PART I

Welcoming Remarks

Welcoming Remarks

Alan Wildeman (University of Guelph, Guelph, ON)
Host of NABC 16

Why a topic like this? About a year ago when we were thinking about what NABC 16 could be about, we asked the question that everybody is asking themselves in different ways: “What is the role of agriculture for the future, for people’s lives, for food, for livelihoods?” This brings the recognition that agriculture touches every human being on the planet. Of course, that sounds trite to say; but it’s absolutely true. We decided to focus the discussion on biotechnology and agriculture back on those kinds of issues—that one could argue indisputably are important to every person on this planet—and to try to put the discussion into a context that is as broad as possible.

So, while we fully anticipate that there will be people who view the issue strictly from the standpoint of whether or not biotechnology is good or bad or whether or not it violates some principle, we wanted to create a meeting within which that discussion could occur, but could occur against a backdrop of safe and healthy food and the environment and the quality of life for people wherever they may be, and we are extremely delighted that NABC agreed that we could host it at Guelph. We are particularly delighted that so many speakers and attendees have come from so far away to visit Guelph. And for all of those who can’t hear me because they aren’t here, we miss you. A number of people wanted to come and couldn’t for various reasons. We recognize that travel is complicated at the best of times, and while we at Guelph think we are at the center of the universe, we sometimes realize that that is not quite true.

I would like to sincerely welcome everyone here and hope that you enjoy your stay. I have had a chance to meet a number of you and I’m sure will have a chance to meet a lot more. It’s very important to us that the university gets to act as host. To the best of our gracious capacity we will try to make your stay here as pleasant as possible and I hope that you have a productive time, a great meeting, and we come out of it with lots of reason to pause for thought about what we do and why we do it, and perhaps rearticulate why we do what we do and where we stand when we sit or where we sit when we stand. Welcome and enjoy your meeting.

Steve Pueppke (University of Illinois, Urbana-Champaign, IL)

NABC Chair, 2003–2004

I work for the University of Illinois and it's been my privilege to have served as the Chair of the National Agricultural Biotechnology Council for the past year. We are glad that you are here to take part in our annual meeting. Our theme is *Agricultural Biotechnology: Finding Common International Goals*. Why are we emphasizing the global context?

Winnipeg, May 21, 2004: Monsanto Canada today welcomes the decision of the Supreme Court of Canada in ruling that the subject matter claimed within its patent for RoundUp Ready® canola falls within the patent act—that Mr. Percy Schmeiser of Bruno, Saskatchewan, infringed that patent.

Bruno, Saskatchewan, May 22: "The Supreme Court handed down their decision yesterday and I have mixed emotions to it," writes Mr. Percy Schmeiser. "I do not have to pay Monsanto one cent for profits, damages, penalties, court costs or their technology fee. On the bigger issue of whether or not their patent was valid, the court ruled that it is and we have to accept that judgment. For this to be changed, our parliament will have to act."

Copenhagen, a few days later: An expert panel including three Nobel Prize winners convenes to ask how the world could best spend its resources to help developing countries. Number 5 on that list is "Development of new agricultural technologies to combat malnutrition."

Geneva, June 2: Government lawyers from the United States, Canada and Argentina tell the WTO that the EU moratorium on GMOs violates international agreements on trade barriers.

Brussels, June 9: The EU issues a written report saying the lawyers are wrong.

Delhi, 1 day earlier: The task force on applications of biotechnology and agriculture headed by Dr. M.S. Swaminathan, from whom we will hear later this afternoon, presents its report to the Indian minister of agriculture. "Biotechnology," says the report, "holds the promise to double food production, ensure adequate nutrition and rid Indian small farmers of poverty."

Bangalore, 1 day later: "The report is problematic," says Greenpeace India. "It suggests a dangerous non-scientific approach to regulating gene constructs and it threatens India's native varieties and valuable exports such as organic and basmati rice. The report fails to recognize that co-existence of genetically engineered and non-engineered plants is impossible."

Will the farmers be freed of poverty? Are the lawyers wrong? Is co-existence really impossible? Will parliament act? And what will be tomorrow morning's agbiotech headline? Stay tuned, listen intently—as this audience always does—and ask lots and lots of questions. Thanks very much for being here. Enjoy.

Ralph Hardy

President, NABC

It is certainly a pleasure to come back to Guelph. Fifty-plus years ago, I was a student at the forerunner of your current institution and I always enjoy my opportunities to return to Guelph, to my roots if you will. I am a dual citizen, a Canadian as well as a naturalized US citizen, and my wife and I spend about 5 months each year in Ontario enjoying the summer. I'm also a small family farmer outside of Toronto, so I have a little bit of a feeling of the reality of what growing soybeans and wheat and all those things are about. We are certainly pleased that the University of Guelph has selected the topic of agricultural biotechnology and specifically *Finding Common International Goals*.

Where do we have commonality across the more-developed and the less-developed worlds? For those for whom this is the first NABC meeting let me give you a few background pieces of information. We are a thirty-seven-member consortium. We are composed basically of what I would call the senior management of most of the not-for-profit agricultural research institutions in Canada and the United States. Collectively our council members probably spend in their jurisdictions somewhere between $2 billion and $3 billion a year in agricultural research, so it's a pretty significant group in terms of public-sector research.

The objective of NABC is to provide a safe, efficacious, and equitable development of agbiotech. Our annual meeting is an open forum. It always has been an open forum and I think we are rather unique—possibly singularly unique—in terms of providing an open forum to discuss issues of agbiotech, and as you've heard from Steve's comments, those issues continue to exist. Over the years we've addressed consumer issues, bio-based industrial products, risk, public good, environment and food safety, among others. Our format is to provide plenary speakers who describe the broad domains of the area that is being considered, and we have workshops where each and every one of you have an opportunity to speak. But if you speak, we ask that you also listen. We realize that that is a little more difficult for all of us; I know it is for me. And then the most difficult thing we ask of you is to learn. I don't think I've come to an NABC meeting and departed with exactly the same viewpoints as I came with, so I hope we will all be impacted as our understanding of these issues expands.

Each year we print about 5,000 hard copies of the proceedings volume, including the plenary talks and the workshops. Each of you will receive one of those and we provide them free to anyone who wants a single copy. Recently, I was talking to the vice-chancellor for international affairs at one of our member institutions who commented: "What we've seen in terms of genetically engineered soybeans and corn and cotton and canola says clearly there are benefits. But those benefits are mainly at this stage in terms of the more developed world. What we've got to figure out is how to do the sorts of things—and I think it's going to involve hugely the public sector—that will allow more transfer of those benefits that will help the rest of the world." I trust you will have a great meeting and thank you all for being here.

PART II

Meeting Summary

Agricultural Biotechnology: Finding Common International Goals

Alan Wildeman
University of Guelph
Guelph, ON

Agriculture is one of the central and universal activities of humans on the planet and whether they know it or not, every person is a stakeholder in it. It, along with the food and fiber and other products it yields, is intimately entwined with nutrition and livelihoods, with changes to the environment, with global markets, and with human emotions. The sixteenth annual meeting of the NABC provided a unique forum to examine agricultural biotechnology's place within this global context.

Agriculture has had a long history of innovation and adaptation as new ideas and practices, and new technologies, emerged. One need only look at the tractor as a not-too-distant example of how technology radically altered food production throughout much of the world. More recently, agricultural biotechnology has emerged as a new engine of change in farming. Through directed genetic alterations, crops have been given new traits that enhance their resistance to insect pests, that permit more targeted and safer control of weeds, and that eventually will improve their nutritional value or their value as industrial feedstocks. Like every new technology, it too is being viewed from the perspective of how it will affect the fundamental activity that for centuries humans have depended upon.

Technology, innovation, change… these all speak to a sense of promise for the future. But, there are significant clouds on the horizon, clouds that for some people are so ominous that they can no longer be dissipated, and that for others merely represent a solvable, albeit tricky, dilemma. The problem stems from a set of global trends that are unprecedented in human history. Since the time our species appeared on the planet, our population hovered far below one billion people. In the last 100 years it has suddenly risen to six billion, and is *en route* to an estimated nine billion before this century is even half over. Some time around 1980, the human ecological footprint exceeded the estimated carrying capacity of the planet, an imbalance that is being sustained only because it is heavily "subsidized" by inputs of non-renewable resources. For many people, particularly in

North America, Europe, Australia and some parts of Asia, it is sustained in excess. For others, in the chronically poor parts of the world, inadequacies in diet and income remain lethally acute and many people remain deprived of basic essentials needed for an acceptable quality of life.

Our species is in uncharted waters when it comes to coping with this problem. The energy that is so crucial for food production is for now at least finite in supply, there is no more arable land to open up, existing arable land is becoming depleted of nutrients or contaminated, the world has in the past few years produced less food than it needs, lifestyle expectations continue to rise, and population growth continues. This is an era in which pessimists have more than enough facts in hand to reinforce their ongoing doubts about the future.

And as has been the case throughout much of our history as a socialized species, agriculture will be a major player in meeting the challenges of there being a safe and healthy food supply, in struggling to minimize our ecological footprint on the planet, and in improving the quality of life of many people. These challenges are more or less indisputable, but finding ways of achieving them will be difficult and frustrating.

NABC 16

Three Goals

For this reason, NABC 16 addressed the issue of "finding common international goals." The conference focused on if and how agricultural biotechnology could be used to address these three goals that are common to all countries. Can it address issues of the environment and minimize the ecological footprint of people on the planet, can it address the quality of life for all people including those who grow crops, and can it continue to address the growing need for safe and healthy food? Over 160 people from more than twenty countries around the world attended, and throughout the meeting there was a strong emphasis on keeping the discussion focused on broad global perspectives.

Opening Global Dialogue

The opening plenary session provided a broad overview of perspectives from different parts of the world. M.S. Swaminathan from India, Kanayo Nwanze from Africa, and Neal van Alfen from the United States spoke about the extent to which biotechnology is now being used in agriculture worldwide. All of the speakers emphasized a theme that was to be repeated throughout the conference. They highlighted the importance of local and national communities and farmer participation in new technology development and implementation. Whether in the most technologically sophisticated systems or in the most rural and traditional settings, they spoke of the importance of local know-how in achieving adequate nutrition and improved livelihoods of people, social and economic stability, and minimal environmental impacts.

Diminishing the Ecological Footprint

Each of the three subsequent modules dealt with one of the three goals that the conference addressed. In the session on the ecological footprint, William Rees (Canada), David Lavigne (Canada), and Klaus Ammann (Switzerland) discussed the complexities of estimating the impact of human activity on the planet, and highlighted not only the fragility of a global food system based on high energy-input agriculture and the toll that self-interest exacts on the environment, but also the opportunity that might be realized by looking for new alternatives for food production.

Improving Quality of Life

Joel Cohen (United States), Ruth Chadwick (United Kingdom) and Tom Remington (Kenya) spoke about agricultural biotechnology and the quality of life, drawing upon many examples of how the regulatory issues associated with biotechnology can both enhance and constrain adaptation of new technology.

Ensuring Safe and Healthy Food

In the final module, Edilberto Redoña (Philippines), Florence Wambugu (Kenya), and Suzanne Harris (United States) discussed the many ways in which nutrition is inadequate for many people in the world, and suggested ways in which these challenges could be overcome and ways in which biotechnology could be of value. They all highlighted the importance of combining biotechnology with traditional plant breeding for improving crop varieties, particularly since traditional approaches not only are scientifically tried and tested, but because they also benefit from local knowledge and cultural familiarity.

Understanding Cultural Differences

In a closing address at the final luncheon, Ron Herring (United States) provided an overview that picked up on many of the themes of the meeting, particularly on the importance of understanding the cultural differences between countries, the attractiveness of biotechnology to farmers who see it giving them a competitive advantage, and the downsides of assuming that the North American approach to regulation of the technology will be reflected worldwide.

NABC Report 16

The meeting was highlighted by exceptional audience participation during the plenary sessions and in smaller breakout groups. Transcripts of the audience Q&A sessions are included in this volume as is a summary of the breakout discussions and recommendation that emerged from them.

This report articulates from different perspectives a strong consensus from the meeting that the ability of agricultural biotechnology to address global challenges is very great, but that it will absolutely require multidisciplinary engagement at many different levels for the benefits to be broadly appreciated. It is also clear that in a global context, agricultural biotechnology means much more than just transgenic crops. It covers a diversity of new technologies ranging from the application of molecular biology to traditional crop breeding strategies to tissue culture.

These proceedings also clearly demonstrate that the scientific issues that speak to the environment, to food, and to the quality of life must be studied hand in hand with the social forces at play in different parts of the world. For that reason, this volume occupies a critical place in the on-going efforts of the National Agricultural Biotechnology Council to help all of us understand why agriculture remains at the heart of human existence on this planet.

PART III

Breakout Sessions

Breakout Sessions Summary of Discussions[*]

ALLAN EAGLESHAM
National Agricultural Biotechnology Council
Ithaca, NY

Discussions in the workshop sessions followed the themes of the plenary-session modules. To help initiate exchanges, participants (assigned randomly to groups) were invited to address the questions below. Facilitators[*] guided the discussions towards developing policy recommendations.

- Diminishing the Ecological Footprint
  - What priority should the environmental consequences of agricultural biotechnology be given?
  - How and by whom should policies be set?
- Improving the Quality of Life
  - To what extent might agricultural biotechnology affect quality of life by creating changes in the relationships that people have with food and the ways in which it is produced?
  - What are the North-South implications for policy?
- Ensuring Safe and Healthy Food
  - What must policy-makers do to ensure that agricultural biotechnology enhances access to safe and healthy food?

[*]This summary draws on verbal reports delivered at the end of the conference by facilitators David Castle, Stewart Hilts, Sally Humphries, Ricky Yada (all of the University of Guelph) and Tony Shelton (Cornell University). The workshop proceedings were recorded by Mei Bi, Janice DeMoor, and Carol Hannam (all of the University of Guelph), Sarah Bates (Cornell University) and Allan Eaglesham (NABC).

Diminishing the Ecological Footprint

The consequences of biotechnology could be positive or negative for the ecological footprint. Positive effects include decreased chemical inputs, less soil erosion [insofar as agricultural biotechnology (agbiotech) supports no-till practices] and opportunities for bio- or phyto-remediation. Also, there are possibilities of developing traits like salt tolerance and salt-accumulating ability. Feed-use efficiency may be improved in animals and fish. On the negative side, promotion and acceptance of agbiotech may result in increasing reliance on fewer species and fewer crop types, with more monoculture farming. The effects could be widespread particularly in combination with gene flow, including hybridization with wild relatives. A community-ecology question arises on scale effects of farm consolidation, which tends to go hand-in-hand with agbiotech: to what extent does farm size affect the ecological footprint? A case can be made that agbiotech has focused predominantly on profitability, begging a counterfactual question: what if the focus had been on a different array of products targeted specifically toward ecological sustainability?

Adoption of an ecological paradigm—a systems-oriented approach—was recommended as a basic tenet. But, how and by whom should policies be set? The process should be consultative, including input from scientists, pro- and anti-biotech groups, and members of the public and industry. In Australia, the consultative process has not included economic-benefit analyses since industry representatives felt that government was not qualified to judge and the public was afraid that a technology with high economic benefits would be pushed through. The policy-making process should be science-based, and should include, from the outset, persons from developing countries in which impacts and potential trade disadvantages are likely to be greater.

Improving the Quality of Life

Again, the concern was raised that success of agbiotech in the South may lead to monoculture farming. In particular, as crop losses are minimized because of reduced risks from disease and insect predation, farmers are likely to reject species and varieties that have been used in the past, which will affect biodiversity. Planting of *Bt* cotton quickly expanded in the Punjab and Gujarat when its benefits became evident to farmers. If there was any perception of environmental risk, it did not impede this spread, nor did concerns about intellectual property rights. There is a need to be wary of the implications of the success of biotechnology.

Gender aspects of adoption of genetically engineered crops received significant attention. Introduction of crops that reduce labor demands—such as herbicide-tolerant varieties—is likely to have negative consequences for female field laborers. Also, as crops become commercially successful, control over them often passes to men from women, who are disempowered as a consequence. Gender aspects of agbiotech need to be fully explored along with concerns about health and nutrition, all of which affect quality of life.

Food security, standard of living and quality of life are nested concepts, which relates to a point made by Ruth Chadwick: you cannot get to quality of life without considering antecedents that indicate a priority for action. First you need food security and then you can talk about quantitative and qualitative measures of standard of living and quality of life. These are underpinned by trust in regulatory systems. Food labeling is an issue in industrialized countries where people want to maintain particular cultural associations with what they eat or they just want to know what they are eating. With labeling, they may not act any differently, or they may opt to avoid all genetically modified foods. In the developing-country context, the issue for improving quality of life is that agricultural biotechnology can lessen labor input. However, with fewer involved in farming, alternative gainful employment would need to be found. It cuts both ways.

It is hard to imagine how enabling technologies will be placed in the hands of the people who need them if there are trade subsidies in the form of research inputs that lead to intellectual property in developed countries and then trade barriers in the form of insurmountable licensing practices.

How are we to understand cross-country differences in acceptance and success of genetically engineered crops? It is likely that what makes agbiotech work is often due less to the technology itself than to the social conditions that must be in place for it to work.

The impact of agbiotech will depend considerably on the country; the higher on the socioeconomic ladder, the less is the potential for effect. In developing countries, subsistence farmers could benefit since they have limited access to pesticides and fertilizers.

Agricultural biotechnology is likely to significantly impact diets in terms of new functional foods and nutraceuticals. It could have considerable secondary impacts on agricultural intensification and soil fertility. Where adoption of salinity-tolerant varieties would promote yields, it may also perpetuate overuse of irrigation that contributes to soil salinity. Concern was expressed that agbiotech will contribute to increased farm size with negative social results from labor-displacement. Interactions between food and migration—internal and international—are complex: might biotechnology eventually have negative impacts?

Ensuring Safe and Healthy Food

The regulation of agri-business is important as is trust in regulators resulting from a positive regulatory influence. Setting up regulatory regimes in developing countries will involve continuous evolution of context-relevant policies. Policies for monitoring the safety and healthfulness of food are not available "off the shelf." While international harmonization of standards may be required, there is also need for contact-sensitivity that is appropriate to the place in which a technology will be applied.

Science education and communication are important. Need-assessments are necessary: what do people really need from agbiotech? What should they plant to ensure food security and environmentally sustainable agricultural practices? The other part of this is the informational aspect: what do you need to tell people in order for them to be familiarized with a technology and to ensure that it actually provides promised benefits? One way is to establish an opinion-leaders' network by tapping into local government structures in a way that helps build trust in new biotechnologies.

There is need to demonstrate and discuss all possible benefits from a new product, which may present added opportunities in certain situations. For example, less susceptibility to fungal infection may occur with *Bt* corn as a secondary effect of less insect damage. In turn, less aflatoxin contamination could have tremendous significance in particular contexts.

The adoption and use of biotechnology and genomics should be approached within the context of conventional practices. Rather than view agbiotech as the wave of the future—it's new, therefore it's good—we should regard it as part of a mélange of new and old, balanced appropriately to meet local needs. The point was emphasized that agricultural biotechnology would be more readily adopted and food security would be more attainable as would environmental sustainability if it were blended back into conventional practices in order that value-added benefits would accrue alongside maintenance of traditions.

Again, stakeholder participation is essential in setting research priorities, including farmers, and, in the South, poor farmers. Public trust needs to be garnered and the public respects the opinions of farmers.

In the North American context, the best method of ensuring that agbiotech enhances access to safe and healthy food is via linkage to the healthcare system. If biotech reduces costs, it will garner attention. A central issue came up in terms of trust: do policy-makers trust, or even understand, biotechnology? Science is becoming more and more politicized, particularly in the United States, which impinges on how we should go about dealing with biotechnology.

In terms of regulation, we may not have to do much in North America where institutions already exist for the management of foods and drugs. We don't need to reinvent the wheel, but we do need to adjust it to fit particular circumstances. On the subject of food labeling, the Canadian system seems to be reasonably constructed—based on the product and not the process—and may serve as a useful model for other countries. However, regulation should be experience-based and should be appropriate to the country where the crop will be grown.

Recurring Themes

Several recurring themes ran through the discussions. Scientists need to communicate more effectively not only with the public, but also with politicians and policymakers. They need to learn how to write in plain language in half-page portions. Until then, there will be need for "translators." Also, there is need for such communication to be couched in questions that the audience being addressed is asking rather than simply trying to get a message across. Scientists must communicate with a range of different audiences. On one hand, there is the political "battle," which needs one style of communication whereas other audiences need to be listened to and questions answered in terms they will understand. Understanding risks and finding a balance between those risks is a key stumbling block in terms of public understanding. Communication may be improved if multiple disciplines are represented in graduate-student programs and on committees, to expose students in the biological sciences to social-science issues and ways of thinking. Related to improvement in communications, public education in agricultural biotechnology is needed. When 50% of the population feels that they don't want DNA in their food, you know you have a real challenge. Such challenges will be specific to each country. We should focus on a long-term educational outreach program in schools. Public outreach is also needed as is public dialogue—not a debate, but a dialogue on agricultural biotechnology—so that interested members of the public can form sound opinions. With traits that are important to the people in the country in question, the dialogue will be much more constructive.

When agbiotech is considered in the international context, private-sector investment must be replaced with public-sector investment. Clearly, there is need for significant public-sector funding initiatives if benefits are to reach resource-poor farmers in developing countries. It will be necessary to work with local communities to ensure acceptance and adoption from the bottom up rather than simply again trying to impose viewpoints from the top down. Thus, needs must be identified—nutritional and environmental (*e.g.* cutting down pesticide use)—so that product traits are country-relevant. The public sector will not make these products become a reality, it has to be in partnership with the private sector; increased investment in the public sector is needed.

Finally, a direct quote is worthy of mention: "Genetically modified crops are only a small part of the problem and only a small part of the solution." Enhancing food production using genetic engineering as a tool faces the same basic problems as with traditional breeding in terms of transferring benefits to the level of the resource-poor farmer.

Breakout Sessions Recommendations

Anthony M. Shelton
Cornell University
Geneva, NY

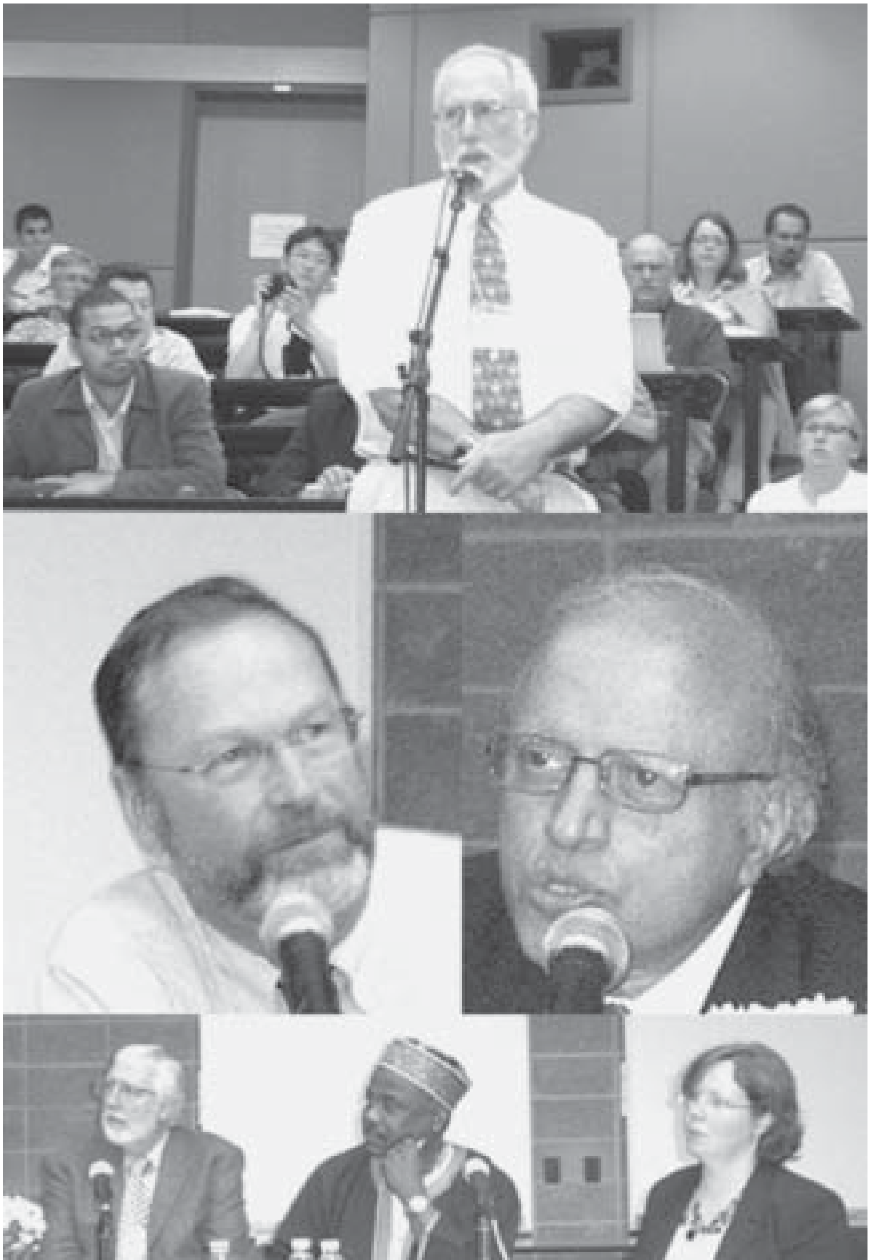
While NABC 16 participants gained from the opportunity of listening to a series of stimulating presentations with diverse viewpoints and having lively discussions in the meetings, breakout sessions, hallways and at social events, the real value of the meeting will be whether it can play some role in helping to implement policies for the wise use of agricultural biotechnology for the common good of international communities.

The broad discussions we undertook at the breakout sessions focused on three major themes that biotechnology should address if it is to have benefits to the international community: to diminish the ecological footprint of agriculture, improve the quality of life for the diverse segments of the world's populations and ensure safe and healthy food. These themes encompass the hopes and aspirations of the world community, regardless of whether one is discussing biotechnology or any other technology. However the hope—and perhaps the hype—of biotechnology have put it front and center in the world's eye and made it subject to increased scrutiny not only about the safety of the technology to humans and the environment but also about how it may affect social, political and economic structures throughout the world. Some would say that biotechnology is being examined more critically and perhaps unfairly than other technologies and that it is just a tool, neither good nor bad in and of itself. However, the tone of the public debate about biotechnology appears to demand more answers, and a list of recommendations, developed from the meeting, may provide some help in developing public policies to ensure that biotechnology is a tool that can be used to help the world community:

- When biotechnology is discussed, it is important to define what one is and is not talking about. To the biologist it is a set of tools of modern biology that are commonly used in most laboratories around the world, including those in many developing countries. This broad term "biotechnology" encompasses many commonly used techniques for understanding how an organism functions or for testing for human diseases, and for developing new plant varieties or medicines. Genetic engineering is one technique within biotechnology that involves specific manipulation of genes, and it is this aspect that has garnered the most controversy. It is important that discussions on biotechnology make these distinctions to identify the real issues. The risks of using a technique such as PCR—common in biotechnology—to detect the frequency of resistance genes within an insect population in a field is far different from developing and releasing a plant tolerant to a specific herbicide.

- When discussing the potential impact of agricultural biotechnology, it is important to recognize that agriculture and food production overall have had tremendous impact on the environment, including biodiversity. The use of genetically engineered plants is but one component of this impact and should be evaluated as such.
- When evaluating the risks and benefits of using agricultural biotechnology, there needs to be a comparison of the risks and benefits of not using it. It must be recognized that every technology has an inherent set of risks and benefits, including older technologies that continue to be used. It also should be recognized that an analysis of risks and benefits should be an on-going process as new evaluation techniques are developed or as new risks or benefits are identified.
- It should be recognized that there are distinct and strongly held cultural values in the world and these must be respected. Each culture may emphasize different points when evaluating the impact of agricultural biotechnology on society. In areas where food is scarce, more emphasis may be placed on crop production than on another common good. No country or culture should be forced to accept or reject biotechnology based on the culture of another.
- The needs of a particular culture or country should come first. For a product of biotechnology to be adopted by a culture or country, it must be a consumer- or farmer-driven product that provides an advantage to that culture. What is perceived as an advantage to one culture may not be to another.
- For biotechnology to serve the needs of those in developing countries, programs in capacity-building within the country/region should be considered as the highest priority. In this context, capacity building should be thought of broadly to include the needed facilities and personnel so that techniques can be learned and policies can be developed. By developing the capacity within a country/region, then the citizens will be best able to develop products and policies that are “home-grown” and will most closely meet their particular needs.

- While intellectual property (IP) remains essential for the development of biotechnology, it should not hinder the development and deployment of products of biotechnology in regions of the world where they can be most useful. Companies have a moral obligation to ensure their scientific capacity in biotechnology provides benefits to the world and should develop appropriate partnerships and strategies so that IP issues do not stand in the way.
- It must be recognized that companies involved in agricultural biotechnology will remain profit-driven and the needs of some cultures and countries may not be fit a company's business model. Therefore, additional channels and resources need to be developed in the public sector. Within the constraints of their business models, companies should be encouraged to play some role in a public-private partnership of agricultural biotechnology for the good of society.
- Agricultural biotechnology may have positive impacts such as modifying foods to be more nutritious, grown with less pesticide or fertilizer, or increased yield potential, improved quality or storability. Use of agricultural biotechnology may also have social impacts such as increased consolidation of the industry, trade implications, or displacement of labor. The rapid, worldwide growth and spread of genetically engineered plants since their introduction in 1996 is likely to continue and make entry into more developing countries. Therefore, it is important to develop programs that will measure the impact of these products on the environment, quality of life, food availability and food safety and to develop programs that will minimize any negative effects. It is essential that such programs be transparent.
- Biosafety programs focusing on environmental and human safety need to be developed and put in place before plantings of genetically engineered plants are approved. Such programs can be difficult and expensive to institute, therefore countries should learn from those that have already enacted such protocols. If appropriate, protocols can be regionalized. The US and European regulatory systems may not necessarily provide good models for developing countries because of their high cost, which may hinder the testing and deployment of genetically engineered crops.
- A multi-focus, long-range educational program tailored to the culture is essential for the further deployment of agricultural biotechnology. The program should consist of a long-term approach through schools as well as outreach programs for the general public.
- It is important that knowledgeable scientists continue to express their opinions publicly in the on-going dialogue about biotechnology.



PART IV

Module I—Opening Global Dialogue

Module I—Opening Global Dialogue

Introductory Remarks

Helen Hambly Odame
University of Guelph
Guelph, ON

In preparing for this afternoon, I noted with interest a statement in the NABC 15 proceedings volume that "communication between the pro- and anti-biotech camps was problematic throughout the meeting." Of course, we are suffering from a world of dualisms when in fact we live in a highly diverse and philosophically pluralistic global society. We should expect of our speakers and ourselves, as participants in NABC 16, a critical analysis of the case-specific nature of biotechnology. Can we not recognize its inherent contradictions because of its positivist tradition and its commercial interest? How might we approach biotechnology if indeed there is new hope for equitable and sustainable agriculture in food-insecure communities throughout the world? If we are unable to recognize and communicate the diversity of viewpoints on this important topic, we are moving away from action towards social and political lethargy, which will accept, not challenge, the global power and food security *status quo*. For me and for many others, this would be totally unacceptable.

This afternoon we will hear from three eminent speakers on agricultural biotechnology in the global context: Kanayo Nwanze, Neal Van Alfen, and M.S. Swaminathan.

