its associated wildlife as farming infringes in those areas.

Concluding Comments

Altieri and Rosset's arguments are neither scientifically supported or even really about biotechnology. Their arguments are primarily directed against Western-type capitalism and associated institutions (e.g., intellectual property rights, the WTO). Biotechnology is used as a Trojan Horse. They fail to acknowledge the scientifically proven potential of biotechnology and the ways it can contribute to environmental sustainability and food security. The developing and developed world will need and use biotechnology in many ways during this century. Those with political battles to fight may want to use other, more appropriate fora to fight them.

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