In Search of the Right Solutions for Africa's Development

Kanayo F. Nwanze, Savitri Mohapatra and Pierre-Justin Kouka
Africa Rice Center
Abidjan, Ivory Coast

What are the right solutions for Africa? Put together, the United States, Europe, India, China, Argentina, and New Zealand are smaller than Africa. For a continent so diverse—in its demography, in its peoples, their cultures and traditions, and untapped resources—to suggest that one can prescribe a set of solutions, let alone find them, is presumptuous.

In examining the problems and possible solutions for Africa, we will limit our focus specifically to sub-Saharan Africa (SSA), a region of multiple natural and man-made disasters that generate horrifying statistics defying the laws of probability. Our paper attempts first to highlight the formidable challenges that face SSA, then opens a window to a thin ray of hope that is piercing the haze of despair. We will present a few examples of remarkable successes in agriculture and the potential—and concerns—regarding agricultural biotechnology.

Our examples of the signs of hope are drawn from the creation of the Africa-led New Partnership for Africa's Development (NEPAD) and the prospects of cutting-edge science. Contributions from centers supported by the Consultative Group on International Agricultural Research (CGIAR), in strong partnership with national programs in SSA, are highlighted. The reasons why highly promising Africa-specific agricultural technologies have not had the expected and much needed impact in SSA are also discussed.

The last section briefly presents the potential of biotechnology as one of the tools to address some of SSA's intractable problems. It also raises the major concerns for SSA regarding biotechnology, such as the predominant role of the private sector in biotechnology, with very little research on poor people's crops; proprietary science; the high cost of biotech research; the general lack of biosafety guidelines, policies and regulations; the absence of informed public awareness on genetically modified organisms (GMOs) in SSA; and, finally, the risk of SSA being left out of the biotechnology or gene revolution.

The concluding section draws from experiences and observations from over 30 years in agricultural research and development, and discusses the prerequisites for sustainable solutions to Africa's problems such as good governance, political commitment, better institutions, infrastructure and a favorable policy-environment that must accompany promising technologies. We call upon African leaders and all Africans for action!

Major Challenges

The challenges facing SSA are multiple and multi-faceted. They are usually illustrated by a number of statistics for which Africa excels. The stark figures do not reveal the underlying individual tragedies and dreadful human suffering. For the purpose of this paper, only selected major challenges and those related to agriculture are presented.

In SSA, about 300 million people live on less than US$1 per day and nearly 200 million people are chronically hungry.

Hunger and Poverty

In SSA, about 300 million people live on less than US$1 per day (Runge *et al.*, 2003) and nearly 200 million people are chronically hungry. In 2003, 25 million Africans required emergency food aid. In 2000, Africa had 44% of the world's hungry. If present trends continue, the number may be 73% by the year 2015 (ERS/USDA, 2000).

About 32 million African children of less than 5 years of age are underweight (Runge *et al.*, 2003). SSA is the only region where the number of malnourished children will rise over the next 20 years. The predicted increase of 6 million under current trends may prove to be an underestimate (Runge *et al.*, 2003).

SSA is also the only region of the world where poverty is increasing. The number of its poor is likely to rise from 315 million in 1999 to more than 400 million by 2015 (UNECA, 2004).

Population Growth

In the past three decades, Africa's population has grown faster than in any other region. It doubled between 1975 and 2000, from 325 to 650 million. In less than three decades it is projected to double again from the current level (Rosen and Conly, 1998). The rate of growth in the population is projected to be twice that of the growth in food production (Pinstrup-Andersen and Pandya-Lorch, 1999).

Epidemics

The epicenter of the global HIV/AIDS crisis and malarial infestation, SSA suffers the world's highest rates of deaths from HIV/AIDS (81%), malaria (90%) and tuberculosis (23%) (WHO, 2001). HIV/AIDS is ravaging the continent, changing its demography, decimating a generation, and creating the phenomenon of "AIDS orphans." Twelve million African children have lost their parents to AIDS, and this number is expected to reach 28 million by 2010 (UNAIDS, 2000). This is the only continent where polio is still a threatening disease, thereby endangering a whole generation of tomorrow's leaders.

It is estimated that the population of SSA will decrease by 84 million by 2015 as a result of the HIV/AIDS epidemic (UN Population Division, 2001). Much of this reduction is likely to come from rural areas where the incidence of the disease is highest. SSA's agricultural labor force is already devastated and will continue to be so for generations, depleting the region of its food producers, generating a spiral of acute poverty and threatening to compromise any economic, social and democratic progress in the region.

Epidemics and inadequate heathcare and social services are affecting life expectancy, which is now less than 50 years in SSA.

Over the past two decades,* per-capita *food production has declined significantly, partly due to neglect of the agricultural sector.

Low Agricultural Productivity

One of the biggest challenges facing SSA is how to feed its population. Over the past two decades, *per-capita* food production has declined significantly, partly due to neglect of the agricultural sector. African states and governments did not invest in economic growth and rural development, resulting in current severe food shortages and insecurity. This issue is accentuated by a number of factors, including:

- the dependence of agriculture on rainfall (making it vulnerable to droughts and low productivity),
- the lack of a significant number of sizeable agricultural businesses,
- limited use of inputs; lack of market infrastructures,
- the inadequacy of policies and regulations aimed at providing incentives to agricultural production and related businesses.

Unlike Asia, where it was possible to prevent famines thanks to Green Revolution technologies that could be applied consistently across millions of hectares of land, SSA is confronted with specific challenges—poor soils, unsuitable conditions for irrigation, and large variations in growing conditions. Green Revolution technologies, which were targeted to high-potential areas of Asia, were not suitable for SSA.

The imbalances of agricultural production are exacerbated by the lack of appropriate policies and regulations in the agriculture sector and high deficits in trade balances of African economies. While most African countries depend heavily on the export of one to two crops or of crude oil, imports meet much of their need for agricultural products to close the gap between production and consumption, making most of SSA dependent on the rest of the world. In addition, conditions imposed by international trade tariffs, anti-dumping regulations and trade barriers are not favorable to African nations.

Prescribed structural adjustment programs introduced in the 1970s aimed at eliminating government control, and subsidies and increasing guaranteed prices to the producers of tradable agricultural commodities have had a tremendous adverse impact on African economies. This situation has accentuated the non-competitiveness of SSA in the international market.

Many experts in agriculture consider decreasing soil fertility as the fundamental cause of declining food security in SSA

Environmental Challenges

Many experts in agriculture consider decreasing soil fertility as the fundamental cause of declining food security in SSA (Sanchez *et al.*, 1997). This statement remains true today as the use of fertilizer has declined in many countries with the disappearance of agricultural subsidies, poor to non-existent roads, high transportation costs, and currency devaluation which has caused fertilizer prices to rise significantly. Farmers in SSA use an average of 9 kg of fertilizer per hectare compared to 241 kg for East Asian farmers and 125 kg for those in developed countries.

Another major environmental threat in SSA is drought, which affects food production. There have been seven major droughts in the region over the last four decades. In 1972–74 and 1981–84, massive displacements and suffering resulted.

Food security cannot be achieved in an environment of turmoil.

Conflicts and Instabilities

Food security cannot be achieved in an environment of turmoil. Poverty's corrosive effects often lead to social and economic instabilities in SSA, which, in turn, keep the populations impoverished and food-insecure. This is a deadly spiral, from which African nations must escape in order to begin to achieve development.

In addition to poverty, the artificial demarcation of Africa that occurred during the colonial period into relatively small political entities and the consequent disruption of existing political and social systems are some of the major causes of current conflicts. Bad and inefficient governance prevalent in many SSA countries has an exacerbating effect.

Decreasing Agricultural Aid

According to the World Bank, agricultural aid to SSA fell from US$4 billion in 1990 to US$2.6 billion in 1999, a loss of 35% (World Bank, 2003). Increasingly, the reduced aid is diverted to emergency relief rather than long-term development.

SIGNS OF HOPE

In spite of the bleak picture painted by the challenges described above, there is reason to believe that hope is on the agenda for Africa. Several initiatives and progress made within the region provide tangible positive signs.

New Partnership for Africa's Development

SSA stands on the verge of exciting opportunities that could place its countries—individually and collectively—on a path to sustainable growth and development. There is a heightened sense of responsibility in the international community as a whole and African leaders are increasingly taking over the reins to define where they want to take Africa.

NEPAD is an ambitious action program launched by a new generation of African leaders and embraced by the newly formed African Union (AU). Its long-term goal—to end poverty in SSA—is underpinned by peace, democracy, good governance, the development of social and physical infrastructure and the full engagement of African countries in international trade. It provides a framework for SSA's stakeholders to:

- target financial and human resources more efficiently as part of a coordinated effort for the sub-continent, and
- to measure their impacts.

NEPAD recognizes the role of agriculture in economic development and has placed agricultural growth as the cornerstone of its poverty-reduction program.

NEPAD recognizes the role of agriculture in economic development and has placed agricultural growth as the cornerstone of its poverty-reduction program. Its Comprehensive Africa Agricultural Development Program (CAADP) has identified technological interventions that can improve food security and the productivity of the region's agricultural sector.

NEPAD and the Forum for Agricultural Research in Africa (FARA)—the apex body of the sub-regional organizations in the continent—are collaborating on the large-scale Dissemination of New Agricultural Technologies in Africa (DONATA). The main objective of DONATA is to increase agricultural production and investment, and thereby reduce food insecurity and raise incomes by disseminating improved agricultural technologies such as NERICA rice (New Rice For Africa), tissue-culture banana and new cassava varieties and by institutionalizing links between major national, sub-regional and regional stakeholders in scaling up promising new technologies.

Endorsing the NEPAD action plan, the G8 countries unveiled the G8 Africa Action Plan at the historic Kananaskis Summit in Canada, 2002. Several G8 countries announced increased assistance for Africa. The Canadian government—a strong supporter of NEPAD—has pledged CAN$500 million for SSA's development. The recent statements from the Sea Island G8 Summit are a far-reaching declaration of commitment to NEPAD and Africa as a whole. The future will assess to what extent commitments are translated into action.

Emerging or Improved Democracies

In spite of the increased number of armed conflicts in some sub-regions, a few countries provide reason to believe in the future of democracy in Africa. With the abolishment of apartheid, South Africa leads SSA on the democratic path and in good governance. Senegal, Mali and Ghana have been cited at different forums for similar significant progress. A recent addition to this list is Uganda, a country poised for major progress in this century. Good governance is high on the agenda of the AU.

Frontier Science

Advances in science and technology such as biotechnology, informatics, geographic information systems (GIS) and sophisticated simulation modeling have opened new frontiers in agricultural research and development. These advances provide hope that solutions to global challenges will also be within the reach of African people.

Today, mankind is on the brink of the golden age of plant science, when we can understand plants so precisely that it is becoming relatively easy to incorporate traits like pest resistance, durability and increased nutritional value in our crops.

Support from International Research Organizations

About 70% of Africans live in rural areas and depend, directly or indirectly, on agriculture. Therefore, agriculture must be at the heart of any effective solution to the problems of poverty, food insecurity, and environmental destruction that beset Africa. The CGIAR centers work closely with national programs to address the agricultural development gap in SSA and help to bring the benefits of modern science to the rural and urban poor.

The research outputs of the CGIAR constitute "global public goods"—freely available to all. This is particularly invaluable for SSA, during a period when a large part of agricultural research and development is moving inexorably towards the private sector.

Several research breakthroughs, including some based on basic molecular genetics, are making a difference in the lives of poor farmers and consumers.

Success Stories

Stories from SSA often paint such a bleak picture of its sub-regions that good and positive stories often go unnoticed because they do not represent the image tagged to Africa.

Several research breakthroughs, including some based on basic molecular genetics, are making a difference in the lives of poor farmers and consumers. Two main factors have contributed to the success of several breakthroughs highlighted in this paper.

A priority-setting process and subsequent involvement of national programs in the development and a sense of ownership of new or improved technologies have provided the opportunity for creating technologies that are tailor-made for Africa. This led to major development and extension efforts that were needed to provide a boost to the up-take, out-scaling and up-scaling of research results.

Other factors are the adaptability and sustainability of new or improved technologies. A number of technologies introduced to sub-regions have suffered from lack of sustainability. Large-scale irrigation schemes provide a good example of failures over the past three decades. Projects conducted over specific life spans without consideration of the priorities of the recipient countries and little involvement of national programs in their conception were doomed to fail. Lack of funding for continuation of projects beyond the initial phase led to a proliferation of bad experiences that are often cited to make a case against any hope for Africa's development.

Biological Control of the Cassava Mealybug

Cassava, introduced from South America several centuries ago, has become one of the major food items in SSA, feeding over 200 million people. In the early 1980s however, a major pest—the cassava mealybug—caused crop losses of about 80% and threatened to completely wipe out the crop (Herren and Neuenschwander, 1991)

Researchers at the International Institute of Tropical Agriculture (IITA) in collaboration with national programs set up a mass-rearing and distribution of a predator of the cassava mealybug using data from earlier research by the International Center for Agricultural Research (CIAT) and the International Institute of Biological Control (IIBC). By 1988, the mealybug threat had been successfully controlled throughout Africa. Conservative estimates place the value of production saved at over US$2.2 billion (Noorgard, 1988).

Banana Tissue Culture

Soil degradation and infestation/infection of orchards with pests and diseases have led to rapid declines in banana production in East Africa over the past 20 years. Applying tissue-culture technology, researchers at the Kenya Agricultural Research Institute (KARI), in collaboration with a local private biotechnology company, successfully produced *in vitro* banana plants commercially. The tissue-culture plants roughly doubled both yield and income under farmers' conditions (Qaim, 1999; Wambugu and Kiome, 2001). The technology shortened maturity time from 15 to 9 months, benefiting mainly women who tend the crop, thereby reducing the gender gap.

Banana currently accounts for more than a quarter of caloric consumption in countries such as Rwanda and Uganda, and the adoption of tissue-culture banana and its further dissemination engineered by the Africa Harvest Biotechnology Foundation International, a private non-governmental organization, is contributing to the economies of rural populations.

Soil Fertility

Leading scientists believe that replenishment of soil fertility will trigger rapid growth in African agriculture in the same way that improved germplasm ushered in the Green Revolution in Asia (Borlaug and Doswell, 1994; Conway, 1997; Sanchez and Jama, 2000).

Joint research by the International Center for Research in Agro-Forestry (ICRAF) and national programs has found that a system involving improved 1–2 year fallow with nitrogen-fixing leguminous shrubs coupled, where available, with an application of local rock phosphate, effectively enhances soil fertility. This research result is currently being practiced by about 20,000 farmers in southern Africa with the possibility of quadrupling maize output (Sanchez and Jama, 2000)

Quality Protein Maize

Maize means survival for hundreds of millions of people in Africa. Quality protein maize (QPM) developed through traditional plant breeding by the International Maize and Wheat Improvement Center (CIMMYT) contains nearly twice as much usable protein as other types grown in the tropics, and yields 10% more grain. It can prevent malnutrition among millions of people in SSA and elsewhere. The varieties produce 70 to 100% more of the two essentials amino acids, lysine and tryptophan—building blocks of proteins needed by all cells in the human body—than the most modern varieties of tropical maize.

For millions of people in West Africa, food means rice.

New Rices for Africa

For millions of people in West Africa, food means rice. Unfortunately, imported rice accounts for roughly 40% of local consumption (WARDA, 2001). The Green-Revolution successes in Asian rice proved difficult to transfer to SSA because the new varieties of rice, wheat and maize could not achieve their yield potential under African conditions. In 1991, researchers at the Africa Rice Center (WARDA) embarked on a wide-crossing exercise that led to the development of the New Rices for Africa (NERICAs): a range of varieties that combine the best traits of Asian and African species.

NERICAs offer many advantages to farmers: yield increases of 25 to 250% under farmers' conditions.

The NERICAs offer many advantages to farmers: maturation in 90 to 100 days compared to 120 to 150 days for traditional varieties, less labor due to reduced weeding time, drought tolerance, and yield increases of 25 to 250% under farmers' conditions with minimum inputs.

NERICAs now occupy about 30,000 ha in Africa and are spreading rapidly to central and eastern Africa. The adoption of NERICA varieties, predicted to reach about 70% by 2006 (WARDA, 2004), is expected to save millions of dollars in rice imports and to increase farmers' incomes and overall well-being.

NEPAD has identified NERICA as one of Africa's best practices, worth scaling up and out, and has endorsed its expansion across the continent as part of its DONATA program to boost agricultural production and food security in SSA.

Absence of Large-Scale Impact of Successful Technologies

Good news is coming out of Africa. However, it is equally true that new or improved technologies that have shown great promise have not had the desired large-scale impact that would provide the necessary leap to African agriculture. The success factors mentioned above also provide some of the reasons for limited impact, one of them being lack of a proactive private sector to lead the development of large-scale farming toward an agricultural revolution.

Nonetheless, the above stories represent seeds of hope and are a good indicator of the tremendous potential of Africa's agriculture. As a vivid testimony to this potential, the leaders and researchers credited for four of these technological breakthroughs—cassava biological control, QPM, the soil fertility initiative and NERICA—were recipients of the prestigious World Food Prize in 1995, 2000, 2002 and 2004.

It is, thefore, fair to conclude that the lack of wide-scale impact of technology on Africa's agricultural development lies elsewhere, that science and technology are on the right track and the onus is on our political leaders and policymakers to provide conducive and favorable policies, a stable environment and the political will to sustain the adoption and dissemination of high-impact technologies.

Agricultural Biotechnology: Potential and Concerns

Potential

Biotechnology is a powerful ally in agricultural research. It provides a variety of tools that are more precise, faster and allow scientists to improve plants and animal breeds in ways that conventional breeding can not. These include:

- tissue culture for improved and more rapidly available planting material,
- embryo rescue for crossing distant relatives that would not normally produce a viable offspring,
- anther culture that enables breeders to develop a compete plant from a single male cell,
- molecular markers to better understand genetic diversity in crops, livestock and their pests.

Thanks to markers, initial breeding can be done in a laboratory, saving the time and money required to grow several generations in the field.

For SSA, agricultural biotechnology can be especially valuable because it helps develop crops that need fewer expensive or otherwise unavailable inputs such as pesticides and fertilizers and vaccines for livestock. An important feature of this technology is that it is packaged in a convenient form: the seed. This is especially useful for resource-poor farmers. It means providing solutions for difficult problems.

Agricultural biotechnology can help boost crop productivity and enhance the nutritional content of staple foods. The latter is especially important in SSA, where more than half of the population suffers from micronutrient deficiencies, *e.g.* of vitamin A and iron. In short, food and nutritional security can be improved using biotechnology.

Concerns

Unfortunately, biotechnology has become synonymous with GMOs or transgenics, although these are only one aspect. For SSA, as in other parts of the developing world, economic, health and environmental issues are among the main concerns with respect to the use of agricultural biotechnology.

Very little research in transgenics is being conducted on subsistence crops of relevance to farmers in SSA.

Socioeconomic

The current focus of biotechnology research is on crops and diseases that are of economic relevance to developed rather than developing countries. Very little research in transgenics is being conducted on subsistence crops of relevance to farmers in SSA.

Most private-sector research focuses on solving problems faced by farmers in industrialized nations because that is how research costs can be recovered. SSA farmers need more drought tolerance in varieties of cassava, maize, sorghum, millet, and rice that are high-yielding and resistant to common pests and diseases.

Once such improved crop varieties are created, they must be within the purchasing power of the small farmer who has evolved complex, cheap and effective systems to save, exchange and use seeds from one harvest to the next. In such an environment, patented GM seeds are completely unsuitable, especially if they cannot be saved for replanting.

Patented GM genotypes, therefore, threaten to restrict the ability of small farmers to conserve, use and sell seeds, which would seriously impact their means of survival and increase their dependence on private monopolized agricultural resources.

Health

The second major concern regarding the use of biotechnology is that most SSA countries are not equipped to address any potential risks to human and animal health.

In 2002, Zambia rejected the GM maize that was offered by the United States as food aid to help an estimated 2.4 million people. Zambian experts cited the absence of conclusive evidence on the food's long-term effects on several factors, including human health, the country's long-term food-production capacity and impact on the environment and trade.

The health concerns in SSA echo those in other parts of the world. For example, in 2004, Monsanto suspended plans to introduce the world's first biotech wheat, bowing to protests from around the world. However, discussing environmental or ethical issues is hard with destitute people who have lost dignity and hope because they have nothing to eat.

Other Concerns

SSA lacks several key factors that are necessary for the region to fully harness biotechnology for its agriculture: appropriately trained scientists, good research facilities, proper biosafety regulations and efficient protocols for transformation and genomics. The high cost of biotechnology is also a serious constraint. At the same time, many leaders are concerned that Africa cannot afford to miss the biotechnology revolution.

ADDRESSING MAJOR CONCERNS AND CONSTRAINTS

Socioeconomic Concerns

It is true that the private sector dominates biotechnology research and needs intellectual property rights (IPR) and equity with respect to its products. But at the same time, it is in the private sector's interest to ensure that farmers in the developing world can afford their products. Novel partnerships are being formed between the private sector, donors and non-profit organizations to find common and acceptable grounds.

The African Agricultural Technology Foundation's mission is to acquire technologies through royalty-free licenses along with associated materials and know-how for use on behalf of SSA's resource-poor farmers.

For example, the Rockefeller Foundation, the United States Agency for International Development (USAID) and the Department for International Development (DFID), are providing ways for North-South partnerships to open up African markets in a mutually beneficial and sustainable manner by facilitating the African Agricultural Technology Foundation (AATF), launched in 2003. AATF's mission is to acquire technologies through royalty-free licenses along with associated materials and know-how for use on behalf of SSA's resource-poor farmers, while complying with all laws associated with the use of these technologies. Four major biotechnology and agrochemical companies have agreed to freely share their technologies with African agricultural scientists through the AATF.

Specific technical challenges—improved nutrient uptake and rooting, biological nitrogen fixation, responses to carbon dioxide, tolerance to key environmental stresses, *etc*.—are difficult to handle through traditional breeding or simple biotechnology. Transgenics offer great possibilities, for example in addressing deficiencies in protein, vitamins and iron. Unfortunately, resistance to complex environmental stresses is governed by multiple genes, making it difficult to achieve even via genetic engineering. It will probably be a long time before farmers and consumers benefit from such research. Most of the short-term successes in biotechnology would be derived from marker-assisted breeding and diagnostics rather than from transgenic crops.

Contributions from the CGIAR Centers

The following are examples of biotechnology research projects by the CGIAR and SSA national agricultural research systems (NARSs) for smallholder farmers:

- HarvestPlus is a major global Challenge Program initiated by the CGIAR for addressing malnourishment using both conventional methods and biotechnology. The International Rice Research Institute (IRRI) is developing improved rice varieties enhanced in beta-carotene, iron and zinc, which would greatly benefit millions of people who depend mostly on rice.
- Researchers at WARDA where NERICA rice was developed are using anther culture and molecular-marker technology in collaboration with their partners to evaluate hundreds of varieties to exploit the genetic diversity present in indigenous rice, and transfer desirable genes from cultivated and related wild species into suitable varieties.
- Rosette virus disease is a scourge of groundnuts in Africa and no effective control has been found. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has developed transgenic groundnuts with a viral coat-protein gene; it is ready for testing in SSA.
- Similarly, the discovery of *Bt* toxins highly effective against the African sweet potato weevil—by the researchers of the International Potato Center (CIP) and their partners—will open the way to the development and deployment of transgenic sweet potato varieties in SSA.

- CIMMYT and its partners have been trying to develop varieties tolerant of *Striga*, a major parasitic weed of maize in SSA. A gene identified from maize itself offers the most exciting possibility.
- Grass pea is an important source of dietary protein for the poor in Ethiopia. Able to grow in harsh conditions and during drought, it is the only hope for the poor. However, it contains a neurotoxin that induces "lathyrism" or paralysis of the legs. Plant regeneration protocols have been used at the International Center for Agricultural Research in the Dry Areas (ICARDA) to obtain plants with low concentration of the neurotoxin through somaclonal variation.

Health and Environmental Concerns

Several African countries are signatories to the Cartagena Protocol on Biosafety, which deals with the conservation of biological diversity and the equitable sharing of benefits from the use of genetic resources.

The Protocol seeks to protect biological diversity from potential environmental risks posed by living modified organisms (LMOs) and GMOs resulting from modern biotechnology, taking into account risks to human health and focusing on trans-boundary movement of LMOs. It establishes an advanced informed agreement (AIA) procedure for ensuring that countries are provided with the information necessary to make informed decisions before agreeing to the importation of such organisms.

The Program for Biosafety Systems (PBS) is another important initiative that has been established to assist national governments in studying the policies and procedures necessary to evaluate and manage potential harmful effects of modern biotechnology on the environment and human health. Awarded about $15 million by USAID, the program's unique approach addresses biosafety as part of a sustainable development strategy, anchored by agriculture-led economic growth, trade, and environment objectives.

Awareness remains the key to narrowing the gap between the public's understanding and this rapidly advancing field of science. More transparency on the part of the organizations conducting biotechnology research or testing its products would reassure the public and other stakeholders.

Increasing Biotechnology Research Capacity in SSA

NEPAD has proposed a continent-wide network of Centers of Excellence in biosciences with four hubs: one in each of four sub-regions to develop the capacity of African scientists to conduct their own cutting-edge bioscience research and develop programs addressing high-priority problems. In 2003, the Biosciences Facility, hosted by the International Livestock Research Institute (ILRI) in Nairobi, Kenya, on behalf of NEPAD, was launched for East and Central Africa with CAN$30 million funding from Canada. The core scientific competencies of the Biosciences Facility will be genomics, bio-informatics and their functional applications.

Technological innovation is just one piece in a large and complex mosaic.

Conclusions

From the foregoing, it is clear that technological options, both conventional and non-conventional, are available in Africa and to Africans for ensuring food and nutrition security while sustaining the environment. But the right solutions for the region require more than just technology. Science and technology alone will work no magic in SSA, nor will technology provide a "quick fix" to result in increased and sustained agricultural growth. Technological innovation is just one piece in a large and complex mosaic.

There are two essential pieces in that complex mosaic: The right leadership and a favourable external environment but with one common thread: a shift in paradigm.

New Forms of Partnerships

Africa features prominently on the G8 agenda. Sea Island was the third G8 summit in succession to which African leaders were invited for what is described as "dialogue": a euphemism in this context for exchanging pious declarations and empty promises. The G8 has endorsed NEPAD and is on record that they would spend 0.7% of national income on development assistance. Yet aid to Africa has dropped on a *per-capita* basis from $33 in the 1990s to $20 today. At the G8 summit in Kananaskis, Canada, South African President Thabo Mbeki's challenge for a Marshall Plan for Africa was met with deafening silence.

In response to Africa's worsening food and political crisis, the United Kingdom recently created the International Commission on Africa to heal the scar of Africa's poverty. The United States has embarked on a series of initiatives to fight hunger in Africa. Kofi Annan's Water, Energy, Health, Agriculture and Biodiversity (WEHAB) initiative, the UN Millennium Development Goals (MDGs), their various task forces and a host of others run parallel to NEPAD's development agenda that each is supposedly committed to support. So far, only Ottawa has provided funds to NEPAD. Where is the coordination?

Beyond immediate humanitarian aid, Africa needs long-term development assistance embedded within the framework of NEPAD. This type of assistance has helped Uganda to turn the corner on AIDS, has put more than a million Kenyan children in school and has helped sustain growth in Tanzania and Mozambique. This is where a definite shift in paradigm must occur, on how the North relates to the South.

Africa's solutions are in Africa.

African leaders should cease trooping to Washington, Tokyo, Ottawa, London, Paris, Bonn, Brussels, the Hague, *etc.*, to be lectured on how Africa's problems can be solved only to return home with empty promises. Africa's solutions are in Africa. If they must wine and dine with the G8, then they should aggressively negotiate with countries in the Organization for Economic Cooperation and Development (OECD) who spend close to $1 billion/day on farm subsidies and impose trade barriers that cost SSA $20 billion a year in exports and prevent Africa's poor farmers from participating in simple market economies in their own sub-regions.

Good Governance and Wise Policies

At independence, the new leaders of emerging African nation-states embraced the new form of western democracy modeled after their colonial masters in London, Paris, Brussels and Lisbon. They then proceeded to invest in building modern state capitals and administrative structures at the expense of rural development. That was the first mistake we made. Copying and imitation is not development. Development is a natural and intrinsic process, generated from within, phenotypically manifesting itself in the beauty of forms and cultures. It is homegrown, reflecting cultural values and our heritage. But we strove to become modern overnight, forgetting that the West had gone through centuries of development. Agriculture—once the backbone of our economies—was relegated to the background, if not altogether forgotten. Africa's food crisis was predictable 40 years ago. It is a simple but sad truth: at independence, Africa did not invest in agriculture and rural development!

The right solutions for SSA call for fundamental changes in the mindset both of leaders and followers: good governance, accountability, wise policies, improved infrastructure and the spirit of self-reliance. Billions of dollars of development assistance or a plethora of successful technologies cannot revive SSA's agriculture as long as there is widespread corruption, inefficient governance and lack of leadership and vision. Africa will benefit from technologies when agricultural policies are favorable and consistent, when there is political support at the highest level, and the technologies are nurtured and shepherded by the producers of the technologies.

Our governments have committed to spending at least 10% of their budgets on agriculture. It is a laudable step. Effective extension services and public-awareness campaigns must spread the word about improved technologies. "Farm lobbies"

Our governments have committed to spending at least 10% of their budgets on agriculture.

are urgently required for the region so that farmers can put political pressure on governments to support agricultural technologies, to institute policies that guarantee prices, create access to credits, inputs and markets, and establish equitable land-tenure systems and safety nets and subsidies to support vulnerable groups.

Rural Development

In the same vein, emphasis should shift to rural development, investment in rural infrastructure, including reliable power supply, good roads linking farmers to markets, and adequate communication facilities. Local agro-industries should be encouraged particularly in terms of post-harvest processing and the transformation of local produce into value-added products. These must not be done by governments, but should be devolved to the private sector. Only when domestic markets are viable and vibrant will competitive regional markets emerge and farmers will aspire beyond existing boundaries.

Women produce up to 80% of basic foodstuffs in Africa.

Governments continue to undermine the role of women in the agricultural sector. Women produce up to 80% of basic foodstuffs in Africa, yet our policies continue to marginalize them. Studies have clearly shown that when female farmers have access to resources such as land, credit, technology, training and marketing, they are more productive than their male counterparts. They invest in child health, nutrition and education and are better heads of single households than are men.

Investment in Human and Institutional Capacity Development

Africa's economic renewal and sustainable development will not be achieved without effective investment in science and technology. But Africa must also have its own capacity to generate these technologies. SSA should not remain just a client of technology. It must take an active part in it, both as an innovator and as a user as part of a holistic strategy for SSA's resurgence, so that the sub-continent can achieve the MDGs and usher in the "Doubly Green Revolution" called for by Gordon Conway (Conway, 1997).

We must, therefore, engage in massive investment in human capital and create institutions that will provide a conducive environment for our scientists. Human-capacity development without parallel favorable and conducive institutional environments have undermined our development efforts, and continue to encourage the steady erosion of our brain power into the diaspora, with thousands of frustrated skilled professionals migrating westwards and northwards for opportunities in the developed world. This loss in human capital has been estimated at 70,000 scholars annually while the region spends $4 billion annually to recruit, educate and train 100,000 expatriate replacements (Ofori-Sarpong, 2003).

Self-Reliance

African people have a rare capacity for resilience and optimism. Centuries of oppression have not dimmed this extraordinary source of strength. And we have proof that when provided adequate resources, with the right leadership, with commitment and conviction, Africans are capable of remarkable achievements. But prophets are never recognized by their own people, which is why our leaders continue to look beyond their boundaries for advice and for development strategies hatched elsewhere and delivered by so-called experts.

We know of no country, no people, whose economic and political development was not an indigenous and intrinsic process, engraved in its own culture and adapted to the soil, climate and race.

We strongly believe that Africa's problems cannot be solved by its partners. The onus is on Africans themselves. For we know of no country, no people, whose economic and political development was not an indigenous and intrinsic process, engraved in its own culture and adapted to the soil, climate and race. Africans should decide for themselves what is best for them. A meaningful partnership begins only when we know what we want for ourselves. Only then would help from others add value to our efforts. We should select the most useful technologies, whether conventional or novel, push the frontiers of science and technology, harness the best of biotechnology and evolve the right policies for our needs so that we can benefit from the powerful economic forces of market liberalization and globalization.

The paradox of our times is to live in a world of plenty, with spectacular technological advances, yet witness millions trapped in tragic poverty. If African leaders continue to treat hunger, disease, and malnourishment as second priorities to building sports facilities and monuments, they should be brought before the International Court of Justice for crimes against humanity, crimes they have committed against their peoples over the past four decades.

Acknowledgments

Information contained in this paper on the success stories and contributions of the CGIAR Centers to African agricultural research and development was provided by the centers. A draft of this paper was reviewed by Shellemiah O. Keya and Samuel Bruce-Oliver who also contributed to its finalization.

Views expressed in this paper are those of the authors and not of the CGIAR nor of the Africa Rice Center (WARDA)

References

Borlaug N Doswell CR (1994) Feeding a human population that increasingly crowds a fragile planet. In: Supplement to Transactions 15th World Congress of Soil Science. Chapingo: International Society of Soil Science.

Conway G (1997) The Doubly Green Revolution: Food For All in the 21st Century. London: Penguin Books Ltd.

Economic Research Service of the United States Department of Agriculture (ERS/USDA) (2000) Food Security Assessment Project, December 2000. Washington, DC: United Stated Deparment of Agriculture.

Herren H R Neuenschwander P (1991) Biological control of cassava pests in Africa. Annual Review of Entomology 36 257–283.

Noorgard R B (1988) The biological control of cassava mealybug in Africa. American Journal of Agricultural Economics 70 366–371.

Ofori-Sarpong E (2003) Effects of Brain Drain in National Development. Accra: Ghanaian Chronicle.

Pinstrup-Andersen P Pandya-Lorch R (1999) Securing and sustaining adequate world food production for the third millennium. In: NABC Report 11: World Food Security and Sustainability: The Impact of Biotechnology and Industrial Consolidation (Weeks D *et al*. Eds). Ithaca: National Agricultural Biotechnology Council.

Qaim M (1999) A socioeconomic outlook on tissue culture technology in Kenyan banana production. Biotechnology and Development Monitor 40 18–22.

Rosen JE Conly SR (1998) Africa's population challenge. Washington, DC: Population Action International.

Runge CF *et al*. (2003) Ending Hunger In Our Lifetime: Food Security and Globalization. Baltimore: The Johns Hopkins University Press.

Sanchez PA Jama BA (2000) Soil fertility replenishment takes off in east and southern Africa. International Symposium on Balanced Nutrient Management Systems for the Moist Savanna and Humid Forest Zones of Africa, Cotonou, Benin, October 2000.

Sanchez PA *et al*. (1997) Soil fertility replenishment in Africa: an investment in natural resource capital. In: Replenishing Soil Fertility in Africa (Buresh RJ *et al*. Eds.). Madison: Soil Science Society of America and American Society of Agronomy.

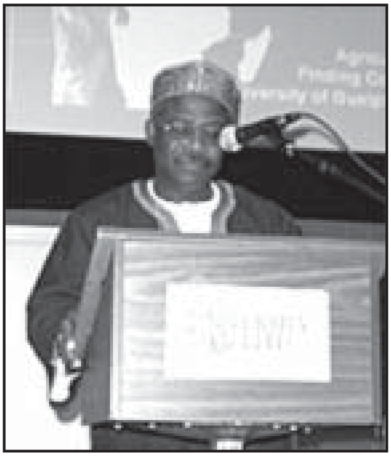
Joint United Nations Program on HIV/AIDS (UNAIDS) (2000) Report on the Global HIV/AIDS Epidemic. Geneva: World Health Organization.

United Nations Economic Commission for Africa (UNECA) (2004) Press Release No. 12/2004. Addis Ababa: UNECA.

UN Population Division (2001) World Population Projections. The 2000 Revision: Highlights. New York: United Nations.

Wambugu F Kiome R (2001) The Benefits of Biotechnology for Small-Scale Banana Farmers in Kenya. ISAAA Briefs No. 22. New York: ISAAA.

WARDA (2001) Bintu and Her New Rice for Africa: Breaking the Shackles of Slash-and-Burn Farming in the World's Poorest Region. Bouake: WARDA.
WARDA (2004) Annual Report 2002–2003. Bouake: WARDA.
World Health Organization (WHO) (2001) World Health Report 2001, Mental Health: New Understanding, New Hope. Geneva: WHO.
World Bank (2002) Africa Database 2002. Washington DC: World Bank.
World Bank (2003) African Development Indicators (ADI) 2003. Washington DC: World Bank.



KANAYO F. NWANZE has served as director general of the West Africa Rice Development Association—now known as the Africa Rice Center—since December 1996. The Africa Rice Center is an autonomous intergovernmental agricultural research association of African member states and one of fifteen international agricultural research centers supported by the Consultative Group on International Agricultural Research (CGIAR). Dr. Nwanze has 30 years experience in international agricultural research, research management, and development work in sub-Saharan Africa (anglophone and francophone countries) and Asia, at CGIAR Centers in Niger, Nigeria, Congo (DRC), Burkina Faso, and India.

He has published extensively and is a member of several scientific associations and a board member of several Africa-based institutions. In 2001, he was conferred with the title of "Commander of the National Order of Merit of Côte d'Ivoire" in recognition of his outstanding leadership of the Africa Rice Center and service to the West African sub-region.

He is the current chair of the Center Directors Committee that regroups the directors general of the fifteen centers supported by the CGIAR. Nwanze holds a BSc in Agricultural Biology from the University of Ibadan, Nigeria, and MS and PhD degrees in entomology from Kansas State University.

Agricultural Biotechnology: How Big is it Globally?

Neal K. Van Alfen
University of California
Davis, CA

Transgenic crops were first grown commercially on a large scale in 1996 when 1.7 million hectares (Mha) were planted. During the intervening years, the area in transgenic crops grew to 67.7 Mha in 2003. This rate of adoption of a new technology is remarkable, but similar to rapid adoption of other breakthrough technologies of the past (James, 2003). While many different types of transgenic plants have been grown experimentally, relatively few have been grown commercially, and only soybean, maize, cotton and canola are grown on a large scale. The limited number of transgenic crops grown, and their concentration in just a few countries, is a reflection of the resistance shown by consumers in some parts of the world to this new technology (Alston, 2004).

Each year since transgenic crops were first planted, it has been anticipated by some that the adoption of this technology will plateau and eventually decline because of consumer resistance and governmental barriers in some regions of the world. This does not seem to be happening and an analysis of recent trends suggests that widespread adoption will continue to expand beyond the United States. The United States remains the largest producer of transgenic crops, with more than half of the world-wide area in 2003. Rates of adoption of transgenic crops in some developing countries, however, have been rapid. Argentina was one of the early adopters of herbicide-tolerant soybean. In 1996–1997, 1% of the crop was genetically modified (GM), but by 2001–2002 more than 90% of the crop was transgenic. An even more-rapid adoption of transgenic maize has occurred in Argentina (Trigo and Cap, 2003). Approval for planting of transgenic soybean in Brazil was given in 2003, and it was conservatively estimated that more than 3 Mha would be planted in 2003–2004 (James, 2003).

Farmers in China planted transgenic cotton for the first time in 1998 and by 2001 approximately 31% of that crop was of GM cultivars. However, these figures do not necessarily reflect how rapidly growers have adopted this technology. The commercial production of transgenic cotton began in a few provinces in the Yellow River cotton region. Within three years it represented 97% of the crop in Hebei Province and 80% in Shandong Province. Introduction of transgenic cotton occurred later in other regions. Cotton farms in China are small; it is estimated that *Bt* cotton had been adopted on more than 3.5 million by 2001 (Pray *et al*., 2002).

Transgenic crops are slowly being introduced in other countries. In 2003, five countries each had more than 1 Mha of transgenic crops (United States, Argentina, Canada, Brazil and China) and another five had between 50,000 and a million ha (South Africa, Australia, India, Romania and Uruguay). Small plantings of transgenic crops have occurred in another eight countries, most of which are not likely to join the group of major producing countries soon (James, 2003).

Where farmers have been given the opportunity to make a choice, adoption has been rapid.

Resistance in some parts of the world to transgenic food products is slowing the spread of both the type of transgenic crops produced and the locations in which they are grown (Alston, 2004). There has been much public discussion concerning the relative costs and benefits of the technology, but unless consumers are confident that benefits substantially outweigh the costs, spread to other crops and countries will be slow. Where farmers have been given the opportunity to make a choice, however, adoption has been rapid. This is true for both large-farm producers in the United States and smallholders in China and South Africa. A number of studies have indicated that the rapid adoption of this technology is primarily driven by economic advantage. Economic incentive is the most important driver of non-mandated change, so it is not surprising that this has occurred.

Economic Advantages of GM Crops

The type of economic advantage provided by the technology has varied from region to region. A survey of literature-source data obtained from US growers regarding farm-level advantages of *Bt* cotton and maize and herbicide-resistant soybean indicated that, in most cases, the growers used less pesticide and had higher profits than they did using comparable conventional technology (Marra *et al*., 2002). It was reported that there was a profit advantage for the farmer of from \$16 to \$173/acre, including the technology fee, for growing *Bt* cotton. A reduction in pesticide sprays of from 1.3 to 3.4 spray events per season was a major reason for this economic advantage.

A more comprehensive survey in China over a three-year period demonstrated the same trend among smallholder farmers (Huang *et al*., 2002a; Pray *et al*., 2002). This study documented the reduction in pesticide use by farmers who adopted *Bt* cotton to be 24–63 kg/ha. To put these savings in perspective, it was reported that in 2001, adoption of *Bt* cotton in China resulted in a reduction of 78,000 tons of formulated pesticide, the equivalent of about 25% of the total pesticide use on all crops in China in the mid-1990s (Pray *et al*., 2002). The net economic advantage to Chinese growers of *Bt* cotton was estimated at approximately $500/ha compared with the growing of non-*Bt* cotton. A similar economic advantage—due to reduction of pesticides and increased yields—was reported for farmers with smallholdings in South Africa (Ismael *et al*., 2002).

The economic advantage of adoption of herbicide-resistant soybean in Argentina appears to be primarily the result of energy savings from switching to no-till cultivation methods, which facilitated double-cropping soybeans with wheat (Trigo and Cap, 2003). In addition, the patent protection for Roundup has expired resulting in competitive pricing of this herbicide; it is estimated that the price in 2001 was less than 30% of the price paid when Monsanto held the patent. The authors of this study indicated that the cost advantage of transgenic soybean to growers was about US$20/ha, primarily due to energy-cost savings from the more effective weed-management strategy.

These various examples from different parts of the world demonstrate that economic advantage to the farmer resulted in rapid adoption of the technology. The particular nature of the economic advantage varied from country to country, but generally was associated with a reduction in the use of pesticides or cost savings that resulted from changing pesticide-use practices.

Within the past fifty years there has been a significant increase in agricultural research by the private sector relative to that funded by the public sector.

Research Investments

Investments in research represent confidence in economic returns. This is particularly true for investments in the applied sciences, such as agriculture. Agricultural research was the first publicly supported research endeavor probably because it was widely recognized in the agrarian world of the time that providing the funds for that research would have immediate, important paybacks. During the past century, the development of agricultural machinery, processed foods and beverages, synthetic fertilizers, hybrid seed, and pesticides opened the doors for agricultural research investments by for-profit companies. Within the past fifty years there has been a significant increase in agricultural research by the private sector relative to that funded by the public sector. Private-sector agricultural research in the United States more than tripled in constant-value dollars between 1960 and 1995 (Shoemaker, 2001).

The first major shift in agricultural research from the public to private sector occurred with the development of pesticides. While pesticides were originally a product of public research, today, essentially all pesticide-development research occurs in private laboratories. Shifts are also occurring in traditional plant-breeding programs: in 1980, 70% of the soybeans planted in the United States were public-sector varieties whereas in 1997 it was estimated that only 10–30% of the soybeans were public-sector varieties. Public-sector cotton seed declined from 37% in 1975 to 1979 to about 7% in 1997. Maize-seed sales in the United States in 1997 were dominated by four private companies, with a combined market share of 69% (Shoemaker, 2001). All major US commercial transgenic crops were developed by private seed companies. This shift to private-sector agricultural research has certainly accelerated with the advent of agricultural biotechnology, and because of the rapid change in the relative roles of public- and private-sector agricultural research, unresolved stresses are occurring. It is not surprising that a recurring theme in discussions about agricultural biotechnology relates to social/economic issues associated with for-profit companies seeking payback on their research investments.

Public institutions continue to actively invest in agricultural biotechnology research, which contrasts with their withdrawal from pesticide research and development. Although private investment in agricultural biotechnology exceeds that of public-sector investment (55%:45%), public-sector investment is growing throughout the world (Huang *et al.*, 2002b). Even in countries such as Japan, where consumers are opposed to transgenic foods, significant investments are being made in agricultural biotechnology research. European scientists play major roles in the research that enables agricultural biotechnology product development and they continue to field-test transgenic crops in a public environment hostile to the technology. China's investment in agricultural biotechnology has increased rapidly, and if proposed increases in spending come to fruition, it will account for about one-third of the public-sector investment worldwide. The payback in China for investment of public funds in transgenic cotton was repaid in social benefits by only the second year of commercial production (Huang *et al.*, 2002b). The anticipation of this type of economic return on investment is what appears to be driving the increasing investment in agricultural biotechnology by public entities, even in those countries that do not permit commercial production of GM crops.

Although many have suggested that the public resistance to agricultural biotechnology is similar to the resistance that resulted in the cessation of expansion of nuclear power in the United States, such comparisons are superficial at best. The growth in research and academic program investments in agricultural biotechnology is not typical of those of an industry in the throes of death. Unlike the nuclear-power industry, which had only a single product to offer, there are unlimited possible uses of transgenic technology in agriculture. Some of these are clearly not suitable for field release or food use, but there are many that will meet strict regulatory standards and provide significant economic and social benefits.

. . . no clear evidence of negative health effects associated with those GM crops that have been adopted.

Human Health Issues

One of the early questions raised about methods used to create transgenic crops was whether there would be increased health risks for consumers, unique to the technology. This is a much-researched topic that has yielded no clear evidence of negative health effects associated with those GM crops that have been adopted. Therefore, little of value can be added here except to point out that most reviewers of the topic have concluded that the methods *per se* do not create a risk (Kaeppler, 2000). It is clear, however, that each new product should be assessed for its risks and benefits, as should be true for any new food product.

Another way to look at the health effects of currently grown GM crops is to examine if any positive, rather than negative, health benefits have resulted from their adoption. One of the most obvious considerations is that related to the shift in pesticide use associated with *Bt* and herbicide-resistant crops. The concern about the toxicity of pesticides has been a major driver in the growth of the organic food industry; it is obviously a topic of great public interest and because of the possible toxicity associated with the consumption of most pesticides, their residues in food are carefully regulated.

Pesticide-Associated Illnesses

In China, more pesticides per hectare are used on cotton than on any other crop (Huang *et al.*, 2002c). Significant reductions in use of pesticides have occurred in that country as a result of the adoption of *Bt* cotton (Pray *et al.*, 2002), with concomitant reductions in occurrence of farmer illness from pesticide exposure. Over the three-year period of 1999 to 2001, between 12% and 29% of the farmers who grew non-*Bt* cotton reported becoming ill because of exposure to pesticides. In contrast, during the same period, only 5% to 8% of farmers growing *Bt* cotton reported becoming ill due to pesticides (Huang *et al.*, 2002a). Clearly, reduced exposure to pesticides resulted in dramatic health benefits for the estimated 3.5 million farmers with smallholdings in China who had adopted *Bt* cotton by 2001 (Pray *et al.*, 2002).

Pesticides in Drinking Water

This reduction of insecticide use, and the replacement of more-toxic, persistent herbicides by a less toxic, easily degraded alternative, should result in public-health benefits. Pesticides are common contaminants of public water supplies. The US national primary drinking water standards lists thirty-three items to be regulated for their presence in drinking water; twenty-three of these are pesticides or their breakdown products (OTA, 1995). The herbicide atrazine is one of the more common and toxic contaminants of drinking water in agricultural regions where it is used (Barbash *et al*., 2001). Replacement with less-toxic, readily degraded glyphosate should result in fewer problems of public water-supply contamination by atrazine (Barbash *et al*., 2001). Likewise, reductions in the use of organophosphate insecticides where *Bt* crops are grown should also reduce the danger of contamination of drinking water.

Mycotoxins in Food

There is growing evidence that *Bt* maize has reduced amounts of mycotoxins in the grain than has non-*Bt* maize. Fungi capable of producing toxins are ubiquitous on crops. Many are weak pathogens and grow on plant surfaces or in wounds. Once established in wounds, they are able to penetrate adjacent living plant tissue. Fungi produce a wide array of secondary metabolites, some of which are toxic and/or carcinogenic to humans and animals. Among the most potent is a closely related group of secondary metabolites known as aflatoxins (Payne and Brown, 1998). These and other mycotoxins, such as the fumonisins—formed in plant tissues including grain—are important health threats and stringently enforced regulations limit their presence in food. In many parts of the world, particularly in Africa, these mycotoxins are responsible for serious health problems since much of the food consumed is not inspected for mycotoxins (Bankole and Adebanjo, 2003; Fandohan *et al*., 2003).

Bt maize contains less of the fumonisins than does non-GM maize probably because there is less predation by insects (Munkvold, 2003). Fumonisins, produced by *Fusarium* spp., cause a variety of health problems in animals, including humans (Bankole and Adebanjo, 2003). The extent of the reduction of fumonisins in *Bt* maize compared with non-GM maize surprised researchers (Munkvold, 2003). It appears that the reduction is the consequence of fewer fungi growing in grain damaged by insects, particularly the European corn borer. Bakan *et al*. (2002) reported that experiments in Spain and France showed that grain of *Bt* maize had 4- to 10-fold less overall fungal presence than did non-GM varieties, as determined by the relative amounts of egosterol, a fungal membrane component, in the grain. In these studies the amount of fumonisin B1 was significantly reduced in *Bt* maize. In summarizing the results of thirteen studies where fumonisin content of *Bt* and near isogenic non-*Bt* maize were compared, Munkvold (2003) reported that in eleven of these studies, significant reductions of fumonisin content were reported in *Bt* maize. Magg *et al*. (2002) found only slight reductions in the amount of fumonisins in *Bt* maize grown in central Europe and suggested that *Bt* maize may not be effective in reducing fumonisins under these growing conditions. Munkvold (2003) indicated, however, that fumonisin content is generally negligible in maize grown in higher latitudes; the most common maize-ear disease of that region—gibberella ear rot—is not associated with insect damage. Similar consistent reductions of aflatoxins in *Bt* maize have not been reported, probably because heat and water stress are more important factors in the development of the fungi responsible for aflatoxin contamination than is insect damage (Munkvold, 2003).

Developed countries have strict standards for the amounts of mycotoxins allowable in food. Foods that contain mycotoxins, such as maize, peanut and other nuts, and dried fruits generally do not represent a large portion of the diet of consumers in developed countries, so the benefits of *Bt* maize, and future transgenes that reduce mycotoxins in food, will not be as important as they are to developing countries where these foods represent a much larger part of the diet, and where there are less-developed regulatory and inspection programs (Bankole and Adebanjo, 2003). It is ironic that the narrow interpretation of the precautionary principle with the intention to protect the health of consumers in some developed countries has created an atmosphere whereby solutions to serious health and economic problems in developing countries are stymied (Otsuki *et al.*, 2001).

The issues related to environmental impacts of agricultural biotechnology thus can be considered as a subset of the issues related to all invasive species, i.e. ***will this technology create new or unique problems that may cause environmental or economic challenges?***

Environmental Issues

A variety of concerns have been expressed regarding the impact of transgenic crops on the environment. Primary among these is that unwanted genes may become fixed into populations of wild species. This is not a new problem since many of our crops have the potential to breed with related wild species, but we obviously do not want to continue to spread plants and animals around the world in ways that may disrupt local ecosystems. Most of the plants and animals that our ancestors domesticated and that we use to feed the world did not evolve where they are grown today; not surprisingly, some of these have become weedy. The issues related to environmental impacts of agricultural biotechnology thus can be considered as a subset of the issues related to all invasive species, *i.e.* will this technology create new or unique problems that may cause environmental or economic challenges?

The primary question regarding agricultural biotechnology is not whether GM crops can have negative impacts on the environment, but whether or not there is something unique about the technology that creates a need for them to be separately regulated. The Ecological Society of America has considered this issue and concluded that the technology does not create unique risks, but that there are potential risks from products of the technology that must individually be evaluated (Snow *et al.*, 2004).

Risk is associated with any change.

Our traditional genetic manipulation technologies, *i.e.* selective breeding and induced mutation methods, create products that have potential risks. The southern corn leaf blight of maize was a consequence of the widespread use of a rare mutation in maize, the cytoplasmic Texas male sterile trait . This useful trait for the breeding of hybrid maize unintentionally created plants that were uniformly susceptible to a previously unknown fungal disease (Bekele and Sumner, 1983). In essence, the use of this naturally occurring gene in traditional breeding programs created a new plant-disease problem. It is impossible to foresee such consequences, and they are clearly not unique to a particular technology. Other examples similar to the southern corn leaf blight incident are known, and they collectively reinforce the reality that risk is associated with any change.

The key question is whether or not the benefits associated with widespread adoption a new product are worth possible unknown risks. Experience to date would suggest that the environmental risk associated with the current generation of GM crops has been minimal and that positive environmental benefits have come from their adoption.

Decreased use of insecticides and the switch to less-toxic herbicides have been significant benefits from the adoption of the first generation of GM crops. These are important not only for human health but also for the environment. Agricultural chemical use is widely considered to be detrimental to the environment, and reduction in use of these chemicals or change to less-toxic or less-persistent chemicals is a public-policy issue in many countries (NRC, 2000). The data documenting pesticide-use changes illustrate the impact that GM crops have had in meeting these public-policy goals. In Argentina there has been an 83% reduction in the use of herbicides of toxicity class II and a total elimination of the use of those of toxicity class III. While there was an increase in the amount of herbicide used, the increase was in the lowest toxicity class. Associated with this change in herbicide use was the adoption of no-till practices on over 9 Mha of double-cropped soybean and wheat. The net benefits from adoption of GM soybean in Argentina were thus decreased energy use, less soil erosion by adoption of no-till practices, and a shift to a less toxic and rapidly degraded herbicide (Trigo and Cap, 2003).

A careful study of pesticide-use changes in China after adoption of *Bt* cotton showed similar positive environmental benefits. Huang *et al*. (2002a, c) concluded that pesticide use with *Bt* cotton decreased sharply compared with non-*Bt* cotton cultivation, in some regions by 70% to 80%. This reduction is an important accomplishment since it has been suggested that farmers in China overuse pesticides to optimize yield and reduce labor inputs on their small-farm plots (Widawsky *et al*., 1998). Host-plant resistance as a means to control insects and disease is recognized as a much more environmentally friendly approach, and needs to be encouraged where such resistance is available (NRC, 1996).

The trends in pesticide use reported above suggest that there is hope for further significant changes in amounts and types of pesticides used as more GM crops are adopted. In the United States, it has been public policy to encourage alternatives to pesticide use in agriculture. California, which accounts for 22% of the national pesticide use, has led this effort, in part by requiring adoption of the world's most comprehensive reporting system for pesticide use. Yet despite significant efforts to reduce California's pesticide use with non-biotech methods, an examination of the data showed no change between 1993 and 2000; the same was true for pesticide use in the rest of the country (Epstein and Bassein, 2003). The impact of adoption of GM crops would not likely be noticed on this scale of reporting since herbicides account for the greatest proportion of pesticides used (68%), and the amount of herbicides used is not expected to drop with adoption of GM crops; a shift to lower-toxicity herbicides is the expected outcome. Also, the greatest use of pesticides in the United States is on high-value crops with which no GM alternatives are commercially available.

Pesticide use is not uniform around the world; the highest relative amounts applied per hectare are in Japan and the European Community (Parris and Melanie, 1993). It is unfortunate that the regions of the world that apply the most pesticides have taken the leadership in opposing adoption of agricultural biotechnology and thus have slowed the adoption of a technology that has the potential to substantially reduce the amounts of toxic, persistent pesticides used in the world. Parris and Melanie (1993) suggested that high use of agricultural chemicals in these regions is the result of the relative political power of farmers who have successfully blocked the adoption of stringent environmental policies that would limit the use of agricultural chemicals. There is ample evidence for the adverse human-health and environmental costs associated with the use of pesticides (Low *et al*., 2004). A proven technology to reduce toxic pesticide use is available and would likely be adopted if the precautionary principle were used with a broader perspective in policy decisions (Levidow, 2003).

Conclusion

The first large-scale planting of GM crops was in 1996. Since then, the rate of adoption of the relatively few types of GM crops available has been dramatic, increasing to almost 70 Mha planted in 2003. Although the largest proportion of

GM crops is grown in the United States, many other countries of the world plant them. The very rapid adoption of available GM crops in developing countries such as Argentina and China attest to the economic advantages to farmers. The particular economic driver of adoption varies between countries, but they are clearly not limited to large farms; more than 3.5 million farmers in China grow Bt cotton on small holdings (Pray et al., 2002).

One of the first concerns expressed was that GM technology would create genetic changes that could pose health risks to consumers. Considerable investigation of this issue, and years of experience with the technology, have revealed no evidence for such risks (Kaeppler, 2000). Each product of the technology, however, needs to be assessed for potential health risks, particularly possible allergenicity (Taylor and Hefle, 2001). This scrutiny should not be limited to foods created by transgenic means. There is strong evidence that adoption of currently available GM crops will have positive health benefits, such as reducing pesticide poisoning of farm workers and reducing the exposure of consumers to highly toxic and carcinogenic mycotoxins (Munkvold, 2003) particularly in the developing world.

Although environmental risks are associated with some of the possible uses of the transgenic technology, it is the product, not the technology, that presents the potential risk.

Although environmental risks are associated with some of the possible uses of the transgenic technology, it is the product, not the technology, that presents the potential risk (Snow *et al*., 2004). Again, each product must, therefore, be carefully studied for its potential risk before it is widely adopted. This is similar in principle to the assessment of any risk to the environment that must be conducted prior to an action, such as the movement of plants and animals into a new area. On the other hand, adoption of some GM crops has resulted in a positive impact on the environment. Pesticide use in some areas has decreased as a consequence of the adoption of *Bt* varieties; toxic, persistent herbicides have been replaced by less toxic easily degraded alternatives, and soil and energy have been conserved by taking advantage of the GM technology to adopt no-till cultivation methods.

Although the adoption of GM crops has been very rapid in countries that have approved them, there has been resistance in many other countries, particularly in Japan and the European Community. The complexity of the social issues driving this resistance is illustrated by the fact that the countries most resistant to adoption of the technology are also by far the largest users per hectare of pesticides

(Parris and Melanie, 1993), which are known to cause health and environmental problems. A systems-level approach to evaluation of the relative value and risk of GM technology would entail studies of how this technology might reduce pesticide use in intensively managed crops, conserve soil by adoption of reduced tillage methods, or reduce human health risks associated with use of pesticides and consumption of mycotoxin-contaminated foods in developing countries. These analyses could be done using the currently available GM crops without even considering all of the other possible benefits that can be derived from adoption of new products of this technology. These comments are not meant to suggest that there does not need to be close oversight and evaluation of new products of GM technology, only to suggest that we need to do just that, *i.e.* allow the evaluation and adoption of products derived from biotechnology.

References

Alston JM (2004) Horticultural biotechnology faces significant economic and market barriers. California Agriculture 58 80–88.

Bakan B *et al.* (2002) Fungal growth and Fusarium mycotoxin content in isogenic traditional maize and genetically modified maize grown in France and Spain. Journal of Agriculture and Food Chemistry 50 728–731.

Bankole SA Adebanjo A (2003) Mycotoxins in food in West Africa: current situation and possibilities of controlling it. African Journal of Biotechnology 2 254–263.

Barbash JE *et al.* (2001) Major herbicides in ground water: results from the National Water-Quality Assessment. Journal of Environmental Quality 30 831–845.

Bekele E Sumner DR (1983) Epidemiology of Southern corn leaf blight in continuous corn Zea mays culture. Plant Disease 67 738–742.

Epstein L Bassein S (2003) Patterns of pesticide use in California and the implications for strategies for reduction of pesticides. Annual Review of Phytopathology 41 351–375.

Fandohan P *et al.* (2003) Infection of maize by Fusarium species and contamination with fumonisin in Africa. African Journal of Biotechnology 2 570–579.

Huang J *et al.* (2002a) Bt cotton benefits, costs, and impacts in China. AgBioForum 5 153–166.

Huang J *et al.* (2002b) Plant biotechnology in China. Science 295 674–677.

Huang J *et al.* (2002c) Transgenic varieties and productivity of smallholder cotton farmers in China. Australian Journal of Agricultural and Resource Economics 46 367–387.

Ismael Y *et al.* (2002) Benefits from *Bt* cotton use by smallholder farmers in South Africa. AgBioForum 5 1–5.

James C (2003) Global Status of Commercialized Transgenic Crops: 2003. ISAAA Briefs No. 30. Ithaca: ISAAA.

Kaeppler HF (2000) Food safety assessment of genetically modified crops. Agronomy Journal 92 793–797.

Levidow L (2003) Precautionary risk assessment of Bt maize: what uncertainties? Journal of Invertebrate Pathology 83 113–117.

Low F *et al*. (2004) Ranking the risk of pesticide dietary intake. Pest Management Science 60 842–848.

Magg T *et al*. (2002) Relationship between European corn borer resistance and concentration of mycotoxins produced by Fusarium spp. In: Grains of Transgenic Bt Maize Hybrids, their Isogenic Counterparts, and Commercial Varieties. Plant Breeding 121 146–154.

Marra MC *et al*. (2002) The payoffs to transgenic field crops: an assessment of the evidence. AgBioForum 5 43–50.

Munkvold GP (2003) Cultural and genetic approaches to managing mycotoxins in maize. Annual Review of Phytopathology 41 99–116.

National Research Council (NRC) (1996) Ecologically Based Pest Management, New Solutions for a New Century. Washington, DC: National Academy Press.

National Research Council (NRC) (2000) The Future Role of Pesticides in U.S. Agriculture. Washington, DC: National Academy Press.

Otsuki T *et al*. (2001) Saving two in a billion: quantifying the trade effect of European food safety standards on African exports. Food Policy 26 495–514.

Parris K Melanie J (1993) Japan's agriculture and environmental policies: time to change. Agriculture and Resources Quarterly 5 386–399.

Payne GA Brown MP (1998) Genetics and physiology of aflatoxin biosynthesis. Annual Review of Phytopathology 36 329–362.

Pray CE *et al*. (2002) Five years of Bt cotton in China—the benefits continue. The Plant Journal 31 423–430.

Shoemaker R (Ed) (2001) Economic Issues in Agricultural Biotechnology. Economics Research Service, USDA. Information Bulletin No. 762. Washington, DC: USDA.

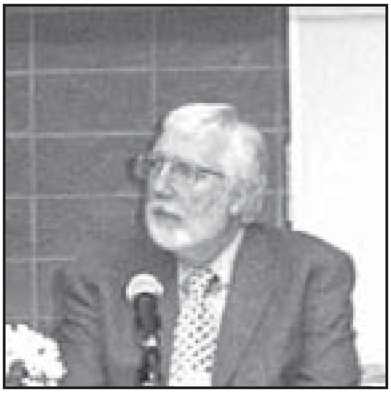
Snow AA *et al*. (2004) Genetically engineered organisms and the environment: current status and recommendations. Ecological Society of America Position Paper. http://www.esa.org/pao/esaPositions/Papers/geo_position.htm

Taylor SL Hefle SL (2001) Will genetically modified foods be allergenic? Current Reviews of Allergy and Clinical Immunology 107 765–771.

Trigo EJ Cap EJ 2003. The impact of the introduction of transgenic crops in Argentinean agriculture. AgBioForum 6 87–94.

United States Congress Office of Technological Assessment (OTA) (1995) Agriculture, Trade, and Environment: Achieving Complementary Policies. OTA-ENV-617. Washington, DC: US Government Printing Office.

Widawsky D *et al*. (1998) Pesticide productivity, host-plant resistance and productivity in China. Agricultural Economics 19 203–217.



Neal Van Alfen was raised in Modesto, California, and received a BS in chemistry in 1968 and MS in botany in 1969 from Brigham Young University. He received a PhD in plant pathology from the University of California, Davis, in 1972.

Dr. Van Alfen started his professional career as a plant pathology research scientist at the Connecticut Agricultural Experiment Station in New Haven studying tree diseases. In 1975 he moved to Utah State University to be a cooperative extension plant pathology specialist and a member of the faculty of the Department of Biology. In 1990 he moved to Texas A&M University, College Station, to serve as head of the Department of Plant Pathology and Microbiology. In 1999, he returned to UC Davis to become dean of the College of Agricultural and Environmental Sciences.

Van Alfen's research interests have focused on controlling plant disease using low-input, sustainable methods. He also has extensive experience as a consultant on effects of air pollution on environmental health.

He has served on numerous national committees and boards, including a number of National Research Council studies on biological control. He recently served as president of the American Phytopathological Society, and currently is editor of the *Annual Review of Phytopathology.*

Ever-Green Revolution and Sustainable Food Security

M.S. Swaminathan
M.S. Swaminathan Research Foundation
Chennai, India

The "green revolution," a term coined by William Gaud in October, 1968, is a process that leads to improved agricultural productivity. In January, 1968, in a lecture at the Indian Science Congress, I emphasized the need to improve productivity in perpetuity without associated ecological and/or social harm (Swaminathan, 1993):

> *Exploitive agriculture offers great dangers if carried out with only an immediate profit or production motive. The emerging exploitive farming community in India should become aware of this. Intensive cultivation of land without conservation of soil fertility and soil structure would lead, ultimately, to the springing up of deserts. Irrigation without arrangements for drainage would result in soils getting alkaline or saline. Indiscriminate use of pesticides, fungicides and herbicides could cause adverse changes in biological balance as well as lead to an increase in the incidence of cancer and other diseases, through the toxic residues present in the grains or other edible parts. Unscientific tapping of underground water will lead to the rapid exhaustion of this wonderful capital resource left to us through ages of natural farming. The rapid replacement of numerous locally adapted varieties with one or two high-yielding strains in large contiguous areas would result in the spread of serious diseases capable of wiping out entire crops, as happened prior to the Irish potato famine of 1854 and the Bengal rice famine in 1942. Therefore the initiation of exploitive agriculture without a proper understanding of the various consequences of every one of the changes introduced into traditional agriculture, and without first building up a proper scientific and training base to sustain it, may only lead us, in the long run, into an era of agricultural disaster rather than one of agricultural prosperity."*

Later, I coined the term "ever-green revolution" to highlight the pathway of increasing production and productivity in a manner such that short- and long-term goals of food production are not mutually antagonistic. In his recent book, *The Future of Life* (Vintage Books, 2002), Edward O. Wilson referred to my concept of ever-green revolution:

> *The problem before us is how to feed billions of new mouths over the next several decades and save the rest of life at the same time, without being trapped in a Faustian bargain that threatens freedom and security. No one knows the exact solution to this dilemma. The benefit must come from an evergreen revolution. The aim of this new thrust is to lift food production well above the level obtained by the green revolution of the 1960s, using technology and regulatory policies more advanced and even safer than those now in existence.*

How do we achieve this ever-green revolution,* i.e. *a balance between human numbers and human capacity to produce food of adequate quantity, quality and variety?

How do we achieve this ever-green revolution, *i.e.* a balance between human numbers and human capacity to produce food of adequate quantity, quality and variety? The growing damage to the ecological foundations essential for sustainable food security—land, water, biodiversity, forests and the atmosphere—is leading to stagnation in yields in green-revolution areas. Climate change may compound such problems with adverse effects on temperature, precipitation, sea level and ultra-violet B radiation.

An analysis of food insecurity indicators in rural India carried out by the M.S. Swaminathan Research Foundation (MSSRF) with support from the World Food Programme (WFP), indicates that the Punjab-Haryana region—India's food basket—may become food-insecure in another 20 years. Indicators used in measuring sustainability of food security are: land degradation and salinization, extent of forest cover, groundwater depletion and the nature of crop rotation. In all of these parameters, Punjab and Haryana occupy low positions. The common rice-wheat rotation has led to displacement of grain and fodder legumes capable of improving soil fertility. The current trend is towards non-sustainable farming resulting from land and water mining.

Forewarned is forearmed. What can we do to launch global agriculture on the pathway to an ever-green revolution, where advances in crop and farm-animal productivity are not accompanied by either ecological or social harm? The following suggestions are aimed at converting the vast know-how now available into field-level *do-how*.

Integrated Attention to the Components of Food Security

Food security has three major dimensions:

- availability of food—a function of production,
- access to food—a function of purchasing power/access to sustainable livelihoods, and
- absorption of food in the body—determined by access to safe drinking water and non-food factors such as environmental hygiene, primary health care and primary education.

Capacity to support even the existing human and animal populations has been exceeded in many parts of the developing world. Hence, the future of food security depends upon population stabilization, the conservation and care of arable land through attention to soil health and replenishment of fertility, and the conservation and careful management of all water sources so that more crop can be produced per drop of water.

Ownership and Sustainable Use

Much of the degraded and desertified land belongs either to resource-poor families or constitutes over-used and over-grazed common property. Ownership patterns of land and water determine the feasibility of introducing integrated and sustainable land- and water-management systems. Even where land is individually owned, locally acceptable systems of social management may have to be introduced through legislation, education and social mobilization. Women's access to land is also important. Water, particularly groundwater, should be a social resource and not private property. Creating an economic stake in conservation is vital for ensuring the sustainable use of natural resources.

Environmental Refugees

Degradation and erosion of arable land and the depletion and pollution of water resources result in the loss of rural livelihoods. This triggers unplanned migration of the rural poor to towns and cities, with proliferation of urban slums. The rise in the numbers of such environmental refugees threatens peace and security. Norman Myers has chronicled the seriousness of the situation. There should be a monitoring mechanism for avoiding loss of rural livelihoods. Development programs should strengthen linkages between ecological and livelihood security.

There are now unique opportunities for launching a food-for-sustainable-development initiative, in the form of a "grain for green" movement.

Grain Mountains and Hungry Millions: The Growing Paradox

There are now unique opportunities for launching a food-for-sustainable-development initiative, in the form of a "grain for green" movement. Such a program could accord priority to:

- restoration of hydrological and biodiversity "hot spots," particularly in mountain ecosystems,
- coastal agro-aqua farms (planting of salicornia, mangroves, casuarina, palms, *etc.* along with coastal agriculture and aquaculture),
- water harvesting, watershed development, wasteland reclamation, and anti-desertification measures,
- recycling of solid and liquid wastes and composting, and
- agro-forestry and other sustainable land-use systems in the fields of resource-poor farmers.

A Global Food for Sustainable Development and Hunger Elimination Initiative could be launched by the International Alliance Against Hunger, proposed by FAO. About 25 million tonnes of grains would provide nearly 100 million person-years of work designed to eliminate poverty-induced endemic hunger and at the same time restore and enhance environmental capital stocks.

Such food-for-ecodevelopment initiatives could be managed at the local level by community food banks (CFBs) operated by women's self-help groups. Such CFBs can be designed to address concurrent issues relating to chronic, hidden and transient hunger. The merit of CFBs will be low transaction cost and transparency. They can also help to widen the food-security basket, thereby saving what could become "lost" crops. Where animal husbandry, including poultry farming, is important to provide additional income and nutrition to families living in poverty, CFBs could also operate feed and fodder banks.

It is the fundamental duty of the state as well as of the well-to-do sections of the population to confer on those who go to bed undernourished the right to food and thereby to opportunities to lead productive and healthy lives. Thanks both to the spread of democratic systems of governance at the grass-roots level and to technological advances, we now have a unique opportunity to foster a community-centered and controlled-nutrition security system. Such decentralized community management will help to improve delivery of entitlements, reduce transaction and transport costs, eliminate corruption and cater to the twin needs of introducing a life-cycle approach to nutrition security and meeting the challenge of seasonal fluctuation in nutritional status. If such CFBs are operated by women, this will help to bridge the gender divide in the area of nutrition.

New Genetics

The elucidation of the double-helical structure of the deoxyribonucleic acid (DNA) molecule in 1953 by James Watson, Francis Crick, Maurice Wilkins and Rosalind

Franklin marked the beginning of what is now known as the "new genetics." Research during the past 51 years in the fields of molecular genetics and recombinant DNA technology has opened up new opportunities in agriculture, medicine, industry and environmental protection. The ability to move genes across species barriers has led to heightened interest in the conservation and sustainable and equitable use of biodiversity, since biodiversity is the feedstock for plant, animal and microbial breeding enterprises.

Considerable advances have been made in the past 25 years, taking advantage of the new genetics, in medical research, production of vaccines, sero-diagnostics and pharmaceuticals for human and farm-animal healthcare. The production of novel bioremediation agents—for example, the new *Pseudomonas* strain for clearing oil spills in oceans, rivers and lakes developed by Anand Chakraborty—is also receiving priority attention because of increasing environmental pollution.

There has also been substantial progress in agriculture, particularly in crop improvement through molecular-marker-assisted breeding, functional genomics, and recombinant DNA technology. A wide range of crop varieties containing novel genetic combinations are now being cultivated in the United States, Canada, China, Argentina and several other countries. A cotton variety containing the *Bacillus thuringiensis* gene (*Bt* cotton), resistant to the bollworm, is now under cultivation in India resulting from official and unofficial (illegal) releases.

There is little doubt that the new genetics has opened up uncommon opportunities for enhancing the productivity, profitability, sustainability and stability of major cropping systems. It has also created scope for developing crop varieties tolerant/resistant to biotic and abiotic stresses through an appropriate blend of Mendelian and molecular breeding techniques. It has led to the possibility of undertaking anticipatory breeding to meet potential changes in temperature, precipitation and sea level as a result of global warming. There are new opportunities for fostering pre-breeding and farmer-participatory breeding methods in order to combine genetic efficiency with genetic diversity.

While the benefits are clear, there are also many risks when entering unknown and unexplored territory. Such risks relate to potential harm to the environment and to human and animal health. There are also equity and ownership issues in relation to biotechnological processes and products. The following are major questions and areas of concern to the public and to the policymaker.

- What is inherently wrong with the technology? Is the science itself safe, an example being the use of selectable marker genes conferring antibiotic or herbicide resistance?
- Who controls the technology? If the technology is largely in the hands of the private sector, the overriding motive behind the choice of research problems will be profit and not necessarily public good. If this happens, "orphans will remain orphans" with reference to choice of research priorities. Crops being cultivated in rainfed, marginal and fragile environments—which are crying out for scientific attention—may remain neglected.

- Who will have access to the products? If the products arising from recombinant DNA technology are all covered by intellectual property rights (IPR), it will result in social exclusion and will lead to further enlargement of the rich-poor divide in villages.
- What are the major biosafety issues? There are serious concerns about the short- and long-term effects of genetically engineered organisms on the environment, biodiversity and on human and animal health.

There is need for transparent and truthful risk-benefit analyses in relation to genetically engineered organisms, on a case-by-case basis.

Thus, there is need for transparent and truthful risk-benefit analyses in relation to genetically engineered organisms, on a case-by-case basis. In the coming decades, Indian farm women and men will have to produce more food and other agricultural commodities to meet home needs and to take advantage of export opportunities, under conditions of diminishing *per capita* availability of arable land and irrigation water and expanding abiotic and biotic stresses. Enlargement of the gene-pool with which breeders work will be necessary to meet these challenges. Recombinant DNA technology provides breeders with a powerful tool for enlarging the genetic base of crop varieties and for "pyramiding" genes for a wide range of economically important traits. The safe and responsible use of biotechnology will enlarge our capacity to meet the challenges ahead, including those caused by climate change. At the international level, the Cartagena Protocol on Biosafety provides a framework for risk assessment and aversion. At the national level, there is need for regulatory mechanisms that inspire public, political and professional confidence.

Science and Organic Seed

To ensure that organic farming leads to higher productivity per unit of land and water used, it is essential that research in the following areas is intensified.

Soil-Health Management

The earlier methods of soil-fertility management, like shifting cultivation, are no longer relevant today due to population pressure on land. Cereal-legume rotations and intercropping are important for replenishing soil fertility. Efficient green-manure plants like the stem-nodulating *Sesbania rostrata* and bio-fertilizers comprising efficient microorganisms (Higa, 1998) have to be packaged in an integrated nutrient-supply system, which includes the application of compost, organic manures and plant residues. Inputs are needed to ensure outputs. For example, a ton of rice needs at least 20 kg of nitrogen along with appropriate quantities of phosphorus, potassium and micronutrients. Research on soil-health management, in order to ensure adequate soil fertility for high productivity, should receive high priority. The efficient-microorganism (EM) methodology of Dr. Higa needs greater emphasis.

All organic farmers should be provided with soil health cards to monitor regularly the physics, chemistry, microbiology and erodability of their soils. Care of soil health is fundamental to productive agriculture.

Sustainable organic farming will also need bioremediation agents that can help to improve soil health through the sequestration of salt, heavy metals and other yield-reducing constraints. A consortium of microorganisms each capable of performing an important function like nitrogen fixation, phosphorus solubilization, and/or sequestration of salts and pollutants will be needed for each major agro-climatic and agro-ecological farming system.

The other area of research that is essential for sustained high productivity is integrated pest management involving concurrent attention to pests, diseases and weeds. For this purpose, there is need for a biosecurity compact that will help to manage not only pests, diseases and weeds, but also invasive alien species and mycotoxins in food. Sanitary and phytosanitary measures and Codex Alimentarius standards of food safety need to be integrated in organic production protocols.

There will be need for productive genotypes of crop plants that can perform well under conditions of soil salinity, alkalinity and acidity.

As population pressure on land and water increases, there will be need for productive genotypes of crop plants that can perform well under conditions of soil salinity, alkalinity and acidity. Special genetic gardens will have to be established for halophytes and drought-tolerant genotypes. Also, suitable donors for tolerance of salinity and drought will have to be used in anticipatory breeding for adaptation to climate change and sea-level rise. Scientists at MSSRF have developed sea-water tolerant genotypes of rice, mustard and legumes using the mangrove species *Avicennia marina* as donor. Similarly, *Prosopis juliflora* is being used as a donor of genes for drought tolerance. Such pre-breeding work needs to be integrated with participatory breeding with farm women and men so that location-specific varieties can be developed. Genetic diversity is essential to avoid vulnerability to pests and diseases. Therefore, gene-deployment strategies will have to be developed jointly by scientists and farm families for each agro-ecological region. Successful organic agriculture will need a paradigm shift from purely experiment-station-based research to participatory research in farmers' fields.

Teruo Higa's complex culture of naturally occurring beneficial microorganisms—photosynthetic bacteria, lactic acid bacteria, yeasts, fermentative fungi and actinomycetes—has multiple uses. It can be used to purify water and sewage, solve sanitary problems, and improve the environment. There is need for more research on such consortia of microorganisms.

Recent research at MSSRF by Loganathan and Nair has led to the isolation of a bacterial strain capable of fixing nitrogen and solubilizing phosphate. *Swaminathania salitolerans* gen. nov., sp. nov. was isolated from the rhizosphere, roots and stems of salt-tolerant wild rice associated with mangrove species. Field trials in rice using this microorganism are now in progress.

It is important to harness all the tools that traditional wisdom and contemporary science can offer in order to usher in an era of bio-happiness. The first requirement for bio-happiness is nutrition and water security for all and forever.

Sustainable organic agriculture will need more science, not less. Artificial barriers should not be created between scientific methods. It is important to harness all the tools that traditional wisdom and contemporary science can offer in order to usher in an era of bio-happiness. The first requirement for bio-happiness is nutrition and water security for all and forever. This is the challenge before all involved in organic farming and the seed industry.

The seed industry has a particularly vital role to play in ensuring genetic diversity in crop plants and in providing organic farmers with genotypes based on a pyramiding of genes for tolerance to major biotic and abiotic stresses. There is also need for greater attention to under-utilized or orphan crops, many of which are not only nutritious but also capable of performing well under fragile and rainfed environments.

In order to change the mindset relating to nutritious millets, the Food and Agriculture Organization (FAO) should change the terminology from “coarse cereals” to “nutritious cereals.” There is need to reverse the narrowing of global food crops by including in the diet a wider range of cereals, millets, grain legumes, vegetables and tubers. In the past, human communities depended upon several hundred species of plants for their nutrition and health security. Diversified farming systems and good dietary habits are essential to confer benefits both to the producer and to the consumer of organic farming products.

Production agriculture and forestry are the major solar-energy harvesting enterprises of the world. An ever-green revolution will help to optimize the production of farm commodities through a symbiotic interaction between solar and cultural energy. This is the pathway to sustainable food security and bio-happiness.

The rich-poor divide is widening and jobless economic growth—better described as joyless growth—is spreading. Although skin-color-based apartheid has ended, technological and economic apartheids are appearing.

Finding Common International Goals: Patents and UN Millennium Development Goals

From the beginning of time, science and technology have been key elements in the growth and development of societies. Entire eras have been named for the levels of their technological sophistication: the stone age, the bronze age, the iron age, the age of sail, the age of steam, the jet age, the computer age and the age of genomics and proteomics. We are now on the threshold of the nano-age. Unfortunately, the scientific revolution is taking place at a faster pace than our social evolution. As a result, demographic, digital, gender, genetic, technological and economic divides are growing. The rich-poor divide is widening and jobless economic growth—better described as joyless growth—is spreading. Although skin-color-based apartheid has ended, technological and economic apartheids are appearing.

Since its inception, the United Nations University (UNU) has been a center for both humanistic science and scientific humanism. It has, therefore, a moral responsibility for showing how we can bridge these various divides and foster unity wherever discord prevails. The UNU should instil pride in performance and excellence. The UNU Institute for New Technologies (INTECH) should promote a global ecotechnology movement based on a blend of frontier science and traditional ecological prudence.

The world is facing a trilemma—a triple dilemma. Over 3 billion women and men, struggling to survive with an income of less than US$2 *per capita* per day, are crying for peace and equitable economic development. Countries in southern Africa, and Ethiopia, Afghanistan and North Korea are in the midst of serious famines. In India, the severe debt burden of small farmers sometime results in suicides. Two thousand years ago, the Roman philosopher Seneca said, "A hungry person listens neither to reason nor religion, nor is bent by any prayer." Thus, one aspect of the trilemma is the craving for peace and development which is equitable in social and gender terms. On another side, there is a growing violence in the human heart. Terms like ethnic cleansing and biological and biochemical terrorism are widely used in the media. The revival of small pox is becoming a possibility. The nuclear peril has again raised its head. Over 30,000 nuclear weapons are stored in the arsenals of major and minor powers. The availability of large quantities of highly enriched uranium increases opportunities for nuclear adventurism.

The third side of the trilemma is the spectacular progress of science and technology, resulting in an increasing technological divide between industrialized and developing countries. Helping to bridge this divide can be an important contribution of advanced educational and research institutions like the University of Guelph.

In the 1994 report of the International Commission on Peace and Food, which I chaired, we anticipated a substantial peace dividend following the collapse of the Berlin wall and the end of the Cold War. No peace dividend has materialized, instead expenditure on military hardware and internal security is increasing day by day, particularly so as a result of the tragic events of September 11, 2001, in the United States and similar events elsewhere.

Contemporary developmental challenges, particularly those relating to poverty, gender injustice and environmental degradation are indeed formidable. However, remarkable advances in information and communication technology, space and nuclear technologies, biotechnology, agricultural and medical sciences, and renewable energy and clean-energy technologies provide hope for a better common present and future. Genomics, proteomics, the Internet, space and solar technologies and nanotechnology are opening uncommon opportunities for converting the goals of food, health, literacy and work for all into reality. It is however clear that such uncommon opportunities can be realized only if the technology push is matched by an ethical pull. This is essential for working towards a world in which unsustainable life styles and unacceptable poverty become features of the past.

There is a growing mismatch between the rate of progress in science, particularly in molecular biology and genetic engineering, and the public understanding of their short- and long-term implications.

Also, there is a growing mismatch between the rate of progress in science, particularly in molecular biology and genetic engineering, and the public understanding of their short- and long-term implications. There is an urgent need for institutional structures that inspire public confidence that risks and benefits are being measured in an objective and transparent manner. Scientists and technologists have a particularly vital role to play in launching an ethical revolution. The Pugwash movement, which I now have the privilege to head, is an expression of the social and moral duties of scientists to promote the beneficial applications of their work and prevent their misuse, to anticipate and evaluate possible unintended consequences of scientific and technological development, and to promote debate and reflection on the ethical obligations of scientists in taking responsibility for their work. Rabelais said, "Science is but the conscience of the soul." It is the enduring task of our universities, which are the breeding grounds of leaders who will shape our future, to ensure that science and technology are employed for the benefit of humankind, and not its destruction.

We now have a Global Convention on Biological Diversity to help in the conservation and sustainable and equitable use of biodiversity. We need urgently a similar Convention on Human Diversity. While a convention alone will not halt the growing intolerance of diversity—particularly with reference to religion and political belief—it will help foster a mindset that regards diversity as a blessing and not a curse. Both biodiversity and human diversity are essential for a sustainable future. The human genome map shows that over 99.9% of the genomic constitution is the same in all members of the human family. Universities should do more to spread genetic literacy.

It is also necessary to reflect on methods of giving meaning and content to the ethical obligations of scientists in relation to society. The 1999 World Conference on Science in Budapest called for a new social contract between scientists and society. With a rapidly expanding IPR atmosphere in scientific laboratories, the products of scientific inventions may become increasingly exclusive in relation to their availability, with access limited to those who can afford to pay. The rich-poor divide will then increase, since orphans will remain orphans with reference to scientific attention and investment. How can we develop a knowledge-management system that will ensure that inventions and innovations of importance to human health, food, livelihood and ecological security benefit every child, woman and man, and not just the wealthy? UNESCO could organize a Global Patents Bank for UN Millennium Development Goals. Scientists and technologists from all universities and public research institutions should be encouraged to assign their patents to such a bank, so that the fruits of scientific discoveries are available for the public good. Such a Patents Bank for UN Millennium Development Goals would stimulate scientists to consider themselves as trustees of their intellectual property, sharing their inventions with the poor in whose lives they may make a significant difference for the better. Over two centuries ago, the French mathematician the Marquis de Condorcet, a contemporary of Thomas Malthus, said that the human population will stabilize if children are born for happiness and not just existence. The Government of Bhutan has taken the lead in developing a Gross National Happiness Index, based on the economics of human dignity, love of art and culture and commitment to spiritual values. Making all well-to-do members of the human family regard themselves as trustees of their financial and intellectual property will be essential for fostering a human happiness movement. The twenty-first century holds great promise for advancing the human condition provided there is an appropriate blend of technology and public action.

Russell and Einstein

I will end with an appeal issued by Bertrand Russell, Albert Einstein and colleagues contained in the Russell-Einstein Manifesto (Born *et al.*, 1955):

> *We appeal, as human beings, to human beings. Remember your humanity and forget the rest. If you can do so, the way is open to a new paradise; if you cannot, there lies before you the risk of universal death.*

The year 2005 marks the sixtieth anniversary of the use of atom bombs on Hiroshima and Nagasaki and the fiftieth anniversary of the Russell-Einstein manifesto. Can we use this opportunity to rid humankind of the nuclear peril and concentrate on harnessing science and technology for achieving the goals of food, water, health and work for all and forever?

References

Born N *et al*. (1955) The Russell-Einstein Manifesto. http://www.pugwash.org/about/manifesto.htm.

Higa T (1998) An Earth Saving Revolution II. Tokyo: Sunmark Publishing Inc.

Swaminathan MS (Ed.) (1993) Wheat Revolution : A Dialogue. Madras: Macmillan India Ltd.

M.S. SWAMINATHAN has been acclaimed by *Time* magazine as one of the twenty most influential Asians of the twentieth century and one of only three from India, the others being Mahatma Gandhi and Rabindranath Tagore. He was described by the United Nations Environment Programme as "the father of economic ecology" and by Javier Perez de Cuellar, Secretary General of the United Nations, as "a living legend who will go into the annals of history as a world scientist of rare distinction."

A plant geneticist by training, Professor Swaminathan's contributions to the agricultural renaissance of India have led to his being widely referred to as the scientific leader of the green revolution movement. His advocacy of sustainable agriculture leading to an ever-green revolution makes him an acknowledged world leader in the field of sustainable food security.

Swaminathan is a fellow of many of the leading scientific academies of India and the world, including the Royal Society of London and the US National Academy of Sciences. He has received forty-five honorary doctorate degrees from universities around the world. He currently holds the UNESCO Chair in Ecotechnology at the MS Swaminathan Research Foundation in Chennai (Madras), India, and is chairman of the Pugwash Conferences on Science and World Affairs.

Module I—Opening Global Dialogue

Q&A

Moderator: Helen Hambly Odame
University of Guelph
Guelph, ON

Alan Wildeman (University of Guelph, Guelph, ON): The comment was made about major corporations now making intellectual property freely available to Africa and I was wondering if you could expand upon what the word "free" actually means. I've followed the discussion around some of the drugs for HIV, for example, and when you dig into it a little bit more deeply you find out that free is not necessarily free. Do you have any comment on the technology around agriculture?

Kanayo Nwanze: When the African Agriculture Technology Foundation (AATF) was being established, I was a member of the Design Advisory Committee until early 2002. My recollection: I will not mention the four major multinationals that are providing technologies to the AATF, but the AATF is basically serving as an honest broker. For instance, if one of those companies gives a construct to the AATF, the AATF will take on responsibility for any risks. This is quite a complicated setup, but it guarantees that companies that provide their technologies, in whatever form to AATF, are absolved from liability. And I also know that one of the clauses in the agreement in the setup of AATF that some of these technologies would not be made available outside of Africa.

Ron Herring (Cornell University, Ithaca, NY): There is one thing that everybody in this debate agrees about: there is going to be an enormous increase in social surveillance of agriculture, and I'm curious how you come down on the type-1, type-2 errors that we might make. That is, not knowing risk particularly of gene flow through agro-ecologies; we don't know what these risks are. So far, they don't seem to be very great. But, not knowing, what kind of biosafety regulations ought to be in place? The experience in Brazil, in Rio Grande do Sul, and in Gujarat of *Bt* cotton movement of uncertified, unofficial seeds—both of these indicate to me that it's unlikely that traditional institutions are going to be able to become effective seed-police. I just don't see it happening. So the question is, how much ought to be invested in biosafety institutions and bioregulation? The type-1 and type-2 error is that if we make a very, very tight regime when it's not necessary we've wasted resources. If we make a very loose regime and there is some very serious threat out there of gene flow, then we have a potential catastrophe. Or we could have very, very tight regulation and we don't need it, or very loose regulation and we do need it, or very loose regulation and we don't need it. I wonder how you come down on this. Everyone wants the scientist to tell the rest of society what level of regulation and what kind of regulation is necessary. We're dealing not with risk, which has a probability distribution attached, we're dealing with uncertainty.

That is our strength as a species. We are very adaptive.

Neal Van Alfen: We have to look with an historical perspective at what we have done, and continue to do, to our planet. Clearly, our environmental standards are changing, and that's one of the realities that we face. Historically, we made a mess of things. Every place that we've moved to, we've carried our favorite foods with us and, inadvertently, our pests. So, rats are everywhere and disrupting ecosystems. Through our movement about the planet, we have created and continue to create environmental problems. Agriculture is part of this, and certainly we have to take responsibility for what we do, but as we do things we learn from our mistakes and we try to adapt. So, I would say that we continue to do the best job we can, recognizing that our standards are constantly changing; more is expected all the time and we ought to be trying to meet those expectations, those standards. Now, can we ever achieve perfection in that regard? I don't see that we will—there will always be things that we don't foresee—but I hope that we will continue to learn from our mistakes. That is our strength as a species. We are very adaptive.

Ron Cox (Science and Technology Committee of the Ontario Federation of Agriculture, Toronto, ON): I guess the previous person started into the idea of gene flow and from my limited reading I understand that research has been done mostly in Australia and New Zealand. I'm not aware of whether more research has been done in your own particular countries, but it seems that people don't seem to be concerned. Is enough being done with isolation strips and other mandated precautions? A lot of research is being done in greenhouses to prevent pollen escape. Do you feel that you are ready to expand further in your own particular countries?

Van Alfen: Is your question in terms of how great of a threat is the release of an undesirable trait into the environment through our experimentations?

Cox: Yes. I have seen roughly 1 to 2% and in many areas it would meet the European standard as well.

Van Alfen: Let me give you an example in terms of rice and red rice. There is a clear danger of putting traits into rice that can move to a weed, which is a very big problem in agriculture. Clearly, studies done on gene flow from domesticated rice to red rice have shown that it is modest. But gene flow occurs and so precautions are necessary. Sorghum to Johnson grass is one in which gene flow could occur very rapidly. On the other hand, there are examples of attempts to establish genetically modified organisms in the environment for pollution remediation and for biological control. The first example in the United States was the release of a microorganism to compete with naturally occurring ice-nucleating microbes, This was an attempt to establish a microbe in the environment for a positive affect. And essentially it failed. Another example is the attempt to establish a transgenic fungus in the environment that has a virus incorporated into its genome as a biological control agent for a disease of trees. Again, this has not been successful. So we cannot make uniform predictions about the escape of transgenes into the environment; some will be easily fixed into natural populations while others will be very difficult to establish, even if we want them to become established in a natural population Unfortunately a mistake could be made; therefore, each should be evaluated on a case-by-case basis, just as we do when we introduce new biological control agents into a region.

Our infrastructure for looking at the problem in its many dimensions is still lacking.

M.S. Swaminathan: I fully support what you said. The major problem now in many developing countries—even in my own land—although we've made some progress, our infrastructure for looking at the problem in its many dimensions is still lacking. We have to build functional capacity and look at each case by case; it is very difficult to generalize at the moment. Maybe 10 years from now, as science progresses, we'll know how to handle it. But at the moment it is better to be cautious, take it case by case. It will involve a lot of money to understand gene flow, how far pollen travels and so on. And, in the context of India, farm animals are also important. Human health, animal health, the environmental health, all of them have to be examined. Take cotton for example, *Bt* cotton: cottonseed cake is used as animal feed then it goes into the human food chain. So, the number of tests you have to make is very considerable. There is insufficient infrastructure, research infrastructure, scientific infrastructure. If this science is to do a lot of good without controversy, we will have to develop public confidence to reach agreements on mechanisms. There seems to be more public confidence in the regulatory mechanism in the United States. In my country, it remains far from satisfactory. People don't have full confidence. There has to be transparency in the whole mechanism of testing. It's complex. We have to learn from each other—how to do it right. Medical biotechnology—particularly vaccines—does not have the problems we see in the food-biotechnology area. There is much wider acceptance of biotechnological products in pharmaceuticals and medicine.

Module II—Diminishing the Ecological Footprint

Module II—
Diminishing the Ecological Footprint

Introductory Remarks

Vernon G. Thomas
University of Guelph
Guelph, ON

This module witnesses the competition between two goods, namely agriculture and its related rural environment. They are goods because we all partake of the benefits of agriculture, and we all agree that the condition of and the services (*e.g.* water cycling, oxygen-carbon dioxide exchange, carbon sinks, pollination, soil formation, nutrient release-capture, and biodiversity) provided by the total environment are vital (Smith, 1974). However, to many environmentalists and conservationists, agricultural development and expansion take place at the expense of the environment; *i.e.* they are competitors. In that regard they are correct, and the challenge is to balance both interests.

As we view landscapes from airplanes, it is clear that agriculture and forestry are the two human cultures that have most shaped the face of the planet. It could be said that agriculture, with its enormous movements of soil and water, and its international movement of nutrients as foods, is now among the largest geological forces acting on Earth's surface. It is inevitable that, as the size of the human population increases, the size of the agricultural impacts on the planet will increase, both directly as wild lands are converted to crop production, and as the energy-technology base increases to service the needs of modern agriculture.

Awareness of the impacts of agriculture on the environment is not new. Bismarck observed that the trends in agriculture and forestry in Europe during the late 1800s selected for species that flourished under those conditions. He termed them culture lovers (*Kulturliebe*), as opposed to those species that required more wilderness habitats, which he termed culture haters (*Kulturhesse*). Indeed, the modern agricultural community has brought about major changes in the community structure of animal populations. This is apparent in the species composition of waterfowl populations of Europe and North America that benefit from the vast areas of cereal grain culture.

Prairie grouse species eclipsed by the advent of agriculture were replaced by introduced game-birds, such as Asiatic pheasants and European partridges. During the last 30 years, the rehabilitation of the once-endangered wild turkey (*Meleagris gallopavo*) has succeeded because it has adjusted to cash-crop/hardwood landscapes throughout its ancestral range. White tailed deer (*Oidocoleus virginianus*) populations have undergone enormous increases throughout North America due to the effects of grain agriculture and the abandonment of agricultural lands to early ecological succession. These are just a few of the examples that can be mentioned.

Generally, most of society sees this as being good, as an ability of nature to profit from agricultural imposition upon the landscape. Modern programs of wildlife management, itself an offshoot of applied production agriculture, exploit the agricultural environment and its new suite of species, to provide recreation for the public. Few are aware of the decline of many native species and their replacement by desirable species, and even fewer see that as environmentally problematic.

During the early 1900s, the ecologist Aldo Leopold documented in detail the very competitive effects of over-grazing on native plant communities by sheep, goats and cattle, the wide-scale erosion of the southwest of the United States, and the introduction of exotic forage species. His writings explained the ephemeral nature of open-range ranching in this part of the continent (Leopold, 1933; Callicott, 1991). What appears natural and acceptable to us depends very much on our personal timeframe: in essence, it is what we can remember and relate to. After some time, exotics and farmed landscapes (just like human immigrants) acquire a sort of ecological citizenship (such as the mustang, the burro, the feral pig, wheat, sheep and cattle). The same can be said of modern forested landscapes, complete with their many exotics, reduced diversity, monocultures, and longer cycles of cash-crop production.

We accept the radically modified landscapes of agricultural Europe and North America, despite their changed biological diversity and community structure. Large, lush expanses of crops engender a positive feeling, no matter how simple the plant community structure. The Caledonian Forest that once covered so much of Britain has, over two millennia, been replaced by a system of small land parcels interspersed by hedges and small woods, the “idyllic” British countryside. Monocultures of grapevines have long clothed the hillsides of much of France, the Rhine-Moselle regions of Germany, and other parts of Europe, generating a high added-value product. For many parts of Europe and North America, nature is now confined largely to the interstices of the agriculturally modified landscape, and is thus highly susceptible to agricultural change. Society has welcomed these cheap agricultural goods, and provided that there were some adjacent areas of unmanaged lands, no great concerns were raised. However, as human conurbations spread permanently like grease spots, and as agriculture appears to be more consumptive of its land base (as in greater soil erosion, salination, and soil organic matter depletion) and exerts more collateral damage on non-target insect species, concerns are being expressed. Now, we add the new dimension of biotechnologically changed phenotypes to that mix.

The recent growth of approaches to agriculture termed "lower-input," "organic," and "ecological agriculture" reflects an awareness of having to conduct agriculture in a different manner from the current emphasis on the high-energy and high-chemical approach (Thomas and Kevan, 1993). Notwithstanding the savings generated by minimal-till and zero-till cultivation, it is clear that the "greening" of agriculture has a long way to go to reduce its many externalities (Jackson, 2004).

This module's title contains two major assumptions: the agricultural production system is intrinsically sustainable,* and *agriculture can be conducted in future with a smaller ecological footprint due to biotechnological advances.

This module's title, *Diminishing the Ecological Footprint*, contains two major assumptions that will be addressed. The first is that the agricultural production system is intrinsically sustainable, and that agriculture can be conducted in future with a smaller ecological footprint due to biotechnological advances. The second assumption is that awareness of the value of wild environments to the human well-being will result in societies having a will to achieve a preservation of those wild environments.

This module presents three experts to shed light on those assumptions: William Rees, Klaus Amman and David Lavigne. None is an agronomist, but all are systems ecologists who understand the nature of biological production. This is in keeping with this conference's desire to solicit insight and debate from outside the discipline of production agriculture.

References

Callicott JB (1991) Reading the Land. Orion, Winter Issue 16–17.

Jackson W (2004) Agriculture: the primary environmental challenge of the 21st century. In: The Human Ecological Footprint (Chesworth W *et al.* Eds). Guelph: University of Guelph, 85–99.

Leopold A (1933) The virgin southwest. In: The River of God and Other Essays by Aldo Leopold. (Flader S Callicott JB Eds). Madison: University of Wisconsin Press.

Smith RL (1974) Ecology and Field Biology, 2nd Edition. New York: Harper and Row.

Thomas VG Kevan PG (1993) Basic principles of agroecology and sustainable agriculture. Journal of Agricultural and Environmental Ethics 6 1–19.

The Eco-Footprint of Agriculture: A Far-from-(Thermodynamic)-Equilibrium Interpretation

William E. Rees
University of British Columbia
Vancouver, BC

Food is the most basic of all resources, and food production has effectively diverted more natural landscape to human purposes than any other ecologically significant human economic activity. Massive famines punctuate the history of human civilization—ironically, since civilization was made possible by agriculture—and, until relatively recently, fear of food shortages was a concern of most human groups.

The reason for fear of famine was most famously explained by the Reverend—and economist—Thomas Malthus in the eighteenth century, in his *Essay On the Principle of Population*. Malthus observed that "population, when unchecked, increases in a geometric ratio, subsistence increases only in an arithmetic ratio." A modern Malthus might say that population increases exponentially (like compound interest) while food production increases only linearly (in constant increments). Regardless of how one expresses the relationship, "a slight acquaintance with numbers will show the immensity of the first power in comparison to the second…" In Malthus's words (1798), "The race of plants and the race of animals shrink under this great restrictive law. And the race of man cannot, by any efforts of reason, escape from it."

Most people in the developed world today believe that Reverend Malthus was wrong, that industrial "man" has indeed, "by efforts of reason, escaped from it." Technology-based developments—from the spread of irrigation, extensive use of fertilizers, pesticides and high-yielding crop varieties, to field mechanization and expanding trade—succeeded in keeping global food production ahead of population increases through the last century, with the most spectacular results in the post-WW-II period. Meanwhile, of course, the human population has increased by 152% from 2.5 billion in 1950 to about 6.3 billion today.

But there is reason for pause. By some estimates, after three decades or more of steady increases, world grain production *per capita* has stabilized or declined since the late 1980s and we have just seen an unprecedented four sequential crop years in which global consumption has exceeded the harvest with each shortfall greater than the one before (Pimentel and Pimentel, 1999; Brown, 2004). According to Brown (2004):

> *The grain shortfall of 105 million tons in 2003 is easily the largest on record, amounting to five percent of annual world consumption of 1,930 million tons. The four harvest shortfalls have dropped world carryover stocks of grain to the lowest level in 30 years, amounting to only 59 days of consumption. Wheat and corn prices are at 7-year highs. Rice prices are at 5-year highs.*

By some assessments, absolute levels of food production (cereals, pulses, roots and tubers) may have fallen over the past four or five years. Meanwhile, groundwater tables are falling in over half the world's agricultural areas, soil erosion is rampant, there is increasing evidence that the era of cheap energy—critical to modern agriculture—is ending and population growth continues at 1.3% per year. Are we waking Malthus's ghost?

In this context, the purpose of this paper is three-fold. First, I examine the prospects for soil/landscape conservation and maintaining adequate global food production through the lenses of ecological-footprint analysis and far-from-equilibrium thermodynamic theory. Can we keep the Malthusian spectre at bay using prevailing approaches to production? Second, I briefly examine the case for genetically modified (GM) crops, the latest "advance" in the so-called high-tech approach to food production. Third, I explain why the prevailing approach to production agriculture, including the introduction of GM crops, has proven so successful in displacing alternatives with arguably more desirable ecological and social characteristics.

Ecological footprint analysis estimates the "load" imposed on the ecosphere by any specified human population or production activity in terms of the land/water area effectively "appropriated" to sustain that population/activity

---

The Ecological Footprint of Agriculture

Ecological footprint analysis (EFA) estimates the "load" imposed on the ecosphere by any specified human population or production activity in terms of the land/water area effectively "appropriated" to sustain that population/activity (Rees,

Agriculture contributes one of the largest components to a typical population eco-footprint.

1992, 1996; Wackernagel and Rees, 1996). Thus, we define the ecological footprint of a study population as (Rees, 2001):

> *the area of productive land and water ecosystems required, on a continuous basis, to produce the resources that the population consumes and to assimilate the wastes that the population produces, wherever on Earth the relevant land/water may be located.*

Agriculture contributes one of the largest components to a typical population eco-footprint (EF). This should be no surprise. Brower and Leon (1999) suggested that, next to transportation, food production (meat, poultry, fruits, vegetables and grains) causes the greatest level of environmental impact associated with the average household (Table 1) Transportation and food, together with household operations (heating of space and water, running appliances and lighting) comprise between 64% and 86% of the total ecological impact of household consumption in the several impact categories shown in Table 1.

TABLE 1. HOUSEHOLD ENVIRONMENTAL IMPACT CONTRIBUTED BY FOOD PRODUCTION/CONSUMPTION COMPARED TO TRANSPORTATION AND HOUSEHOLD OPERATIONS (FROM BROWER AND LEON, 1999)

Contribution from	Global warming	Air pollution		Water pollution		Habitat alteration	
	Greenhouse gases	Common	Toxic	Common	Toxic	Water	Land
			(%)				
Transportation	32	28	51	7	23	2	15
Food	12	17	9	38	22	73	45
Household operations	35	32	20	21	14	11	4
Sub-total	80	77	80	67	59	86	64

A major component of the food production impact is landscape alteration. For example, about 60% of the US land area is dedicated to crop production or livestock grazing and 45% of the nation's habitat loss or alteration is due to agriculture. (The US is the world's greatest agricultural powerhouse.)

Figure 1 shows the *per capita* cropland eco-footprints (demand) for a selection of countries, and compares these to available domestic cropland *per capita* (supply). To facilitate comparisons, estimates for each country are presented in terms of world average cropland equivalents using data from the World Wildlife Fund (WWF, 2002). Only land area actually used for growing crops is included in the calculations. Consumption by agriculture to maintain production—energy, fertilizers, pesticides, *etc*.—is accounted for in other components of the total EF. Nor does this figure include adjustments to reflect unsustainable use of cropland; such adjustments would significantly increase the agricultural eco-footprints of many countries.

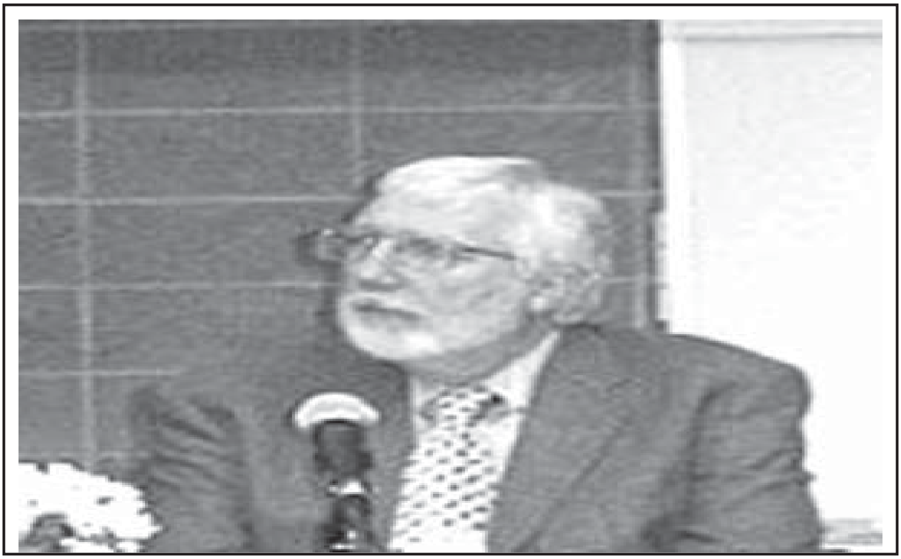


Figure 1. *Per-capita* cropland ecofootprints and domestic cropland for selected countries (1999).

Note that the area of world-average cropland used to produce the diets of today's high-income consumers can be as high as 1.5 hectares (3.7 acres) *per capita*, typically four to eight times the cropland required by the poorest of the world's poor. Canada's *per capita* demand for cropland at about 1 hectare is about twelve times that of a typical Bangladeshi or Mozambican.

With prevailing practices, it actually needn't take more than 0.5 hectares (1.2 acres) to provide a diverse high-protein diet like that enjoyed by western Europeans and North Americans (Pimentel and Pimentel, 1999). The fact that there are only 0.25 hectares of cropland available *per capita* on Earth is a measure of the difficulty in bringing the entire world population up to "northern" dietary standards. To complicate matters, the domestic cropland available in many poor countries is barely equivalent to national aggregate demand, and in some cases is considerably less (*e.g.*, Peru and Pakistan) (Figure 1). Many densely populated countries have far less than 0.25 hectares of cropland, the area that might be considered their "fair share" of the global total. These countries have no hope of reaching a European-style diet without massive imports of food, a highly unlikely prospect given their chronic poverty and increasing competition on world food markets.

Not only poor countries are net importers of food. Wealthy countries such as Spain, the Netherlands and the United Kingdom have agricultural eco-footprints up to several times larger than their domestic agricultural land bases. Unlike the poorer developing countries, these wealthy nations have, so far, financed their considerable food-based "ecological deficits" with the rest of the world.

Actually, countries that are net food importers are more the rule than the exception. Most of the world's 183 nations are partially dependent on food imports. Just five countries—the United States, Canada, Australia, France and Argentina—account for 80% of cereal exports and most of the safety net in global food markets (Pimentel and Pimentel, 1999). These countries have exceptionally high cropland-to-population ratios and relatively few soil constraints, and use intensively mechanized, fossil-energy dependent production methods.

It should be clear from even this brief discussion of cropland eco-footprints relative to land supply that land constraints represent a major barrier to increased food production in the future, particularly for those countries that need it the most. Increasing the total area of cropland is possible in some cases, but would require expansion of agriculture into inferior land and massive damage to remaining wildlife natural habitat. Moreover, the following section shows that cropland scarcity is only one of the problems confronting prospects for large-scale increases in food production.

The Biophysical Context: Far-From-Equilibrium Thermodynamics

[Production] agriculture is the use of land to convert oil into food.

—Albert Bartlett

Why is thermodynamic theory relevant to the future of agriculture? Think for a moment of verdant forests, natural grasslands, thriving estuaries, salt marshes, and coral reefs, and of mineral and coal deposits, petroleum, aquifers and arable soils. These are all forms of "natural capital" that represent *highly-ordered* self-producing ecosystems or rich accumulations of energy/matter with high use potential (low entropy). Now contemplate despoiled landscapes, eroding croplands, depleted fisheries, toxic mine tailings, anthropogenic greenhouse gases, acid rain and anoxic/polluted waters. These all represent *disordered* systems or degraded forms of energy and matter with little use potential (high entropy). The

Far-from-equilibrium thermodynamics explains why contemporary growth-bound fossil-energy subsidized development of all kinds must ultimately necessarily destroy the very ecosystems that support it.

main process connecting these two system states is human economic activity, particularly industrial activity, including production agriculture (Rees, 2003). Far-from-equilibrium thermodynamics explains why contemporary growth-bound fossil-energy subsidized development of all kinds must ultimately *necessarily* destroy the very ecosystems that support it.

The starting point for this interpretation is the second law of thermodynamics. In its simplest form, the second law states that any spontaneous change in an isolated system, one that can exchange neither energy nor matter with its environment, produces an increase in entropy. This means that when a change occurs in an isolated complex system it becomes less structured, more disordered, and there is less potential for further activity. In short, isolated systems always tend toward a state of maximum entropy, a state in which nothing further can happen.

For purposes of this discussion, imagine a homogenized, totally disordered world in which everything is evenly dispersed—there are no distinguishable forms or structures, no gradients of energy or matter. In effect, no finite point in the ecosphere would be distinguishable from any other. We can take this hypothetical randomized distribution of all naturally occurring elements and stable compounds to represent a state of maximum global entropy. It is also, by definition, a state of thermodynamic equilibrium. This is the state toward which the ecosphere would spontaneously gradually descend over time in the absence of sunlight and life. (Entropy can be likened to a relentless form of biophysical gravity.)

Of course, the real world could hardly be more different from this randomized primordial soup. The ecosphere is a highly ordered system of mind-boggling complexity, of many-layered structures and steep gradients represented by accumulated energy and differentiated matter. In the course of several billion years, the trend in the ecosphere has been one of increasing order and complexity, even after allowing for occasional catastrophic setbacks. Millions of emergent organisms have adapted to the many physical environments on Earth, co-evolved in response to each other and their physical environments, and self-organized into differentiated communities and ecosystems. In short, the ecosphere—life—has clearly been moving ever further from thermodynamic equilibrium. So fundamental is this process that, according to Prigogine (1997), "distance from equilibrium becomes an essential parameter in describing nature, much like temperature [is] in [standard] equilibrium thermodynamics."

How is it that the ecosphere can apparently exist and evolve greater complexity apparently in conflict with the second law? The key is in recognizing that all living systems, from cellular organelles through individual organisms to entire ecosystems are complex, dynamic, *open* systems that can exchange energy and matter with their host "environments." As Erwin Schrödinger (1945) observed, organisms are able to maintain themselves and grow "…by eating, drinking, breathing and (in the case of plants) assimilating..." Schrödinger recognized that, like any isolated system, a living organism tends continually to "produce[s] positive entropy—and thus tends to approach the dangerous state of maximum entropy, which is of death. It can only keep aloof from it, *i.e.* alive, by continually drawing from its environment negative entropy…" ("Negative entropy"—also called "negentropy" or "essergy"—is free energy available for work.) In short, rather than tending toward equilibrium, living systems, from individual foetuses to entire ecosystems, consume "extra-somatic" resources to gain in mass and organizational complexity over time.

In the case of green plants, the extra-somatic energy is actually extra-planetary. Photosynthesis is the chemical process by which plants "fix" as chemical energy a small portion of the incident solar energy reaching Earth. The plants use the resultant products—carbohydrates, fats and proteins—to produce themselves and in the process provide the fuel for most other life-forms, including humans. Indeed, photosynthesis provides the free energy and the organic material building blocks of virtually the entire ecosphere.

Appearances to the contrary, none of this violates the second law. Despite the "negentropy" represented by living, growing systems, production in the ecosphere actually increases the net entropy of the universe as expected. All living systems maintain their local level of organization at the expense of increasing global entropy, particularly the entropy of their immediate host (Schneider and Kay, 1994, 1995). As noted, the ecosphere develops and evolves—maintains itself far-from-equilibrium—by permanently dissipating solar energy. However, since photosynthesis and evapotranspiration degrade a much larger quantity of solar energy than is incorporated in the products, the entropy of the total system increases. Because individual plants, ecosystems and other self-organizing systems develop and grow by continuously degrading and dissipating available energy, they are called "dissipative structures" (Prigogine, 1997).

Like ecosystems, humans and their economies are self-organizing, far-from-equilibrium dissipative structures. However, the human enterprise is but a single sub-system, or "holon," fully contained within the loose overlapping hierarchy of living, self-organizing, holarchic open (SOHO) systems that comprise the ecosphere (Kay and Regier, 2000). This means that the growth and development of the human enterprise are fuelled all but entirely by the products of photosynthesis, both ancient and contemporary. Human economic activity necessarily feeds on and destroys gradients of usable energy and material first produced by nature. In effect, the human enterprise is thermodynamically positioned to consume the ecosphere from the inside out (Rees, 1999).

Herein lies the proximate cause of the (un)sustainability conundrum in general and the potential crisis in agriculture in particular. Uniquely among sub-systems of the ecosphere (*i.e.*, other consumer organisms), the human enterprise is dominated by positive feedback and auto-catalytic processes. Therefore, it grows continuously, disordering the ecosphere in the process. A critic might argue that every increment of human population growth, each new factory, every addition to the world's expanding fleet of SUVs, the daily additions to the population of high-tech electronic devices, *etc., etc.*, adds to the scale and complexity of the human enterprise, thus increasing internal order and seemingly moving us ever further from equilibrium. Again, however, beware the illusion—the continuous growth of the human subsystem simultaneously degrades and dissipates the very resources and ecosystems that sustain it. The increasing negentropy of the human sub-system is greatly outweighed by the increased disordering of the ecosphere: global net entropy rises with the erosion of our earthly habitat.

The two most important gradients feeding the human enterprise are soils and fossil fuels.

THE KEYSTONE GRADIENTS—SOIL AND OIL

Arguably, the two most important gradients feeding the human enterprise are soils and fossil fuels. Arable lands and productive soils represent concentrated stocks of the nutrients and organic matter essential for food production. The vital components in soil have accumulated over thousands of years of negentropic interaction among parent soil material, climate and thousands of species of bacteria, fungi, plants and animals, both below and above ground. However, since the dawn of farming 8,000 to 10,000 years ago, agricultural practices have tended to degrade soils and even entire landscapes. This entropic process has tended to accelerate the more allegedly "sophisticated" and productive our agricultural technology becomes. Agriculture-induced erosion, water-logging, acidification, and salination of soils, combined with the dissipation of nutrients (removed with the harvest) and organic matter (the oxidation of agricultural soils is a major source of anthropogenic atmospheric carbon dioxide), have seriously compromised the productivity of large areas of cropland around the world. Since virtually all the readily cultivable land on Earth is already under the plough, more land is coming out of production today because of degradation than is being brought into production.

In recent decades, high-yielding crop varieties, abetted by fossil-energy subsidized irrigation and mechanization and agricultural chemicals (the latter also partly derived from fossil hydrocarbons) have more than compensated for losses of land and natural soil fertility while actually accelerating these losses. Global food production continued to outpace population growth. But, as noted at the outset, ebullience over the so-called "Green Revolution" has been somewhat muted lately as the growth of food production stalls and there is increasing evidence that the era of cheap, accessible fossil fuel is coming to an end; accessible reserves are rapidly being dissipated. In this light, consider the following challenges to agriculture in the twenty-first century:

- To keep pace with UN medium population-growth projections, food production will have to increase by 57% by 2050. Improving the diets of billions of people could push the increase toward 100%.
- By 1990, 562 million hectares (38%) of the roughly 1.5 billion hectares in cropland had become eroded or otherwise degraded, some so severely as to be taken out of production. Since then, 5 to 7 million hectares have been lost to production annually (SDIS, 2004). According to the UN Food and Agriculture Organization (FAO, 2000), a cumulative 300 million hectares (21%) of cultivated land—enough to feed almost all of Europe—has been so severely degraded "as to destroy its productive functions." Only 35% of global arable land is free from degradation.
- Depending on climate and agricultural practice, topsoil is being "dissipated" sixteen to 300 times as fast as it is regenerated.
- Fifty-eight countries, including twenty-one in Europe have no undegraded cropland. More than 60% of the croplands of fifteen European, and twenty-five Asian, African and Latin American nations are severely or very severely degraded (FAO, 2000).
- Since 1967, intensification of agriculture—double-cropping, irrigation, mechanization and chemicals—has accounted for 79 to 96% of the increased yields of wheat, rice and maize (Cassman, 1999). Fossil energy is a major factor, both as a feedstock in fertilizer and pesticide production and as a direct energy source. Primary level (farm level) agriculture in Canada, for example, now represents 5% of the national energy budget and energy accounts for 20% of annual farm expenses (CAEEDAC, 1998).
- While sparing natural ecosystems from conversion to agriculture, this intensification of crop production has accelerated the degradation/dissipation of natural soils, disrupted nutrient cycles, lowered groundwater tables, and contributed to ground and surface water pollution (Cassman, 1999; FAO, 2000; Gregory *et al.*, 2002; Matson *et al.,* 1997).
- Consistent with the above, growing populations and increasing land constraints suggest that any future increase in agricultural output on the current path will depend largely on further intensification of irrigation, chemical inputs and mechanization, *i.e.*, ever-greater reliance on fossil energy stocks. This, in turn, implies increased ecological damage (Conforti and Giampetro, 1997).

- Fossil energy supplies may be problematic. Petroleum reserves are finite and global consumption of oil has exceeded discovery for at least 20 years. North American petroleum reserves and production have been in decline even longer and natural gas is now also declining. In response to rising demand, North American domestic natural gas prices have risen steeply and are now 300% or more above those of just a few years ago. Several fertilizer plants have closed or moved operations to Eurasia for reasons of rising costs and diminishing feedstocks. According to various industry experts, global conventional petroleum output is likely to peak within this decade (Campbell, 1999; Duncan and Youngquist, 1999; Laherrere, 2003; Longwell, 2002). Other analysts argue that we still don't know enough to chose among different energy-supply scenarios or among feasible renewable energy technologies (Hall *et al*., 2003). Given the uncertainty over suitable substitutes for many uses of liquid, portable fossil fuel, still others are speculating on the implosion of industrial civilization (*e.g*., Duncan, 1993). Manning (2004) provided an engaging popular account of the crisis.
- Because of market conditions, land degradation, and diminishing returns from inputs, the area of irrigated cropland has declined by 12% and the use of fertilizers by 23% from peak levels. Grain production *per capita* has been in decline for almost a decade and aggregate food production has fallen for the past 4 years (Pimentel and Pimentel, 1999; Brown, 2004; EarthTrends Data tables compiled from UN-FAO statistics).
- Partially as a result, millions are plagued by hunger. As many as 800 million people remain chronically malnourished and up to 3 billion have inadequate diets. (Contributing to this are patterns of land-ownership and trade that deny impoverished people access to either land for subsistence agriculture or commercially produced food. The poor often cannot participate in food markets for want of cash. Thus, some countries with serious food shortages and nutritional problems are net exporters of luxury cash crops for first world markets.)

The foregoing makes clear that the Green Revolution has by no means been an unqualified success. Food production has increased dramatically in the past 50 years, but this has allowed a 156% increase in the human population. The result is that we now have over 6 billion people, on the way to perhaps 9 billion by the middle of the century, all with rising expectations and all dependent on a bio-physical resource base that has been severely eroded by the same agricultural revolution that made their existence possible. Ominously, various important crops in all categories seem to be approaching production plateaus in many parts of the world.

ARE TRANSGENIC CROPS THE SOLUTION?

How has mainstream agricultural science responded to this complexity of problems? Probably the major development in recent years has been the development and rapid introduction of transgenic or genetically modified crops. The most frequently cited potential benefits of transgenic crop varieties include:

- use of fewer, less-toxic or less-persistent pesticides,
- potential for increased crop yields, thus reducing the pressure to convert pasture, woodlands, and other habitats and land-types to agricultural production,
- decreased water use, thus conserving water and providing a buffer against climate change,
- reduced soil tillage and an attendant reduction in mineralization and erosion.

Ostensibly to take advantage of these benefits, transgenic crops (TCs) have become an increasingly dominant feature of the agricultural landscapes of the United States and other countries such as China, Argentina, Mexico and Canada. Between 1986 and 1997, an estimated 25,000 field trials were conducted on more than sixty crops using ten traits in forty-five countries. Worldwide, the areas planted to transgenic crops increased dramatically from 1996 to 1999, from 3 million hectares in 1996 to nearly 40 million hectares in 1999 (Altieri, 2000, 2004). This is no small incursion into the agricultural landscape. According to Altieri (2000): "In the USA, Argentina and Canada, over half of the acreage for major crops such as soybean, corn and canola are planted in transgenic varieties. Herbicide-resistant crops and insect-resistant crops (*Bt* crops) accounted respectively for 54 and 31% of the total global area of all crops in 1997."

Is this significant commitment paying off? Regrettably, the jury is still out. Despite their own extensive survey, Ervin *et al*. (2000) stated that: "Most studies of the environmental effects of transgenic crops have been confined to laboratories or small fields. The lack of detailed environmental impact data required for commercial approval and releases has hindered risk and benefit assessment efforts." Nevertheless, some trends do seem to be emerging in two of the key areas pertaining to pesticide use and yield.

As noted, the initial expectation was that farmers who planted TCs would use fewer or less-toxic pesticides, thus reducing the negative ecological effects of intensive agriculture. The rapid spread of these crops suggests that some farmers are benefiting economically, perhaps mainly from simplified weed control. However, various analysts have concluded that, with the possible exception of *Bt* cotton, there is little evidence that pesticidal and herbicide-resistant TCs require less pesticide. Roundup Ready® soybeans actually require up to 30% more herbicide than the conventional counterpart, despite claims to the contrary (Benbrook, 2001a).

More generally, herbicide-tolerant varieties seem to have modestly reduced the average number of active ingredients applied per acre but have modestly increased the average pounds applied per acre. Depending on the measure used, these crops have either reduced or increased pesticide requirements—either measure alone gives an incomplete picture of the overall impact of herbicide-tolerant varieties on pesticide use and the sustainability of weed-management systems (Benbrook, 2001b). The bottom line is that it is too early to know the long-term impact of transgenic plants on pesticide use—TCs may induce entirely new patterns and volumes of total pesticide use. "Unfortunately, at this stage in crop biotechnology, the cumulative shifts in use of many pesticide compounds are mostly uncertain" (Ervin *et al.*, 2000).

The effect of transgenic varieties on yield is no less ambiguous. Proponents of TCs argue that increased yield would reduce the need for further land conversions for agriculture. However, this simplistic view ignores the multiple possible interactions of different kinds of genetic modification with pest conditions, weather factors, soil types, *etc.* (Ervin *et al.*, 2000). Keep in mind, too, that the most widely accepted transgenic varieties, such as Roundup Ready® soybeans, were not intended to achieve yield increases. Even in the case of *Bt* cotton and corn, increased yield projections were based only on improved pest control and results have been variable (Ervin *et al.*, 2000). On the negative side, there is solid evidence that Roundup Ready® soybean cultivars produce 5 to 10% fewer bushels per acre in contrast to otherwise identical varieties grown under comparable field conditions (Benbrook, 2001a). In the longer term, it is possible that transgenes involving the manipulation of basic physiological processes such as photosynthesis will improve yields dramatically, but this will likely be accompanied by complications such as increased demand for water and nutrients. At present, there is no empirical evidence that TCs change water use or tillage requirements.

While the promise of TCs has yet to be unambiguously realized, numerous authors have speculated on the potential for serious ecological damage. Emergent and anticipated problems include (Rissler and Mellon, 1996; Altieri, 2000, 2004):

- spread of TCs threatens crop genetic diversity by simplifying cropping systems and promoting genetic erosion,
- potential transfer of genes from herbicide-resistant varieties to wild or semi-domesticated relatives thus, creating super weeds (a form of genetic pollution),
- herbicide-resistant volunteers become weeds in subsequent crops,
- use of herbicide-resistant crops undermines possibilities for crop diversification, thus reducing agrobiodiversity in time and space,
- vector-mediated horizontal gene transfer and recombination could create new pathogenic bacteria,
- vector recombination could generate new virulent strains of virus, especially in trangenic plants engineered for viral resistance with viral genes,

The net benefits of many transgenics, even to producers, are by no means clear and their widespread use poses a range of threats to food security.

- adverse effects on non-target organisms,
- insect pests are developing resistance to crops with *Bt* toxin (as they do to synthetic biocides).

In short, the net benefits of many transgenics, even to producers, are by no means clear and their widespread use poses a range of threats to food security (quite apart from any possible risk associated with consuming genetically engineered food). It is telling, in this light, that the transgenic revolution is being developed and promoted by the same corporate interests that brought us the first wave of agrochemically based agriculture. Altieri (2004) argues: "As long as transgenic crops follow closely the pesticide paradigm, such biotechnological products will do nothing but reinforce the pesticide treadmill in agroecosystems, thus legitimizing the concerns that many scientists have expressed regarding the possible environmental risks of genetically engineered organisms."

In summary, at this stage it seems that (Wolfenbarger and Phifer, 2000):

> *neither the risks nor the benefits of [GM organisms] are certain or universal. Both may vary spatially and temporally on a case-by-case basis… At the same time there is increasing evidence of significant unanticipated negative consequences to the unchecked spread of transgenics. Our capacity to predict ecological impacts of [GM organisms] is imprecise and [available data] have limitations.*

WHY DO WE STAY THIS ERRATIC COURSE?

Wall Street science will find only what satisfies Wall Street. The fact that it is championed as sound science makes it no more sound or truthful than a cult leader on an ego trip (Salatin, 2004).

More than a decade ago, a World Resources Institute study compared conventional and organic farming practices in Pennsylvania and Nebraska. In Pennsylvania, conservation cultivation of corn and corn-soybean production eliminated chemical fertilizer and pesticides, cut costs by 25%, reduced erosion by 50% and actually increased yields over conventional norms after 5 years. Researchers estimated that these practices would reduce off-farm damages by $75 per hectare of farmland, and avoid 30-year income losses (present value $306 per hectare) by preventing a 17% loss in soil fertility. All things considered, the resource-conserving practices outperformed conventional approaches in economic value per hectare by a two-to-one margin. In flat-land Nebraska, where the costs of erosion are lower, low-input cultivation was slightly less financially competitive than the prevailing high-input corn-bean rotation but was found to be environmentally superior overall (Faeth *et al.*, 1991, cited in WRI, 1992).

This is only one of many studies suggesting that more-sustainable agricultural practices work and can be learned by farmers in developed as well as less-developed countries. Indeed, enough evidence is available to suggest that low-input ecologically based agro-technologies could contribute to food security at many levels.

Just how productive and sustainable agroecological systems are is to some degree still an empirical question. Certainly, as critics of alternative production systems like to point out, there may be lower yields of particular crops than in high-input conventional systems. Yet, as Altieri *et al.* (2004) argued:

> *All too often it is precisely the emphasis on yield—a measure of the performance of a single crop—that blinds analysts to broader measures of sustainability and to the greater per-unit-area productivity obtained in complex, integrated agroecological systems that feature many crop varieties together with animals and trees. There are also cases where even yields of single crops are higher in agroecological systems that have undergone the full conversion process.*

Altieri *et al.* (2004) recognized that some of this apparent advantage may be due to the well known inverse relationship between farm size and production—smaller farms make far more productive use of the land resources than do large farms. Yet, in some situations:

> *even medium- and large-scale producers are increasingly making use of the agroecological approach, recognizing the advantages of these principles and techniques over conventional approaches.*

If agroecology and other approaches to sustainable agriculture show such promise, why is it that mainstream agro-biotechnology remains steadfastly focused on chemically based agriculture and genetic engineering? Part of the answer emerges from the fundamental "value program" that underpins techno-industrial society. John McMurtry (2004) built the case that:

> *the deep causal structure at work in the cumulative environmental catastrophe of our era is the deciding values of the global market economy itself.*

The dominant value-system of our contemporary growth-oriented globalizing world is a social construct that philosopher McMurtry (1998) refers to as "the money sequence of value": "The name of the game of the money sequence of value is to maximize money or money-equivalent holdings as a good in itself…" Money is invested in processes or commodities that lead to more money outputs for investors in a kind of self-perpetuating economic perpetual motion machine. Since its proponents purport to believe that this system has the potential to enhance human well-being better than any other, it follows that any other value or position that opposes it must be overridden. Dominance of the money sequence of value is thus ruinous to the alternative life sequence of value" (investment in things that sustain life leads to more opportunities for life). The money sequence of value (McMurtry, 1998):

> *now expropriates and attacks the civil commons at its edges, trunk and roots, 'privatizing,' 'axing,' and 'developing' so that its life-spaces and functions are stripped across society with no sense of loss.*

It follows that in this value framework, the decisions of the marketplace are supreme.

McMurtry's framing of the global market paradigm provides a perfect context for Jack Manno's explanation of why certain goods become "privileged" in modern societies. Manno (2000) asked:

> *Why, when it is clearly rational…to do so, can't we put at least as much attention and resources toward conserving energy and materials as we do toward mining and harvesting more and more?…Why not do as much research into organic agriculture as the fertilizer and pesticide [and TC] industries do on their R&D? Why do we not spend as much on disease prevention as we do on pharmaceuticals and high-tech treatments?*

The choices seem self-evident, yet it is just as obvious that modern society is not about to pour anything like the equivalent resources into alternative energy systems, sustainable agriculture, public health, *etc*., as it does into the prevailing ecologically destructive alternatives.

> *If anything, the opposite is true: ecologically destructive ways of living are continually spreading into societies and cultures that once managed to live more frugally and in balance with nature. Why? (Manno, 2000).*

Manno answered his own question by arguing that in market societies goods with certain qualities tend to be favoured over all others (Table 2). Driven by the money sequence of values, markets automatically work to address every human need and desire with those goods that can most easily be produced for market and sold. Other goods and services—even those that might give more satisfaction and cause less damage—tend to wither and fade away. For example, "soil additives, chemical fertilizers, and insecticides (and we might add GM seeds) are all products patented, packaged, distributed and sold. The farmer who knows and protects the soil from erosion and overuse has as her most important product her knowledge and skill, which cannot easily be packaged and sold" (Manno, 2000). Thus the hard-edged products of commerce dominate agriculture today while the softer intimate knowledge of the land fades from cultural memory.

Table 2. Selected characteristics of privileged commodities contrasted with those of non-privileged commodities (after Manno, 2000).

Attributes of goods and services with low commodity potential	Attributes of goods and services with high commodity potential
Openly accessible—widely available; difficult to establish property rights; hard to price and market.	Appropriable—excludable; enclosable; assignable; easy to establish property rights; easily priced and marketed.
Rooted in local ecosystems and communities.	Mobile and transferable; easy to package and transport.
Particular, customized, decentralized and diverse; unique to each culture and environment.	Universal, standardized, centralized and uniform; adaptable to multiple contexts.
Systems-oriented—development occurs in context of wider system; goal is overall optimization; products develop to serve the system.	Product-oriented—development focuses on maximizing output; goal is profit maximization; system is transformed to serve the product.
Dispersed energy—energy is used and dissipated at the site of the activity or at point of exchange or consumption.	Embodied energy—production is energy intensive; packaging, promotion and transportation add to energy 'content' of the product.
Low capital intensity.	High capital intensity.
Design follows and mimics natural flows and cycles.	Design resists or alters natural flows and cycles.
Variable—unpredictable, unreliable, discontinuous.	More stable—predictable, reliable, continuous.
Contributes little to GDP—non-market goods don't show up in national statistics.	Contributes to GDP—GDP is essentially a measure of marketed goods and the scale of commoditization.

Various material inputs to "traditional" production agriculture—fertilizer, pesticides, irrigation equipment, mechanized tools and equipment—all possess the properties of highly commoditizable goods and services, the kinds so privileged by techno-industrial society and its money sequence of value. Genetically modified seeds and genetic material generally share these qualities, particularly since the courts have supported the rights of firms to patent and licence the use of "their" inventions for profit.

Manno (2000) calls this subtly unconscious process "commoditization":

> *At its core, commoditization is the continuous pressure to transform as much of the necessities and pleasures of life as possible into commercial commodities.*

Given the nature of the market economic process, it is to be expected that many of the qualities that characterize privileged commodities are precisely the qualities that concentrate energy and materials and do the greatest ecological and social damage.

Even a cursory look at Table 2 confirms that the various material inputs to "traditional" production agriculture—fertilizer, pesticides, irrigation equipment, mechanized tools and equipment—all possess the properties of highly commoditizable goods and services, the kinds so privileged by techno-industrial society and its money sequence of value. Genetically modified seeds and genetic material generally share these qualities, particularly since the courts have supported the rights of firms to patent and licence the use of "their" inventions for profit. Little wonder that the transgenic revolution in agriculture is being brought to us by "the same corporate interests that brought us the first wave of agrochemically-based agriculture" (Altieri, 2004). As Salatin suggested, what passes for "sound science" in the marketplace is that science that adds the most to the short-term corporate bottom line. Contemporary sound science in agriculture may well be "killing" us (Salatin, 2004).

Epilogue

According to popular and even much "scientific" belief, the good Reverend Malthus's dismal theorem has long been put to rest. However, the foregoing analysis suggests that, despite advances in technology, humanity may yet be confronted

The aggregate human ecological footprint of consumption and waste dissipation made possible by abundant energy supplies is 20% greater than the biocapacity of the planet.

with a global food/population crisis in coming decades. The industrial revolution and industrial agriculture greatly increased global food production and staved off starvation for billions in the twentieth century, but hundreds of millions more have yet to join the table, and the human family is expected to grow by an additional 2 to 3 billion in the first half of this century. Meanwhile, increased intensity of crop production has accelerated the degradation of arable soils, irreversibly dissipating thousands of years' accumulations of vital nutrients and organic matter. While irrigation, mechanization and chemical inputs have temporarily made up for productivity losses, these technologies are dependent on fossil fuels that are, in turn, rapidly being consumed.

The second law of thermodynamics cannot be overturned. The much-exalted seemingly vibrant far-from-equilibrium state of the modern human enterprise, and the very existence of today's 6.3 billion people, is possible only because of the prior accumulation of large stocks of natural capital (resource stocks). In particular, since 1850, the plot of human population growth is virtually identical with the plot of fossil energy usage. Unfortunately, the most critical of our natural capital stocks—soils and oil—are rapidly being irreversibly depleted and the dissipated by-products (*e.g.*, carbon dioxide) now threaten to double the damage through climate change. Meanwhile, the aggregate human ecological footprint of consumption and waste dissipation made possible by abundant energy supplies is 20% greater than the biocapacity of the planet (WWF, 2002).

The introduction of transgenic crops is arguably just one more step down the slippery slope toward entropic disorder and systemic chaos.

This situation is not sustainable. To the truly rational mind—not the merely self-interested utility-maximizing economic mind—it would seem to call for a radical change in humanity's relationship to the ecosphere. Ecosystems are self-producing and self-perpetuating, and in the right physical environments they accumulate species, biomass and life-giving nutrients while forever recyling the chemical basis for life. By contrast, industrial agroecosystems are self-consuming quasi-parasitic systems that shed biodiversity, dissipate energy and nutrients and convert natural cycles into terminal throughput. Attempting to maximize production of a single variable—the food crop—using an external energy subsidy destroys the structure and functional integrity of the whole. The introduction of transgenic crops is arguably just one more step down the slippery slope toward entropic disorder and systemic chaos.

In these circumstances, we need instead "an agriculture that more nearly mimics the structure and functions of natural ecosystems" (Jackson, 2004). Indeed, we need to extend the concept of biomimicry to the whole-systems level. Species in ecosystems co-evolve in mutual dependence and support. Ecosystems are autopoietic: the relationships among the interacting components—living organisms—are essential for the continued production and functioning of the components themselves (Maturana and Varela, 1987). We humans must learn to be a constructive participant in, rather than a combatant against, the ecosystems that sustain us. Adopting this goal would actually move us toward a much more intensely knowledge-based system of agriculture. Ecologically sustainable agriculture requires a vastly more sophisticated understanding of complex systems theory and ecosystems behavior than does the corporate, high-input, "brute force" production agriculture ravaging the planet today. Ecosystems science should become the agricultural biotechnology of the twenty-first century. Without an evolutionary ecologically based agriculture, our arable lands and soils, our rural families and communities, will continue to languish in a state of siege.

Ecologically necessary and economically feasible, sustainable agriculture based on an agroecological model is also socially desirable for rural areas. The realistic pricing of resources, attention to the ecology of land, and eco-technology implies a return to smaller farms and more labor- and information-intensive practices. The countryside might, therefore, regain population as human labor and ingenuity once more become an important (renewable) factor in primary food production. In this way, sustainable agriculture would help restore an historical cultural landscape through salvation of the family farm and revitalization of dependent communities. Meanwhile, urban society would reap special dividends with the restoration of ecological diversity and beauty to the rural landscape, and through reduced pollution of air, water, and soil and other off-farm impacts. We might even enjoy more-wholesome, safer food.

If* Homo sapiens *does not learn to live within the means of nature, we will wind up permanently dissipating our habitat.

The motive for the needed revolution is simple and strong. If *Homo sapiens* does not learn to live within the means of nature, we will wind up permanently dissipating our habitat. Resources degraded, the human enterprise would necessarily plunge toward a new (and dismal) closer-to-equilibrium state. Food production could fall below pre-industrial levels and the human population to fewer than 2 billion.

References

Altieri MA (2000) Executive Summary, International Workshop on the Ecological Impacts of Transgenic Crops. March 2–4, 2000. http://www.biotech-info.net/summary1.pdf.

Altieri MA *et al*. (2004) The Potential of Agroecology to Combat Hunger in the Developing World. Agroecology in Action. Berkeley: University of California. http://www.agroeco.org/doc/ the_potential_of_agroecology.html.

Altieri MA (2004) The Ecological Impacts of Transgenic Crops on Agroecosystem Health. Agroecology in Action. Berkeley: University of California. http://www.agroeco.org/doc/ the_ecological_impacts.html.

Benbrook, M (2001a) Troubled Times Amid Commercial Success for Roundup Ready Soybeans. AgBioTech Infonet Technical Paper #4. Sandpoint Idaho: Northwest Science and Environmental Policy Center.

Benbrook M (2001b) Do GM crops mean less pesticide use? Pesticide Outlook (Royal Society of Chemistry) October 2001.

Brower M Leon W (1999) The Consumer's Guide to Effective Environmental Choices, New York: Three Rivers Press.

Brown LR (2004) World Food Security Deteriorating: Food Crunch in 2005 Now Likely. Washington, DC: Earth Policy Institute. http://www.earth-policy.org/Updates/Update40.htm.

Canadian Agricultural Energy End-Use Data Analysis Center (CAEEDAC) (1998) Energy Consumption in the Canadian Agricultural and Food Sector (Report Presented to Agriculture and Agri-Food Canada). Saskatoon: Canadian Agricultural Energy End-Use Data Analysis Center, University of Saskatoon.

Campbell CC (1999) The Imminent Peak of World Oil Production. http://www.hubbertpeak.com/campbell/commons.htm.

Cassman KG (1999) ecological intensification of cereal production systems: yield potential, soil quality, and precision agriculture. Proceedings of the National Academy of Sciences 96 5952–5959

Conforti P Giampietro M (1997) Fossil Energy Use in Agriculture: An International Comparison. Agriculture, Ecosystems and Environment 65 231–243.

Duncan RC (1993) The Life-expectancy of Industrial Civilization: The Decline to General Equilibrium. Population and Environment 14 325–357.

Duncan RC Youngquist W (1999) Encircling the peak of world oil production. Natural Resources Research 8 219–232.

Ervin D *et al*. (2000) Transgenic Crops: An Environmental Assessment. Morrilton: Wallace Centre for Agriculture and Environmental Policy at Winrock International.

Faeth P *et al*. (1991) Paying the Bill: US Agricultural Policy and the Transition to Sustainable Agriculture, Washington: World Resources Institute.

Food and Agriculture Organization (FAO) (2000) Land Resource Potential and Constraints at Regional and Country Levels. Rome: Land and Water Development Division, Food and Agriculture Organization of the United Nations.

Gregory PJ *et al.* (2002) Environmental consequences of Alternative Practices for Intensifying Crop Production. Agriculture, Ecosystems and Environment 88 279–290.

Hall C *et al.* (2003) Hydrocarbons and the evolution of human culture. Nature 426 318–322.

Jackson W (2004) Agriculture: The primary environmental challenge of the 21st Century. In: The Human Ecological Footprint (Chesworth W *et al.* Eds.). Guelph: Faculty of Environmental Sciences, 85–99.

Kay J Regier H (2000) Uncertainty, complexity, and ecological integrity. In: Implementing Ecological Integrity: Restoring Regional and Global Environment and Human Health. NATO Science Series IV: Earth and Environmental Sciences, Vol. 1 (Crabbé P *et al.* Eds.). Dordrecht: Kluwer Academic Publishers, 121–156.

Laherrere J (2003) Forecast of oil and gas supply to 2050. Paper presented to Petrotech 2003, New Delhi. http://www.hubbertpeak.com/laherrere/Petrotech090103.pdf.

Longwell HJ (2002) The future of the oil and gas industry: Past approaches, new challenges. World Energy 5 102–105.

Malthus TR (1798) An Essay on the Principle of Population: A View of its Past and Present Effects on Human Happiness; with an Inquiry into Our Prospects Respecting the Future Removal or Mitigation of the Evils which It Occasions (Sixth Edition, 1826). London: John Murray.

Manning R (2004) The oil we eat: following the food chain back to Iraq. Harper's Magazine 2 37–45.

Manno J (2000) Privileged Goods. Boca Raton: Lewis Books.

Maturana H Varela F (1987) The Tree of Knowledge. Boston: Shambala.

Matson PA *et al.* (1997) Agricultural intensification and ecosystem properties. Science 277 504–509.

McMurtry J (1998) Unequal Freedoms: The Global Market as an Ethical System. Toronto: Garamond Press.

McMurtry J (2004) The life code versus the money code of value: Understanding the planetary ecological crisis. In: The Human Ecological Footprint (Chesworth W *et al.* Eds.). Guelph: Faculty of Environmental Sciences, 115–134.

Pimentel D Pimentel M (1999) Population growth, environmental resources and global food. Journal of Sustainable Forestry 9 35–44.

Prigogine I (1997) The End of Certainty: Time, Chaos and the New Laws of Nature. New York: The Free Press.

Rees WE (1992) Ecological footprints and appropriated carrying capacity: What urban economics leaves out. Environment and Urbanization 4 121–130.

Rees WE (1996) Revisiting carrying capacity: Area-based indicators of sustainability. Population and Environment 17 195–215.

Rees WE (1999) Consuming the earth: The biophysics of sustainability. Ecological Economics 29 23–27.

Rees WE (2001) Ecological footprint, concept of. In: Encyclopedia of Biodiversity Vol. 2 (Levin S Ed-in-Chief). San Diego: Academic Press 229–244.
Rees WE (2003) Economic development and environmental protection: an ecological economics perspective. Environmental Monitoring and Assessment 86 29–45
Rissler J Mellon M (1996) The Ecological Risks of Engineered Crops. Cambridge: MIT Press.
Salatin J (2004) Sound science is killing us. Acres 34. http://www.acresusa.com/toolbox/reprints/April04_Salatin.pdf.
Schneider ED and Kay JJ (1994) Complexity and thermodynamics: toward a new ecology. Futures 26 626–647.
Schneider ED Kay JJ (1995) Order from disorder: the thermodynamics of complexity in biology. In: What is Life: The Next Fifty Years. Reflections on the Future of Biology (Murphy MP O'Neill LAJ Eds.). Cambridge: Cambridge University Press.
Schrödinger E (1945) What is Life: The Physical Aspect of the Living Cell. Cambridge: Cambridge University Press.
Sustainable Development Information Service (SDIS) (2004) Disappearing Land: Soil Degradation. Sustainable Development Information Service, Global Trends. Washington: World Resources Institute. http://www.wri.org/wri/trends/soilloss.html.
Wackernagel M Rees WE (1996) Our Ecological Footprint: Reducing Human Impact on the Earth. Gabriola Island, BC: New Society Publishers
Wolfenbarger LL Phifer PR (2000) The ecological risks and benefits of genetically engineered plants. Science 290 12 2088–2093.
World Resources Institute (WRI) (1992) World Resources 1992–93. Oxford and New York: Oxford University Press.
World Wide Fund (WWF) (2002) Living Planet Report 2002. Gland, Switzerland: Worldwide Fund For Nature International.

William Rees has taught at the University of British Columbia since 1969 and is currently professor in the School of Community and Regional Planning. His teaching and research emphasize the public policy and planning implications of global environmental trends and the necessary ecological conditions for sustainable socioeconomic development.

Much of Dr. Rees's work is in the realm of ecological economics and human ecology. He is best known in this field for his invention of "ecological footprint analysis," a quantitative tool that estimates humanity's ecological impact on the ecosphere in terms of appropriated ecosystem (land and water) area. This research reveals the fundamental incompatibility between continued material economic growth and ecological security, and has helped to reopen debate on human-carrying capacity as a consideration in sustainable development.

Rees is currently a co-investigator in the Global Integrity Project, oriented toward determining the necessary ecological conditions for biodiversity preservation. He has been lectured on his work across Canada and the United States, as well as in Australia, Austria, China, Finland, Germany, Great Britain, Japan, Mexico, the Netherlands, Norway, Indonesia, Italy, Korea, the former Soviet Union, Spain, Sri Lanka, and Sweden.

In 1996, he was awarded a UBC Killam Research Prize in acknowledgement of his research achievements.

The Impact of Agricultural Biotechnology on Biodiversity: Myths and Facts

KLAUS AMMANN
University of Bern
Bern, Switzerland

I will discuss biodiversity and I will discuss agriculture, but I cannot avoid going into social matters, into cultural matters. Let me begin with a brief background to the great debate. All participants in this conference are participants also in the discussion of world-food problems and we should feel privileged to be involved in this historic debate. A technology boost is coming to biology, and, in turn, biology will be the source of the biggest technology advancement that humankind has ever gone through. Hence biology has lost its innocence, and we need to understand the background.

GENETIC SYMPHONY

Many still have no idea where we should be headed. William Reese gave us a brilliant example of rethinking knowledge-based agriculture. The complexity of genomics research is recognized. Although the interrelationships among chromosomes are known to be complex, even with *Arabidopsis*—one of the best-characterized genomes—we are far from understanding what is going on at the gene level. We are all painfully aware of the rapid growth in knowledge; it is accumulating at such a speed that it is likely that no one in this room would claim to be able to stay abreast of developments even in her/his own field.

Each genome is extremely complex. Genes should not be viewed singly, in isolation, but rather as a concept, working together in a fantastic symphony. By understanding how genes interrelate, the possibilities for progress will be immeasurable; we will move beyond the current phase of single-gene-altered crops—paleogenetics, as I call it—with insect-resistance and herbicide tolerance.

We live in a risk-averse society; although human longevity is increasing, paradoxically many people believe they live under increasing risk.

RISK PERSPECTIVE

We live in a risk-averse society; although human longevity is increasing, paradoxically many people believe they live under increasing risk. We should view this aspect from a historical perspective. The introduction of coffee in London met with stiff resistance. Women's petitions attempted abolishment of coffee shops on the grounds that it caused impotence in their spouses. Pope Clement VIII (1593–1605) took a different tack: "Why this Satan's drink is so delicious…it would be a pity for the [sinners] to have exclusive use of it. We shall fool Satan by baptizing it and making it a truly Christian beverage." Thus, ideology was brought to bear. During the great coffee debate the notion of systemic or substantial equivalence was fielded. There was much discussion in that regard, and we now know that coffee contains at least sixteen carcinogens. It would have no chance of being approved as a new beverage today, which illustrates a modern-day schizophrenia about risk. The Greens demand a ban on the release of genetically engineered organisms, because they maintain there is no proof that they are safe, yet they promote the use of cannabis. Joking aside, there is a serious problem here. It is not unreasonable to be concerned over the genetic engineering of plants. Those without anxiety are the fools in my eyes.

Precautionary "principle" is inappropriate terminology resulting from poor translation within the European Union. Consultation of the original text reveals that it is an "approach."

PRECAUTIONARY APPROACH/PRINCIPLE

Part of the complexity of the debate results from the use of the precautionary approach in legislation. Precautionary "principle" is inappropriate terminology resulting from poor translation within the European Union. Consultation of the original text reveals that it is an "approach."

Linear planning processes are insufficient in this debate. A systems approach is needed. We also need to take a step back to gain perspective in this debate. One of the foremost principles I would make clear is the symmetry of ignorance. As stated already in this conference, as long as scientists try to explain the world with scientific facts alone, we will encounter more and more difficulties; it's a clash between post-modernism and modernism. I have insufficient time to go into the elements of the systems approach, but we know that this is not functioning today. Look at US corporate entities: they cannot understand why Europeans refuse their soybeans. Scientists working at the bench often feel little social responsibility for what they do and feel no obligation to debate the issues with the public.

Everyone fond of Italian food has eaten spaghetti produced by gamma-irradiation of the whole genome of wheat.

Manipulation of Evolution

Let us go to the heart of the matter: with respect to biodiversity, we should address the argument of the manipulation of evolution rationally and realistically. It does not seem to be generally understood that pollen drift did not begin with the engineering of transgenes. But, because non-containment of transgenes is now an issue, it is likely that the next generation of transgenic plants will not result from complex manipulations for drought resistance, for example—which will take 5 to 10 years—but with non-alien genes. Useful traits will be taken from progenitor landraces and restored to modern cultivars of the same species. If you think that genes are being transferred for the first time across hybridization barriers, you would be wrong; it has been done for years with protoplast technologies. And if you think that we did not manipulate genomes artificially before genetic engineering you would also be dead wrong. Everyone fond of Italian food has eaten spaghetti produced by gamma-irradiation of the whole genome of wheat. This is "Frankenstein"—if you ask me—but it is not genetic engineering. It has been used hundreds of times to produce superior cultivars. The FAO Web-site shows a list of over 500 cultivars produced by gamma irradiation. Yet, although we don't know what we have done to these genomes, we eat the products without reservation. In fact, not even a red nose has resulted.

There is a common misperception that Golden Rice™ is uniquely artificial; in fact, the parent cultivars of Golden Rice™ were already artificial. Figure 1 was provided by Ingo Potrykus; each "@" sign indicates a breeding event in the pedigree, the result of each of which is totally unpredictable. If safety rules for transgenic crops were applicable, a hundred years of probation and safety tests would be needed. Although the normal process of breeding and selection involves many unpredictable steps, fortunately, pragmatism has prevailed.

One-sided views are inappropriate in this great debate.

One-sided views are inappropriate in this great debate. For instance, when Charles Benbrook claimed that more pesticides are used with transgenic crops he mad two mistakes. First he followed the rule that you should believe only the statistics you have falsified yourself; it has been shown that his figures are 20% too high. The bases of all statistics should be examined carefully. Second, he failed to take toxicity as the critical parameter. Toxicity is reduced in conjunction with Roundup Ready® cultivars. Even if it's from Monsanto it is less toxic, I'm sorry.

In the monarch butterfly case it was shown that no differences exist between *Bt* and non-*Bt* maize fields. If I were a non-target insect, I would prefer to visit a *Bt* field because there would less likelihood of being showered with pesticide. But, to be honest, I would most prefer to vacation with an organic farmer.

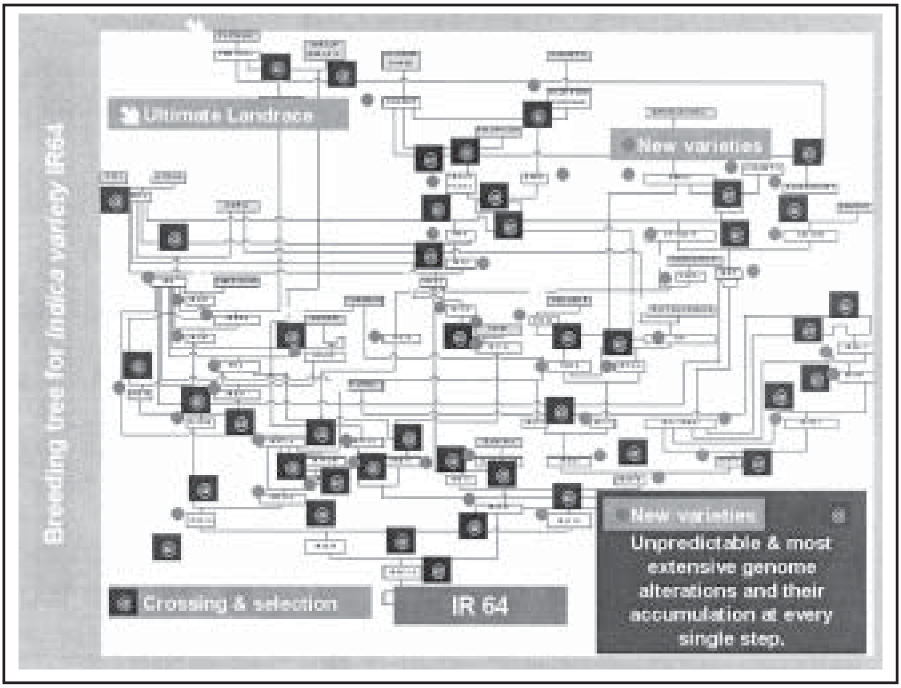


Figure 1. The pedigree of rice cultivar IR 64.

That *Bt* is toxic to certain classic non-target insects is a myth. In a 2004 publication Romeis *et al.* came to the conclusion that the classic studies of Hilbeck *et al.* (1998) were done with the wrong insects (half dead), with the wrong concentrations and with the wrong statistics. We should be careful in interpreting the scientific literature.

Mutually contradictory data have been published in peer-reviewed journals from a number of studies on maize pollen deposition on leaves. This is not to suggest that such experiments on pollen deposition have been done with the wrong methods, but the data have demonstrated regional and seasonal differences; sometimes firm conclusions are impossible from so-called exact scientific results. Care in interpretation is needed. Dr. Reese made that very clear in his discussion of ecosystems.

Gene flow is not new; it's an important component of evolution.

We found no problem with barley, wheat, rye, potato, clover, maize, but we did identify problems with alfalfa and its wild relatives and the grasses of course; and I would like to put lettuce and carrot behind bars!

Gene Flow

Gene flow is not new; it's an important component of evolution. Careful attempts to measure pollen drift have yielded highly variable data from cultivar to cultivar and from year to year. In Switzerland we have developed, together with Dutch groups, a method of deriving data from hybrids in herbaria, which is a curious approach for bench workers. We used a statistical approach—I won't dwell on the morphometrics and numerical taxonomy—to quantify gene flow to wild relatives of nineteen crops in Switzerland: we found no problem with barley, wheat, rye, potato, clover, maize, but we did identify problems with alfalfa and its wild relatives and the grasses of course; and I would like to put lettuce and carrot behind bars! These data, accumulated over many decades, show that seed-producing hybrids are possible. This is agriculturally relevant and more important than producing hybrids by embryo rescue. These findings will soon be reflected in Swiss law.

Apomixis—development of seeds without pollination—offers the most effective means of precluding gene flow. Although some 10% of the wild flora have this capability, its reliable induction in crop plants is proving to be difficult.

Need for Vision

We need knowledge-based agriculture and you at the University of Guelph are making significant contributions in this regard, and I am glad to have been invited here. I am impressed by your publications record and all the things you are doing here. But we also need vision. As already stated, we need to seriously consider organic farming strategies. A 21-year trial in Switzerland—comparing organic and conventional farming systems—revealed 30% to 40% more earthworm biomass and 50% to 80% higher earthworm density in the former. Clearly, positive effects of organic strategies on soil fertility merit attention. Organic farming should not be the brunt of jokes. (On the other hand, insect-resistant potato would be a wonderful thing to have.)

People in other countries must be free to decide which technologies they wish to adopt and adapt. Progress is not always defined in terms of new technologies. Local traditions are important and we should refrain from corporate and eco-imperialism. Neither should we joke about the precautionary principle: we should develop it as a systems approach, a discursive approach, an open-minded approach. I have debated Buddhists, Zen Buddhists, abbots of Catholic monasteries and Amish farmers, and, in my experience, spirituality goes hand-in-hand with open-mindedness and genuine curiosity. After a 2-hour discussion with Amish farmers, they agreed to plant transgenic crops; Monsanto happily supplied the seed. They tried them out and have adopted them. My best such encounter was with a noble and dignified teacher of the Dalai Lama when he was *en route* to Hollywood for the premier of *Seven Years in Tibet*; we had a wonderful discussion. Three world views need to be taken into account:

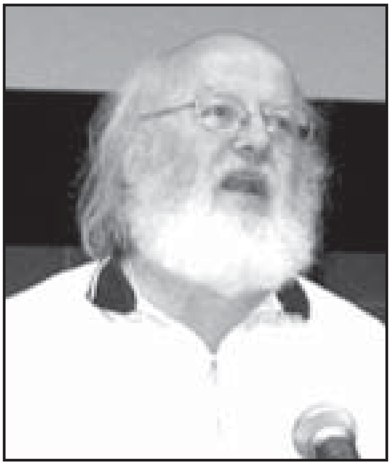
- through the eye of the flesh—the level at which scientists generate data;
- through the eye of the intellect—the more intelligent scientists view their work in context and ask themselves, “What am I doing here?”;
- through the eye of the spirit—which cannot be intellectualized, but must be felt and practiced.

I believe that a “lacuna” exists in our society, illustrated by the fact that organo-transgenic crops—combining the potential of precision-biotechnology with organic approaches—should be our target. Data generated for length of time of quail chicks to satisfy daily nutritional requirements showed that they foraged for 4.2 hours under no-till herbicide-tolerant soybean whereas they had to forage for 22 hours per day in conventionally tilled soybean fields. Clearly, ecology and herbicide tolerance can be positively correlated.

References

Hilbeck A *et al.* (1998). Effects of transgenic *Bacillus thuringiensis* corn-fed prey on mortality and development time of immature *Chysoperla carnea* (Neuroptera: Chrysopidae). Environmental Entomology 27 480–487.

Romeis J *et al.* (2004) *Bacillus thuringiensis* toxin (Cry1AB) has no direct effect on larvae of the green lacewing *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae). Journal of Insect Physiology 50 175–183.



Klaus Ammann has served as director of the Botanical Garden at the University of Berne, Switzerland, since 1996. As an honorary professor at the university, he teaches plant systematics and evolution, and biogeography. He also teaches air-pollution biomonitoring at the Federal Institute of Technology, Zurich.

Dr. Ammann's research interests encompass the chemotaxonomy of macro-lichens, calibrated biomonitoring of air pollution with lichens, molecular systematics of lichens, ethnobotany in Jamaica, and ecological monitoring in Bulgaria. He is involved also in ecological risk assessment of vertical geneflow in Switzerland, and in measuring gene flow of the *Brassicaceae* in Europe as the Swiss coordinator. In collaboration with the United Nations Industrial Development Organization (UNIDO) he is assembling a Compendium on Risk Assessment Research and is a participant in the Global Initiative on Education in Biotechnology.

Ammann contributed to reports on The Impact of Agricultural Biotechnology on Biodiversity and on Systems Approaches to Biosafety.

His committee work includes chairing the European Group of Plant Specialists, serving as a member of the coordination group of the European Science Foundation on risk assessment of transgenic crops, and membership of the Biosafety Committee of the Government of Switzerland.

Reducing the Agricultural Eco-Footprint: Reflections of a Neo-Darwinian Ecologist

David M. Lavigne
International Fund for Animal Welfare
Guelph, ON

We humans live on a finite planet. Yet, our numbers have been increasing exponentially for thousands of years and continue to do so. At the turn of the century we numbered over 6 billion (United Nations, 1999). During the early 1980s, the human ecological footprint (Wackernagel and Rees, 1996) surpassed Earth's capacity to maintain our current lifestyles and, by the end of the twentieth century, it was estimated that it had exceeded the bio-capacity of the planet by some 20% (Rees, 2002; WWF, 2002; Wackernagel *et al.*, 1999; 2002a, b). In short, we now require more than 1.2 planet Earths to support present conditions. By 2050, the United Nations predicts that the human population will have increased to about 9 billion (United Nations, 2003).

The problems facing the planet—or, more precisely, the human species—are well documented and have been discussed in previous National Agricultural Biotechnology Council (NABC) Reports (*e.g.* Kirschenmann, 2003). As the global human population grows, resources (especially non-renewable) continue to be depleted and the environment becomes increasingly degraded (*e.g.* Meadows *et al.*, 2004). Our unsustainable practices include the clearing of forests (Pimm, 2001), the loss of productive soils (Chesworth, 2004; Jackson, 2004), and the overexploitation of fisheries (FAO, 2002a; Pauly *et al.*, 2002), all of which contribute to the on-going loss of biodiversity that some have characterized as the "sixth extinction" (Leakey and Lewin, 1996; Eldredge, 2001; Ward, 2004). In addition, we are interfering with fundamental evolutionary processes through the exploitation of natural resources (e.g. selective hunting, such as trophy hunting, fishing, and forestry), the introduction of exotic, alien, or non-native species, and, most recently, through the production and release of genetically modified (GM) organisms into the environment (S.J. Holt, pers. comm.). We are also depleting reserves of oil and natural gas (P. Roberts, 2004), increasing greenhouse-gas emissions and contributing to global climate change (IPCC, 2001). Superimposed on all these realities is the growing social inequity and economic disparity between the North and South, the so-called developed and developing worlds, respectively (*e.g.* Elliott, 2001). Of particular relevance is the fact that millions of people (some say billions), most of whom live in the developing world, are going hungry and suffer from malnutrition (*e.g.* Mittal, 2000; Pimentel, 2004).

In this symposium, we have been asked to consider the prospects for reducing the agricultural eco-footprint. In order to attempt that, I will first try to place agriculture into a broader global ecological context. I will then consider the "problem" of feeding the world's hungry, including possible roles for agricultural biotechnology. Finally, I will examine the prospects for reducing the agricultural eco-footprint, given our evolutionary legacy as Darwinian animals. I will end on a note of optimism: that humans really can change the current situation, if there is the collective will to do so.

Agriculture and the First "Law" of Ecology

If there are "laws" in ecology, one would be that "everything is connected to everything else" (Commoner, 1971). Agriculture is a case in point (Figure 1). Human

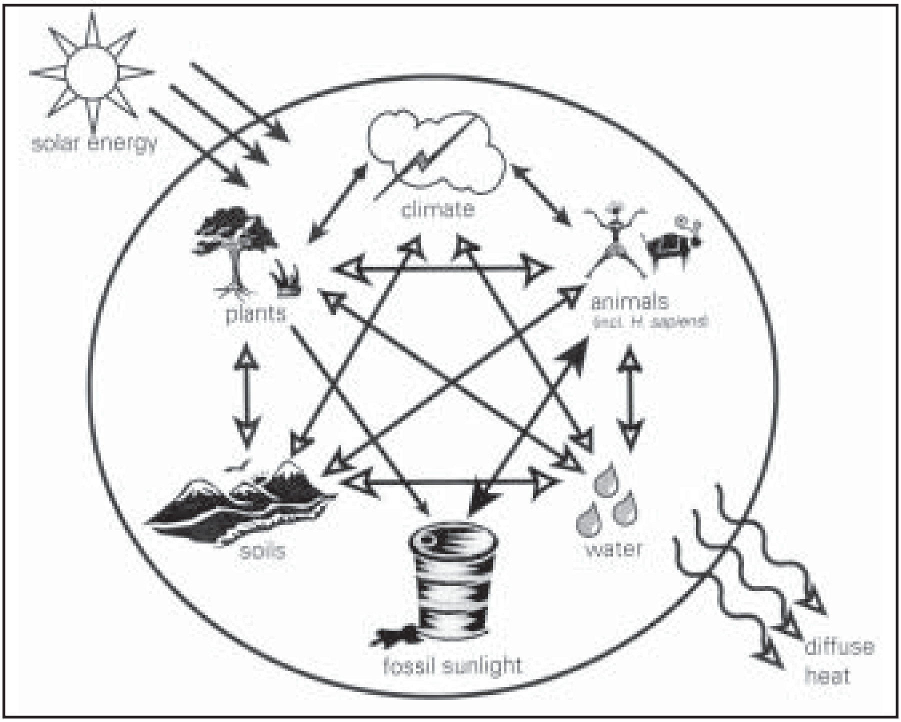


Figure 1. Commoner's first law of ecology: "Everything is connected to everything else" (Commoner, 1971).

animals have practiced it for some 10,000 years; it obviously has effects on both non-human animals and plants that collectively constitute what these days we call biodiversity. Agriculture also affects the quality and quantity of soil and the quality and availability of water (Pearce, 2004) and, in recent decades, it has used increasing amounts of "fossil sunlight," including oil and natural gas, to maintain soil fertility and to increase food production. The latter results in the release of increasing amounts of carbon dioxide to the atmosphere, adding to the accumulation of greenhouse gases, which are thought to be contributing to climate change on a global scale.

We can accept that there are problems and look for potential solutions.

Given the problems associated with the human condition outlined in the introduction and reiterated in relation to agriculture in the preceding paragraph, we have at least two options. We can deny that there are problems, following the examples of the late Julian Simon (*e.g.* 1992) and his modern disciple, Bjorn Lomborg (2001; EAI, 2002). Alternatively, we can accept that there are problems and look for potential solutions. I will deal only with the latter alternative.

One Putative Solution

One suggested "solution," widely embraced and promoted since 1987, is the concept of "sustainable development." Formally introduced in the 1980 World Conservation Strategy produced by the International Union for Conservation of Nature and Natural Resources (IUCN), in conjunction with the United Nations Environment Programme (UNEP) and the World Wildlife Fund (WWF), it was brought to the public consciousness by the 1987 report of The World Commission on Environment and Development (WCED), entitled Our Common Future. (This widely cited and influential document is commonly referred to as the Brundtland Report after its chair, Dr. Gro Harlem Brundtland, the former prime minister of Norway.) The WCED report was followed by a second—almost forgotten—world conservation strategy, Caring for the Earth (IUCN, 1991), which attempted to insert the ideas of sustainable development back into a conservation agenda (Robinson and Redford, 2004). But what Caring for the Earth really did was to subsume "conservation under the development agenda and [confuse] the distinct goals of conservation and development" (Robinson and Redford, 2004; Robinson, 1993).

The WCED (1987) defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (p. 8). This definition has been criticized not only because it is circular (development defined in terms of development), but also because it does not specify precisely what it is that needs to be sustained (*e.g.* Lavigne, 2002). Some commentators, like Robinson (2002), regard the lack of a precise definition as a virtue, termed "constructive ambiguity." Being vague and ambiguous allows so-called "stakeholders" with very different values and objectives to sit at the same table and come to some "agreement" about "sustainable development." The fact that each participant interprets the words quite differently and has quite different—and, often, diametrically opposed—views on what needs to be done really doesn't seem to matter.

Among many others, I take quite a different view, agreeing with those, like Chesworth *et al.* (2001), who characterize sustainable development as the oxymoron of the latter twentieth and early twenty-first centuries (Lavigne, 2002). Unlike Robinson (2002), I do not see the ambiguity implicit in the term sustainable development to be constructive in any redeeming way. Rather, I argue that the vagueness of the term actually facilitates something called "deceptive ambiguity" (Lavigne, 2002). To my mind, sustainable development is actually part of a "conspiracy"—in the words of my colleague Sidney Holt—"devised to maintain capitalism as the only and permanent economic system," and to allow the developed world to maintain and increase the size of its ecological footprint at the continuing expense of the developing world (Lavigne, 2002). Viewed in this light, sustainable development really is "a new world deception," something that Willers (1994) recognized and described rather early in the game (for a detailed critique of the concept, see Beder, 1996).

If such a view seems overly harsh, consider what has happened in the world, post-Brundtland. We have managed largely to sustain economic growth in the developing world. Meanwhile, according to the World Bank, the gap between rich and poor nations has widened to the point that 20% of the world's population now controls 80% of the wealth (Elliott, 2001). Furthermore, somewhere between 800 million (Mittal, 2000; http://www.monsantoafrica.com) and 3 billion (Pimentel, 2004) people remain hungry and malnourished. After the 2002 United Nations conference on environment and development in Johannesburg, one observer went as far as to suggest that "sustainable development is dead" (Bruno 2002). Nonetheless, many world leaders, among others, continue to promote it as the solution to the world's ills (Lavigne, 2002).

With this as background, let's move on to the topic at hand: agriculture's contribution to the current state of the human condition, and how we might reduce the size of the agricultural eco-footprint.

The Nature of Agriculture

Non-agricultural scientists often view agriculture quite differently from many who work in the field. Niles Eldredge (2001)—an evolutionary biologist, best known perhaps for his work with Stephen J. Gould on punctuated equilibria (Eldredge and Gould, 1972)—suggested, for example, that "agriculture represents the single most profound ecological change in the entire 3.5 billion-year history of life."

While Eldredge's claim may be open to debate (but, see Ward, 2004), Wes Jackson's (2004) more modest claim that "our farming has never been sustainable" is difficult to refute. Jackson, a geneticist by training, argues that our agriculture, based as it is on annual crops, is an historical accident that replaces natural ecosystems with monocultures, contributes to the on-going loss of biodiversity, reduces soil fertility, leads to soil erosion, and promotes environmental contamination through the application of human-made pesticides, fungicides, and herbicides. According to Jackson, some 38% of the world's agricultural soils are now degraded. The logical extension of his argument appears in a commentary by Ward Chesworth (2002), a geochemist: "The fact that we have not yet invented a truly sustainable agricultural system means that we have not yet achieved a truly sustainable civilization."

The solutions to the problems described above are not trivial, but they do seem quite obvious. We must limit our numbers or nature will impose its limits on our quality of life, our numbers, or our very existence as a species. We must also reduce our consumption of the biosphere (especially those of us in the developed world) and thereby reduce the size of the human ecological footprint, including, of course, the agricultural eco-footprint.

A dilemma (noted previously) is that the human population continues to grow, especially in the developing world. So, can we even contemplate feeding the world's hungry without increasing further the size of the agricultural eco-footprint?

The "food shortage" problem is actually one of distribution and affordability.

FEEDING THE WORLD'S HUNGRY

Not being a specialist in agriculture, I did some research on the Internet to see what ideas had been put forward for solving the problem of feeding the world's hungry. According to the non-governmental organization, the FoodFirst Institute for Food and Development Policy, food production is actually not the problem *per se*; we already produce enough food to feed the world's 6 billion inhabitants (Mittal, 2000). In fact, 78% of countries reporting child malnutrition actually export food. The "food shortage" problem is actually one of distribution and affordability[1].

Mittal's claims were substantiated in a report from the Food and Agriculture Organization of the United Nations (FAO, 2002b): there is not only enough food for the present, but for the future as well. And, of particular relevance to an NABC

[1]On a visit to Ireland following NABC 16, I learned that such occurrences are nothing new. During the Irish potato famine of the mid-1800s—when millions starved to death or were forced to emigrate—Ireland exported food (O'Grada, 1993; Woodham-Smith, 1991).

symposium, there is enough food without GM crops. (Indeed, GM crops, livestock, and fish were omitted from the FAO analysis due to ambiguities over long-term promise, safety and consumer acceptance.) According to the FAO, poverty and poor food distribution will continue to limit access to food in some countries for the foreseeable future (also see Union of Concerned Scientists, 2000).

Contrary views are also to be found. According to Hassan Adamu—at the time, the Nigerian Minister of Agricultural and Rural Development—agricultural biotechnology holds great promise for areas of the world like Africa where poverty and poor growing conditions make farming difficult: "GM food could almost literally weed out poverty" in Africa and "without the help of biotechnology, many people will not live" (Adamu, 2000).

And, according to Monsanto (http:// www.monsantoafrica.com), agricultural biotechnology can increase crop yields, provide more nutritious foods, and reduce costs to farmers, in an environmentally sustainable manner. The corporation goes on to say that the biotechnology revolution must not bypass Africa (as did the Green Revolution of the 1960s and 1970s; Manning, 2004a). In light of my earlier comments, it was interesting to note that "Monsanto welcomes the opportunity to be a partner for progress, working toward the *sustainable development* of farmers in Africa and across the world" (emphasis added).

Biotechnology holds great promise for agriculture in developing countries. Poor farmers can benefit only from the products of biotechnology if they have access to them on profitable terms.

A more recent report from FAO (2004) seems to reveal a change in perspective from that offered in 2000. By 2004, FAO was of the view that biotechnology holds great promise for agriculture in developing countries. But its newly found enthusiasm for GM crops was tempered with several caveats. Poor farmers, FAO noted, can benefit only from the products of biotechnology if they "have access to them on profitable terms." (Again, we have an example of the distribution and affordability problems mentioned earlier.) These conditions, the report continues, are being met only in a handful of developing countries. The report also notes that the basic cash crops of the poor—cassava, potato, rice and wheat—actually receive little attention from practitioners of agricultural biotechnology in the developed world. This is, of course, entirely consistent with the assessment of sustainable development above.

The differing opinions outlined above notwithstanding, the fact is that we continue to look to increasing agricultural production as the means for reducing both hunger and poverty around the globe (*e.g.* ADM, 2004; Watson and Mcintyre, 2004), and for accommodating the expected increase in the size of the human population over the coming decades. As in the past (Donald, 2004; P. Roberts, 2004), increases in agricultural production can be achieved in two ways: we can increase the area of land planted (*e.g.* Meadows *et al.*, 2004) or we can—in theory at least—increase the yield achieved per unit area (*e.g.* Donald, 2004; Meadows *et al.*, 2004).

If we take the first approach, we must clear more forests, especially in the developing world, thereby exacerbating the depletion of wildlife (as in the on-going bushmeat crisis in Africa and Latin America; Robinson and Bennett, 2000). By 2050, Tilman *et al.* (2001) estimate that 10^9 ha of land may be cleared for cultivation in the developing world, particularly Latin America and sub-Saharan Africa. This is an area approximately equal to that of all of the remaining tropical forests (Mayaux *et al.* 1998). In addition to the concomitant loss of biodiversity—tropical forests are characterized by high species diversity (Donald, 2004)—forest clearance by burning already accounts for about 25% of the total CO_2 emissions, making it a major contributor to global climate change (Newmark, 1998).

The second approach, continuing to intensify production—to the extent that further increases are even possible (Meadows *et al.*, 2004)—will require ever-increasing inputs of energy. Remember the second law of thermodynamics (Rees 2004) and Barry Commoner's (1971) reminder, reiterated by Garrett Hardin (1977): "there is no such thing as a free lunch." For every calorie of food produced by intensive agriculture, we already invest ten or more calories of energy (Jones, 2003), much of it in the form of fossil fuels (Manning, 2004a, b). And we are rapidly running out of fossil fuels (P. Roberts, 2004).

Further, if GM plants and animals continue to be part of the equation, then any increases in the productivity of intensive agricultural systems will be accompanied by the introduction of truly alien species into the environment. Noting that "naturally occurring" introduced, non-native species already represent one of the major threats to endemic species (*e.g.* Groombridge, 1992; Simberloff, 2000), one can only begin to speculate on the potential impacts of GM organisms on natural biodiversity in the years to come.

Regardless of any anticipated benefits from biotechnology, such as the reduced use of fertilizers and environmentally contaminating chemicals, increasing production in an agriculture based on annual crops (whether assisted by biotechnology or not) seems destined to increase, rather than decrease, the size of the agricultural eco-footprint (Jackson, 2004). That may even be the not-so-hidden objective, if we may take literally the promotional materials of one prominent agricultural biotechnology company (ADM, 2004). In the center of one page, there is a globe, oriented—tellingly—to feature the United States. Superimposed over the planet in white lettering are the words, "What if we looked at the world as one giant farm field?" Now that really is increasing the size of the agricultural eco-footprint. At the bottom of the advertisement are the alarming (to an ecologist, at least) words: "The Nature of What's to Come."

REDUCING THE SIZE OF THE AGRICULTURAL ECO-FOOTPRINT

The promotional material referred to in the preceding paragraph also tells us, "Nature has answers" and asks the question, "Is anyone listening?" It is Wes Jackson's (2004) view, in fact, that nature does have some answers. But the answers he is referring to are quite different from those implied in the ADM materials. I suspect, however, that he too would ask whether anyone is really listening.

Wes Jackson argues that we can make agriculture sustainable only by applying ecological principles. We must reverse the accident of history and develop an agriculture based on perennials and dependent solely on contemporary sunlight (as opposed to fossil fuels). It might even use agricultural biotechnology to hasten its realization. Such an agriculture would reduce soil degradation and loss through erosion, and would be ecologically sustainable.

Jackson (2004) argues that we can make agriculture sustainable only by applying ecological principles. We must, he says, reverse the accident of history and develop an agriculture based on perennials and dependent solely on contemporary sunlight (as opposed to fossil fuels). It might even use agricultural biotechnology to hasten its realization. Such an agriculture would reduce soil degradation and loss through erosion, and would, in his view, be ecologically sustainable.

In theory, Jackson's proposal sounds convincing. In practice, it may be difficult to achieve. He estimates, for example, that it would take about 50 years to complete the transition from an agriculture based on annuals to one based on perennials. And, if we were successful, such a transition might buy *Homo sapiens* another 10,000 years ("maybe"), and result in a carrying capacity of about 2 billion people (one-third of the 2004 world population and two-ninths of the population anticipated within fifty years (Jackson, 2004; Lavigne, 2004a).

In my opinion, Jackson's vision will be difficult to sell. It will be opposed by traditional agriculture, including seed suppliers, and fertilizer and pesticide producers; organic farmers; the producers of annual GM crops; and their existing (and well established) lobbies. It will also be resisted by politicians with their short time horizons (4 to 5 years in western democracies) (Lavigne, 2004a).

A Way Forward

There is, however, a way forward. First and foremost, we need to identify the real problems. In the case of feeding the world's hungry, we must decide whether the real problem is a food shortage or a distribution/affordability issue. Once the real problem has been identified, we must then work toward developing solutions that actually deal with it. For example, we currently have a global over-fishing problem. One question today is whether we need to cull marine mammals (including whales) because they are draining the oceans of fish (Tamura and Ohsumi, 1999; Lavigne, 2003) or do we work to make fishing an ecologically sustainable activity?

We also have problems with overexploited wildlife populations and an increasing number of endangered species. Do we provide increased protection for endangered species with a view to halting their decline and promoting their recovery, or do we promote their commercial consumptive use and free trade in order to "save" them (Child and Child, 1990; Baskin, 1994; SASUSG, 1996; Lavigne, 2004b; Lavigne *et al.*, 1999)?

In the case of the human food crisis, do we work to solve the distribution problems, or do we recommend the development of GM foods, recognizing—among other things—that the delivery of GM technology is plagued by the same distribution and affordability issues as the delivery of food. Similarly, where we have problems of economic disparity and social inequity, do we consider implementing real debt-reduction schemes, or do we simply maintain the *status quo*?

We must recognize that humans are part of nature, not outside of it. Generally, we must increasingly incorporate ethics into science and technology.

If society wants to find solutions to real problems, the answers to the above questions should be self-evident. But more can be done if we really want to change the unsustainable practices of the last 10,000 years. One suggestion that has been made frequently over the past 50 years is the need for a new conservation ethic. This idea was central to Aldo Leopold's (1949) Land Ethic, in which he argued that we must adopt a more ecological and eco-centric approach to our dealings with the rest of nature. In other words, we must recognize that humans are part of nature, not outside of it. Generally, we must increasingly incorporate ethics into science and technology (*e.g.* Lynn, 2004). We must also recognize and accept that nature has intrinsic and other values and, to paraphrase Eugene Odum (1971), that money is not the common currency of ecosystems (Lavigne, 2004b). In addition, we must reduce (rather than promote) human population growth; get treatment for our addiction to consumerism (*e.g.* Gore, 1992); and adopt truly precautionary approaches to conservation (Lavigne, 2004b).

We should also abandon the idea of sustainable development, including the simple-minded, three-legged stool model that depicts sustainability as being perched on legs of environment, economy and social equity (for a discussion, see Dawe and Ryan, 2003). In such a model, economic considerations always take priority over environmental (and, indeed, social) concerns. Yet, the reality is that we cannot have a healthy economy or ever hope to enhance social equity unless we have—first and foremost—a sustainable environment (Dawe and Ryan, 2003).

Conservation in the twenty-first century must also recognize that different regions of the world have different values, objectives and needs (Menon and Lavigne, 2004). Conservation, therefore, must become "a more elastic concept, stretching to meet the distinct social contexts, cultural matrices, and political environments in which it must function" (Miller, 2001). The latter, of course, is the antithesis of globalization, the path down which the world community currently gallops.

And, in keeping with the theme of NABC 16, Finding Common International Goals, we must, as Gifford Pinchot—arguably the father of the modern conservation movement—said over 50 years ago, "see to it that the rights of people to govern themselves shall not be controlled by great monopolies through their power over natural resources" (Pinchot, 1945, cited in Miller, 2001).

Reasons for Pessimism

While there does seem to be a way forward, the fact remains that there are a number of reasons for doubting that much progress will be made in finding solutions to our global problems and, in particular, in reducing the size of the agricultural eco-footprint. These reasons relate to our evolutionary legacy: the nature of individual human animals, and—not unrelated—our group behavior in social situations.

Our Evolutionary Legacy as Darwinian Animals

The first reason for doubt lies in our evolutionary legacy. We are good Darwinian animals concerned primarily with selfish, self-interest. Altruistic behavior required to solve many of our global problems does not come easily to Darwinian animals (Lavigne 2002).

In addition, all life forms seem to practice deception in one form or another. In the case of human beings, however, we appear to have elevated the art to include self-deception. Indeed, we seem to have evolved what some academics call "Machiavellian intelligence" (Whiten and Byrne, 1997). One of the unfortunate consequences of Machiavellian intelligence, especially in the present context, is that we have "considerable capacity for self-delusion when the truth is unpalatable" (Gaskin, 1982).

Let me give one example where self-delusion plays a role in the current situation. As a species, we have difficulty coming to grips with our individual mortality. Rather than confront our limited life spans, most human societies have developed as myths to get around the issue. These myths take a variety of forms, but almost invariably involve a "life-after-death." How can a species in which individuals deny their own mortality even begin to contemplate the death (*i.e.*, extinction) of our entire species (Orr, 2002)? Personally, I don't think we can. But even if we could, it is unlikely that we will. The possibility of our extinction—well, actually, its inevitability—is simply too far down the road, *i.e.* beyond our own lifetimes and those of our children and grandchildren, to disturb us very deeply or keep our attention for very long.

The Behavior of Humans in Groups

According to Whiten and Byrne (1997), "The evolution of [human] intellect [including Machiavellian intelligence] was primarily driven by selection for manipulative, social expertise within groups, where the most challenging problem faced by individuals was dealing with their companions." It is not surprising, therefore, that further evidence of deception and self-deception becomes evident when one examines even superficially the behavior of humans in groups. I discuss two examples below: the behavior of governments and corporations, the two most powerful institutions in the modern world.

Let's begin with governments and examine the practice of politics. Politics is "bloodless conflict among individuals, groups, and nations…among alternative values, or…competing visions of what is 'good' " (Donovan *et al.*, 1981). Politics is also "the father of lies. In political arenas…the participants will distort the advantages of their positions and the disadvantages of their opponents." Fair enough, but "they will [also] shade the truth—first for their audiences; then in many cases, for themselves" (Donovan *et al.*, 1981). As noted previously (Lavigne 2002), shading the truth for their audiences is deception; Byrne and Whiten (1997) would call it "tactical deception." Shading the truth "for themselves" requires self-deception.

Of course, this sort of behavior is to be expected. Machiavelli (1469–1527) long ago described the need for such deceptive behavior among political leaders in his classic work The Prince (see Bull, 1961). But what perhaps is less well understood are the consequences that often emerge from such group behavior.

The late historian, Barbara Tuchman (1984), for example, described a "phenomenon… noticeable throughout history: the pursuit by governments of policies contrary to…the self-interest of the constituency or state involved." She termed this phenomenon "wooden-headedness," which, she wrote, "plays a large role in government…acting according to wish while not allowing oneself to be deflected by facts." I expect that the pursuit of continued economic growth, sustainable development, and an unsustainable agriculture in a finite world, will one day be recognized as examples of twenty-first century wooden-headedness.

Now let's turn to modern corporations. Like governments, corporations are made up of human beings and so provide another opportunity to examine human group behavior (Achbar *et al.*, 2003; Bakan, 2004). Corporations, like individuals, are characterized primarily by selfish self-interest. They are concerned, first and foremost with their shareholders and with profit-maximization. The bottom line is more important than the public interest. Generally, they exhibit no moral conscience (as a number of high profile recent events attest). Indeed, if corporations were people, their behavior would be seen to exhibit all the traits of a prototypical "psychopath" (Achbar *et al.*, 2003; Anon., 2004; Bakan, 2004). The analogy is not as stretched as it might seem at first glance. Through an accident of history, corporations—in the United States at least—have the same rights and legal standing as individual citizens (Bakan, 2004). In a remarkably constructive review of the Achbar *et al.* film, The Economist's parting shot was that the "infinitely more powerful…modern state has the capacity to behave…as a more dangerous psychopath than any corporation can ever hope to become" (Anon., 2004).

Maybe so, but either way, when you put a number of selfish, self-interested individual Darwinian human beings into a group (*e.g.*, have them form a government, or work together in a bureaucracy or a corporation) something that appears quite un-Darwinian typically emerges: decisions that ultimately act against (rather than promote) the collective self-interest of the group.

When Will Things Change?

It seems unlikely that we humans will overcome our self-delusional tendencies and come to grips with the reality that our ecological footprint (including our agricultural eco-footprint) exceeds the capacity of the planet to support us.

The world's dominant institutions—governments and multi- and trans-national corporations—continue their blind pursuit of increasing economic growth and increased profits. Today, it is difficult to imagine how individuals and nongovernmental organizations who recognize the folly in such policies can really do anything to change the course of history. But, as several authors have noted recently, they probably can, if only they have the will to do so. While governments and corporations may represent the two most powerful institutions in the world today, there is a third potential power broker: people.

Indeed, modern society can be viewed as having three realms: the economic, the political and the cultural (Perlas, 2000). On the world stage, the economic realm is the purview of international corporations and three major international organizations concerned with development: the International Monetary Fund, the World Bank—both established by the West following World War II—and the World Trade Organization, which emerged out of the General Agreement on Tariffs and Trade (GATT) in the mid-1990s (Parrish 1999). Governments, of course, dominate in the political realm. That leaves the cultural realm and it is occupied—in Perlas's scheme—by civil society, which comprises individual human beings [for independent but apparently complementary views on this topic, also see Dowie's (1995) discussion of the "fourth wave" of the environmental movement—grassroots activists—and Chomsky's (2003) comments about public opinion, which he terms the "second superpower"].

While it is obvious that corporations and governments currently have the power and are in control of the world situation, individual human beings also have power, should they choose (or be allowed) to exercise it. In democratic societies, at least, they have power in the political realm because they cast the votes that elect the politicians. Governments (not to mention political parties and individual politicians) really have only one overriding goal and that is to be elected (or re-elected). Consequently, they are reactive—as opposed to being proactive—which explains why they spend so much of the people's money monitoring public opinion. Al Gore put it as succinctly as anyone, before he became the Vice President of the United States. "When enough people insist upon change to embolden the politicians to break away from the short-term perspective," Gore predicted that "the political system will fall over itself to respond to this just demand that we save the environment for future generations" (cited in Lavigne, 1992).

Corporations are just as vulnerable as governments to public pressure, but in the economic realm consumer behavior in the marketplace counts rather than votes. If no one buys their products, they lose their market-share, their profits drop and their shareholders get anxious. Eventually, they respond in predictable and understandable ways and bow to public pressure.

A recent and relevant example of how this works may be seen in Monsanto's decision to delay further development of Roundup Ready® wheat (Monsanto, 2004). News stories, columns and op-ed pieces (*e.g.* McCallum, 2004; O. Roberts, 2004; Scoffield, 2004) tell us that it was a "calculated business decision" influenced by "public opinion." In this particular instance, public opinion was shaped—in large part—by the Canadian Wheat Board, grower and consumer resistance, and by international political pressure from places like Europe and Japan. At the end of the day, the decision was made because of poor market conditions now and in the foreseeable future.

There are increasing numbers of examples where the power of global civil society (or public opinion) has shaped events on local, regional and global scales.

There are increasing numbers of examples where the power of global civil society (or public opinion) has shaped events on local, regional and global scales. Examples include the civil rights and women's movements of the 1960s (Chomsky 2003), and the environmental movement during its heyday of the 1960s to 1980s (Dowie, 1995). A more recent example was the derailment of the Multilateral Agreement on Investment (MAI), perhaps one of the first examples where the power of the people was mounted using the Internet (*e.g.* Shah, 2000, 2003).

Noam Chomsky recently wrote, "One can discern two trajectories in current history: one aiming toward hegemony [*i.e.* power], acting rationally within a lunatic doctrinal framework as it threatens survival; the other dedicated to the belief that 'another world is possible'" (Chomsky, 2003). My parting question is whether society will remain uninvolved, complacent and silent [remember Richard Nixon's (1969)"silent majority"?], and accept the "lunatic doctrinal framework" that currently threatens human survival. Or will it say enough is enough, and demand change, in the belief that "another world" really is still "possible"?

Either way, it will provide another test of Suroweicki's (2004) hypothesis about the "Wisdom of Crowds." He argues that "large groups of people (and here, I'm thinking of Perlas's civil society) are smarter than an elite few (governments and corporations)—no matter how brilliant—better at solving problems, fostering innovation, coming to wise decisions, even predicting the future." My earlier observations about the emergent behavior of humans in groups notwithstanding, we can only hope he is right.

Acknowledgments

I thank Alan Wildeman, Vice-President (Research), University of Guelph, for inviting me to participate in NABC 16. This reiterates and extends some ideas I began to develop in two earlier papers (Lavigne 2002, 2004a). Those ideas have been influenced and refined through various discussions and interactions with a number of colleagues, particularly: Ron Brooks, Ward Chesworth and Sidney Holt. Bill Lynn pointed me in the direction of the ADM website while Eamonn Cregan, University of Limerick, filled in gaps in my education regarding the Irish Potato Famine and put me in contact with Pattie Punch in the UL library, who directed me toward the authoritative literature. Sheryl Fink helped find and compile the list of references and produced Figure 1 from my earlier draft. I also thank Sheryl, Ward Chesworth, Jan Hannah, and Sue Wallace for comments on earlier drafts of the manuscript. Any opinions expressed herein are mine and do not necessarily represent those of my current employer, the International Fund for Animal Welfare.

References

Achbar MJ *et al*. (2003) The Corporation. Big Picture Media Corporation MMIII. http://www.thecorporation.com.

Adamu H (2000) We'll feed our people as we see fit. Washington Post, 11 September, p. A23. http://www.foodfirst.org/media/opeds/2000/9-enough.html.

Anon. (2004) The lunatic you work for. The Economist, 6 May. http://www.economist.com.

Archer Daniels Midland Company (ADM) (2004) The nature of what's to come. http://www.admworld.com.

Bakan J (2004) The Corporation: The Pathological Pursuit of Profit and Power. Toronto: Viking Canada.

Baskin Y (1994) There's a new wildlife policy in Kenya: Use it or lose it. Science 265 733–744.

Beder S (1996) The Nature of Sustainable Development, Second Edition. Newham, Australia: Scribe Publications.

Bruno K (2002) Sustainable development: R.I.P. Corpwatch, 4 September. http://www.corpwatch.org/print_article.php?&id=3831.

Bull G (1961) Niccolò Machiavelli. The Prince. Translation, with an Introduction. Reprinted 1995. London, New York: Penguin Books.

Byrne RW Whiten A (1997) Machiavellian intelligence. In: Machiavellian Intelligence II. Extensions and Evaluations (Whiten A Byrne RW, Eds). Cambridge, U.K.: Cambridge University Press, 1–23.

Chesworth W (2002) Sustainability and the end of history. Geotimes, October. http://www.agiweb.org/geotimes/oct02/comment.html.

Chesworth W (2004) The evolution of soil. In: From the Ground Up. The Importance of Soil in Sustaining Civilization. Symposium, AAAS Annual Meeting. Seattle, WA, 12–16 February. (abstract)

Chesworth W *et al.* (2001) Malthus and sustainability: A codicil. In: Malthus and the Third Millenium. The Kenneth Hammond Lectures on Environment, Energy and Resources. 2000 Series (Chesworth W *et al.*). Faculty of Environmental Sciences, University of Guelph, Guelph, Canada, 163–167.

Child G Child B (1990) An historical perspective of sustainable wildlife utilization. Paper prepared for Workshop 7, 18th IUCN General Assembly, Perth, Australia.

Chomsky N (2003) Hegemony or Survival: America's Quest for Global Dominance. New York: Metropolitan Books, Henry Holt and Company.

Commoner B (1971) The closing circle: nature, man, and technology. In: Thinking About The Environment (Cahn MA O'Brien R Eds). Armonk, NY: M.E. Sharpe, Inc. 161–166.

Dawe NK Ryan KL (2003) The faulty three-legged-stool model of sustainable development. Conservation Biology 17 1458–1460.

Donald PF (2004) Biodiversity impacts of some agricultural commodity production systems. Conservation Biology 18 17–37.

Donovan JC *et al.* (1981) People, Power & Politics. An Introduction to Political Science. Reading: Addison-Wesley Publishing Company.

Dowie M. (1995) Losing Ground. American Environmentalism at the Close of the Twentieth Century. Cambridge, MA: The MIT Press.

Eldredge N (2001) The Sixth Extinction. American Institute of Biological Sciences. http://www.actionbioscience.org/new frontiers/eldredge2.html.

Eldredge N Gould SJ (1972) Punctuated equilibria: An alternative to phyletic gradualism. In: Models In Paleobiology (Schopf TJM Ed). San Francisco: Freeman, Cooper & Co., 82–115.

Elliot J (2001) The West knows now there is no wall to hide behind. The Guardian. 13 November 2001. http://www.guardian.co.uk/business/story / 0,,592418,00. html.

Environmental Assessment Institute (EAI) (2002) Assessing the ecological footprint. A look at the WWF's Living Planet Report 2002. Institut for Maljøvurdering, Kobenhavn, Dk. http://www.imv.dk.

Food and Agriculture Organization of the United Nations (FAO) (2002a) The State of World Fisheries and Agriculture. Rome: FAO. http://www.fao.org /sof/sofia/index_en.htm .

Food and Agriculture Organization of the United Nations (FAO) (2002b) The State of Food and Agriculture 2000. Rome: FAO. http://www.fao.org/docrep/x4400e/x4400e00.htm.

Food and Agriculture Organization of the United Nations (FAO) (2004) The State of Food and Agriculture 2003–2004. Agricultural Biotechnology. Meeting the Needs of the Poor. Rome: FAO. http://www.fao.org/ docrep/006/y5160E/Y5160E00.htm.

Gaskin DE (1982) The Ecology of Whales and Dolphins. London: Heinemann Educational Books Ltd.

Gore A (1992) Earth in the Balance: Ecology and the Human Spirit. Boston: Houghton Mifflin Company.

Groombridge B (Ed) (1992) Global Biodiversity. Status of the Earth's Living Resources. London: Chapman Hall.

Hardin G (1977) Rewards of Pejoristic Thinking. Stalking the Wild Taboo. http://www.lrainc.com/swtaboo/stalkers/gh_vpoj.html.

Intergovernmental Panel on Climate Change (IPCC) (2001) Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (Houghton JT *et al.* Eds). Cambridge UK and New York: Cambridge University Press.

International Union for Conservation of Nature and Natural Resources (IUCN) (1980) World Conservation Strategy: Living Resource Conservation for Sustainable Development. Gland, Switzerland: International Union for Conservation of Nature and Natural Resources.

International Union for Conservation of Nature and Natural Resources (IUCN) (1991) Caring for the Earth. A Strategy for Sustainable Living. Gland Switzerland: IUCN—The World Conservation Union, United Nations Environment Programme, and World Wildlife Fund.

Jackson W (2004) Agriculture: The primary environmental challenge of the 21st century. In: The Human Ecological Footprint. The Kenneth Hammond Lectures on Environment, Energy and Resources 2002 Series. (Chesworth W *et al.* Eds). Guelph: Faculty of Environmental Sciences, 85–99.

Jones A (2003) Eating Oil. Resurgence 216. http://www.resurgence.gn.apc.org/issues/jones216.htm.

Kirschenmann F (2003) Technologies for a sustainable future: Therapeutic intervention versus restructuring the system. In: Biotechnology: Science and Society at a Crossroad. Ithaca: National Agricultural Biotechnology Council, 73–85.

Lavigne, D.M. (1992) Republicans vs owls. BBC Wildlife, November 1992. Bristol: Origin Publishing, 74.

Lavigne DM (2002) Ecological footprints, doublespeak, and the evolution of the Machiavellian mind. In: Sustainable Development: Mandate or Mantra. The Kenneth Hammond Lectures on Environment, Energy and Resources 2001 Series (Chesworth W *et al*. Eds.). Guelph: Faculty of Environmental Sciences, 61–91.

Lavigne DM (2003) Marine mammals and fisheries: The role of science in the culling debate. In: Marine Mammals: Fisheries, Tourism and Management Issues (Gales N *et al*. Eds). Collingwood, VIC, Australia: CSIRO Pusblishing, 31–47.

Lavigne D (2004a) The human ecological footprint: a commentary. In: The Human Ecological Footprint. The Kenneth Hammond Lectures on Environment, Energy and Resources 2002 Series (Chesworth W *et al*. Eds). Guelph: Faculty of Environmental Sciences, 169–190.

Lavigne D (2004b) The Return of Big Brother. BBC Wildlife, May 2004. Bristol: BBC Worldwide Publishing, 66–68.

Lavigne DM *et al*. (1999) The evolution of North American attitudes toward marine mammals. In: Conservation and Management of Marine Mammals (Twiss JR Reeves RR Eds). Washington: Smithsonian Institution Press, 10–47.

Leakey R Lewin R (1996) The Sixth Extinction: Patterns of Life and the Future of Humankind. New York: Anchor Books.

Leopold A (1949) A Sand County Almanac, and Sketches Here and There. New York: Oxford University Press, Inc.

Lomborg B (2001) The Skeptical Environmentalist. Cambridge, U.K.: Cambridge University Press.

Lynn W (2004) From sound science to sound ethics: What science and the scientific method can and cannot contribute to conservation and sustainability. Paper presented at the IFAW Forum 2004, Wildlife Conservation: In: Pursuit of Ecological Sustainability. 16–19 June, Limerick. http://www.ifaw.org/ifaw/general/default.aspx?oid=87328 (abstract).

Manning R (2004a) The oil we eat: Following the food chain back to Iraq. Harper's Magazine 308 37–45.

Manning R (2004b) Against the Grain: How Agriculture has Hijacked Civilization. New York: North Point Press.

Mayaux P *et al*. (1998) Global tropical forest area measurements derived from coarse resolution satellite imagery: a comparison with other approaches. Environmental Conservation 25 37–52.

McCallum C (2004) Separating wheat from GM chaff. Guelph Mercury, 18 May, A9.

Menon V Lavigne DM (2004) Attitudes, values, and objectives. The real basis of conservation. Paper presented at the IFAW Forum 2004, Wildlife Conservation: In Pursuit of Ecological Sustainability. 16-19 June. Limerick http://www.ifaw.org/ifaw/general/default.aspx?oid=87327 (abstract).

Meadows D *et al*. (2004) Limits to Growth. The 30-Year Update. White River Junction, VT: Chelsea Green Publishing Company.

Miller C (2001) Gifford Pinchot and the Making of Modern Environmentalism. Washington: Island Press.
Mittal A (2000) Enough food for the whole world. Washington Post, Friday, 15 September, A26. http://www.foodfirst.org/media/opeds/2000/9-enough.html.
Monsanto (2004) Monsanto to realign research portfolio, development of roundup ready wheat deferred. Decision follows portfolio review, consultation with growers. News Release, 10 May. http://www.monsanto.com/monsanto/layout/ media/04/05-10-04.asp.
Newmark TE (1998) Carbon sequestration and cocoa production: financing sustainable development by trading carbon emission credits. Proceedings of the Smithsonian Migratory Bird Center Cacao Conference. http://www.nationalzoo.si.edu/ConservationAndScience/MigratoryBirds /Research/Cacao/newmark.cfm .
Nixon RM (1969) Speech. 3 November. www.cnn.com/SPECIALS/ cold.war/episodes/11/documents/nixon.speech.
O'Grada C (1993) Ireland Before and After the Famine: Explorations in Economic History. New York: Manchester University Press.
Odum E (1971) Fundamentals of Ecology, Third Edition. Philadelphia: W.B. Saunders Company.
Orr D (2002) Four challenges of sustainability. Conservation Biology 16 1457–1460.
Parrish D (1999) Who rules the world?—the International Monetary Fund, the World Bank and the World Trade Organization. New Statesman, 2 April. http://www.findarticles.com/p/articles/mi_m0FQP/is_4430_129/ai_54682688.
Pauly D *et al*. (2002) Toward sustainability in world fisheries. Nature 418 689–695.
Pearce F (2004) Asian farmers sucking the continent dry. New Scientist, 28 August. http://www.newscientist.com/news/print.jsp?id=ns99996321.
Perlas N (2000) Shaping Globalization: Civil Society, Cultural Power and Threefolding. Quezon City, Philippines: Center for Alternative Development Initiatives. http://www.cadi.com.
Pimentel D (2004) Food production and modern agriculture. In: From the Ground Up. The Importance of Soil in Sustaining Civilization. Symposium. AAAS Annual Meeting. Seattle, WA. 12–16 February (abstract).
Pimm SL (2001) The World According to Pimm. A Scientist Audits the Earth. New York: McGraw-Hill.
Rees WE (2002) Footprint: Our impact on Earth is getting heavier. Nature 420 267–268.
Rees WE (2004) Growing humanity, dissipating the ecosphere: Using SOHO theory and eco-footprint analysis to ynterpret humanity's dependence on soil. In: From the Ground Up. The Importance of Soil in Sustaining Civilization. Symposium. AAAS Annual Meeting. Seattle, WA. 12–16 February (abstract).

Roberts O (2004) Genetically modified wheat did not die with Monsanto move. Guelph Mercury, 17 May.
Roberts P (2004) The End of Soil. On the Edge of a Perilous New World. Boston: Houghton Mifflin Company.
Robinson J (2002) Squaring the circle? On the very idea of sustainable development. In: Sustainable Development: Mandate or Mantra. The Kenneth Hammond Lectures on Environment, Energy and Resources, 2001 Series (Chesworth W *et al*. Eds). Guelph: Faculty of Environmental Sciences, 1–34.
Robinson, J.G. (1993) The limits of caring: Sustainable living and the loss of biodiversity. Conservation Biology 7 20-28.
Robinson JG Bennett EL (2000) Carrying Capacity Limits to Sustainable Hunting in Tropical Forests. In: Hunting for Sustainability in Tropical Forests (Robinson JG Bennett EL, Eds). New York: Columbia University Press. 13–30.
Robinson JG Redford KH (2004) Jack of all trades, master of none: Inherent contradictions among ICD approaches. In: Getting Biodiversity Projects to Work: Towards More Effective Conservation and Development (McShane TO Wells MP). New York: Columbia University Press. 10–34.
Scoffield H (2004) Biotech giant backs off on wheat. Genetically modified product won't be sold. 11 May. http://www.globeandmail.com.
Shah A (2000) Free Trade and Globalization: Multilateral Agreement on Investment. http://www.globalissues.org/TradeRelated/MAI.asp.
Shah A (2003) Free Trade and Globalization: Public Protests Around the World. http://www.globalissues.org/TradeRelated/FreeTrade/Protests.asp.
Simberloff D (2000) Introduced species: The threat to biodiversity and what can be done. An actionBioscience.org original article. December.http://www.actionbioscience.org/biodiversity/simberloff.html.
Simon J (1992) Scientific establishment now agrees: Population growth is not bad for humanity. In: Rational Readings on Environmental Concerns (Lehr JH Ed). New York: Van Norstrand Reinhold, 557–578.
Southern Africa Sustainable Use Group (1996) Sustainable Use Issues and Principles. Gland, Switzerland: Southern Africa Sustainable Use Group, IUCN Species Survival Commission.
Suroweicki J (2004) The Wisdom of Crowds. New York: Doubleday.
Tamura T Ohsumi S (1999) Estimation of Total Food Consumption by Cetaceans in the World's Oceans. Tokyo: Institute of Cetacean Research.
Tilman D *et al*. (2001) Forecasting agriculturally driven global environmental change. Science 292 281–284.
Tuchman BW (1984) March of Folly from Troy to Vietnam. New York: Alfred A. Knopf.
Union of Concerned Scientists (2000) Backgrounder. FAO Report: Enough Food in the Future—Without Genetically Engineered Crops. http://www.ucsua.org/food_and_environment/biotechnology/page.cfm? pageID=331.

United Nations (1999) The World at Six Billion. Population Division Department of Economic and Social Affairs United Nations Secretariat. ESA/P/WP.154. 12 October 1999. http://www.un.org/esa/population/publications/sixbillion/sixbilcover.pdf.

United Nations (2003) World Population Totals for 1980—2050, According to the United Nations Revisions of World Population Estimates and Projections. New York: United Nations Department of Economic and Social Affairs, Population Division. http://www.un.org/esa/population/publications/longrange2.htm.

Wackernagel M Rees W (1996) Our Ecological Footprint. Reducing Human Impact on the Earth. Gabriola Island, BC: New Society Publishers.

Wackernagel M *et al.* (1999) National natural capital accounting with the ecological footprint concept. Ecological Economics 29 375–390.

Wackernagel M *et al.* (2002a) Tracking the ecological overshoot of the human economy. Proceedings of the National Academy of Sciences, USA 99 9266–9271. http://www.pnas.org/cgi/doi/10.1073/pnas.142033699.

Wackernagel M *et al.* (2002b) Ecological fooprints of nations. November 2002 Update. How much nature do they use? How much nature do they have? Redefining Progress for People, Nature, and the Economy. Oakland, CA: Sustainability Issue Brief. http://www.RedefiningProgress.org.

Ward P (2004) The father of all mass extinctions. Conservation In Practice 5 12–19.

Watson R Mcintyre B (2004) Thought for food. New Scientist 7 August 17.

Whiten A Byrne RW Eds. (1997) Machiavellian Intelligence II. Extensions and Evaluations. Cambridge, UK: Cambridge University Press.

Willers B (1994) Sustainable development: A new world deception. Conservation Biology 8 1146–1148.

Woodham-Smith C (1991) The Great Hunger: Ireland 1845–1849. London: Penguin Books.

World Commission on Environment and Development (WCED) (1987) Our Common Future. Oxford: Oxford University Press.

World Wide Fund for Nature (WWF) (2002) Living Planet Report 2002. Gland, Switzerland: WWF International, Gland. http://www.panda.org.

David Lavigne has studied seals, sea lions and walruses (pinnipeds) for thirty years. A zoology professor at the University of Guelph from 1973 to 1996—and author of more than one hundred publications on marine mammal biology and conservation—he has been the science advisor to the International Fund for Animal Welfare (IFAW) since 1999. He is a long-standing member of the Seal Specialist Group of the International Union for Conservation of Nature and Natural Resources (IUCN).

Prior to joining the IFAW, Dr. Lavigne served as executive director of the International Marine Mammal Association, an international non-governmental organization concerned with the conservation of marine mammals worldwide.

Today, his major interests are conservation biology, natural resources policy, and the pursuit of ecological sustainability.

Module II—
Diminishing the Ecological Footprint

Q&A

MODERATOR: VERNON G. THOMAS
University of Guelph,
Guelph, ON

Uko Zylstra (Calvin College, Grand Rapids, MI): A couple of the speakers made mention of the fact that we need to reduce the human population—I do agree with that—but I want to raise a point that was not mentioned. In the 1970s, George Borstrom, then at Michigan State University, analyzed human population equivalents with regard to animals. And the animal to human population equivalence, as I recall, was about 14 to 15 billion. That's a pretty large number of human population equivalents. Why isn't that in your analysis and your attempt to deal with some of the problems with regard to ecological footprints? Animals have large ecological footprints. It's not in the equation that I saw this morning. Any explanation? And to what extent should we incorporate that? In other words, Borstrom dealt with domestic, not wild, animals, and that's a pretty large impact. How does that relate to our own dietary system, *etc.*, our whole food system?

William Rees: A couple of points: obviously animals do have a large footprint, but in our analysis, for example, much of it is attributable to the human footprint because domestic animals are simply a way-station for energy and material flows from the ecosystem into humans. That massive population of animals is a supportive network for the human system. There is no question that if we eliminate the animals we could sustain a larger population of humans. Something like half the grain grown in North America is fed to animals. If we moved toward a more vegetable- and fruit-based diet and eliminated the animal intermediaries you could sustain a larger human population. But it doesn't get at the fundamental problem, which is the constant pushing upward of human population numbers. And as wealth increases, the quantity of animals and animal protein in our diet increases apace. It goes right back to some of the things that Dave said. People want those higher dietary standards. China is becoming a huge meat-eating country. If you simply extrapolate—one of their specific objectives is to attain the same levels of meat consumption as the West—you'd have to have the entire planet covered in grazing lands just to sustain that demand of the Chinese. So there is inherent conflict here and I think you are right in pointing out that these animals in fact have a huge footprint; but it's really part of the human footprint.

Klaus Ammann: A study was done in the 1970s by an interdisciplinary group at the University of Stuttgart and Berkeley on how much space does humanity need, if it could be organized in an ideal way with agriculture, with vacation space, with everything involved. Their result was the size of the island of Taiwan. So I don't want to comment further on that but I would just like to say there is some hope still. With respect to our behavior and our organization we can do much better and the potential is gigantic.

David Lavigne: One reason why it wasn't in my talk was largely the time constraint, but I think you've probably seen a paper by Palmer, who calculated the agricultural footprint of the United States, and the largest component of that was beef. And I think he recommended that the United States could reduce its agricultural footprint by consuming far less beef than currently. And the other reason I left it out was I assumed most people here would be from the plant biotech field so I didn't want to take a shot at beef.

Rees: If I may just add something: you could contain the whole of humanity on a place like Taiwan but if you put it in the context of the second law of thermodynamics about half of the rest of the planet would be directed towards sustaining the consumptive activities going on in that little space. You can read all kinds of crazy notions about the whole of the human population, if condensed, would occupy less than a cubic kilometer. It's irrelevant when you'd need the productive capacity of half of the rest of the planet to sustain the consumptive activities of that relatively small mass of humans.

Ammann: You don't even know the study and you ridicule it. They did the study by using all the parameters including food production and were baffled themselves that it was this size, not more. Not a few cubic meters—about the size of the island of Taiwan. Let's think about this. It should not be dismissed out of hand.

Module III—Improving Quality of Life

Module III—Improving Quality of Life

Introductory Remarks

Nancy Cox
University of Kentucky,
Lexington, KY

The title of this session, *Improving Quality of Life*, implies optimism. A similar optimism was expressed in the title of Module II, *Diminishing the Ecological Footprint*. The speakers in that module presented some challenging and mixed assessments of optimism that are certain to make us think long and hard about the implications of biotechnology and the eco-footprint. Quality of life is certainly related to the other topics—ecological footprint and food safety—but, as we've seen so far in this conference, food is a major component of the quality of life for many people in the world and is a less significant component for others. Also, problems related to food distribution have been discussed, as have the challenges associated with incorporation of appropriate cultural practices to enable people in developing nations to utilize and produce food.

This session's distinguished group of speakers will address the relationships people have with food, the way it's produced and distributed and the larger implications for both industrialized and developing nations: Tom Remington, Ruth Chadwick, and Joel Cohen.

How Might NGOs Handle Genetically Modified Seeds for Small Farmers in Africa?

Tom Remington
Catholic Relief Services
Nairobi, Kenya

Paula Bramel
International Institute of Tropical Agriculture
Nairobi, Kenya

Catholic Relief Services (CRS) works through partners throughout the developing world to help farm families recover from disaster and increase incomes and resilience, and collaborates with international and national research institutions to facilitate farmer access to seeds of new and promising varieties. It supports farmer evaluation of new materials, the multiplication of farmer-selected varieties and their subsequent promotion and dissemination. CRS expects that genetically modified (GM) varieties will soon be available, and is articulating guidance for Country Program and Partners on how to handle these materials in our technology-transfer work with farm communities.

Agriculture in Developing Countries

A report by the United Nations Food and Agriculture Organization recently discussed the potential benefits of biotechnology for resource-poor farm families in developing countries (FAO, 2004). It surveyed the current state of agricultural biotechnology, its potential use by smallholder farmers in the developing world, possible risks, and the status of biosafety regulation. The report stated that agriculture is faced with many difficult challenges as the world population expands and agricultural production falls behind consumption for the fourth year in a row. There will be an additional two billion customers for agricultural products within 30 years. At present, 384 million people are chronically food insecure, most resid-

Although the global need for food aid has declined in the past 15 years, the need continues in Africa, where thirty-eight of the forty-three countries were found to be in need of assistance in 2003. Seven of the eight countries in the CRS East Africa region were declared food emergencies in 2004.

ing in rural areas of the least developed countries. Many more suffer from nutritional deficiencies due to poor food quality and lack of diet diversity. Although the global need for food aid has declined in the past 15 years, the need continues in Africa, where thirty-eight of the forty-three countries were found to be in need of assistance in 2003. Seven of the eight countries in the CRS East Africa region were declared food emergencies in 2004.

Comparing and Contrasting the Green and the "Gene" Revolutions

The contribution of technological innovation to sustained growth in food production and to reduced poverty and hunger in developing countries was also recently reviewed (FAO, 2004). The Green Revolution was compared and contrasted with the "gene" revolution since both are encapsulated in the seeds of new improved varieties. The successful dissemination and exploitation of the Green Revolution varieties was dependent on the availability of international public goods and sufficient national agricultural research capacity to adapt new varieties to local conditions. The majority of this research was done by public institutions and was freely transferred. The Green Revolution initiated a major international plant-breeding effort and the development of germplasm-exchange mechanisms which are still important for the crops grown by smallholder farmers in Africa. It established a model for public international cooperation in plant breeding, germplasm evaluation and variety testing still present in conventional crop improvement today. While the approach to agricultural development initiated with the Green Revolution has made substantial improvements in productivity in Asia, its impact on resource-poor farmers in Africa remains disappointing.

The "gene revolution," with its reliance on products of biotechnology such as GM plants, has a different approach. The majority of the research products are being developed by the private sector for commercial purposes. The focus has been on traits that are of value to farmers in developed country, such as herbicide tolerance and insect resistance. Because this research has not been done in the public sector, there is no easy spillover of the technology to crops and traits of

This restricted access, and the increased cost of regulation, will impact the ability of NGOs to promote GM crops as part of the development package for smallholder farmers in Africa.

greater value to developing-country farmers. The private cost of biotechnology research, development, and the approval processes is much greater than with the conventional approach. Consequently, the products of biotechnology are held under restricted access with patents and exclusive licenses. This restricted access, and the increased cost of regulation, will impact the ability of NGOs to promote GM crops as part of the development package for smallholder farmers in Africa.

High Cost of Biosafety Regulation

The development of biosafety regulations and the approval and release of specific GM products has taken more than a decade in the United States and Canada (CBI, 2004). These regulatory processes are elaborate, complex and expensive, involving a number of regulatory agencies and procedures at various stages of the approval process. The cost of regulation can be in the range of $50–300 million and require 6 to 12 years. It is a high-risk venture with only a 0.4% probability of any gene or trait making it to the market. In developed countries, the development and commercialization of a GM variety is recovered in the price and volume of its seed sales. In developing countries, who will pay the cost of this technology? Smallholder farmers are not likely to bear the high cost of seed or purchase the required volumes. The exception in Africa is cotton, a vertically integrated cash crop.

The majority of developing countries do not have a regulatory system for GM plants. Tawanda Zidenga (2003), reporting on the status of biosafety regulation in Africa, identified four issues where African countries differ from developed countries:

- the prevalence of farmer seed saving,
- the importance of informal seed exchange to variety dispersal,
- the introduction of GM products as food aid, and
- weak scientific and technical capacity.

Despite these constraints, there has been progress in biosafety. Two countries, South Africa and Zimbabwe, have GM legislation and a functioning biosafety framework. Seven other countries are formulating legislation, while forty-three countries are in the UN Environment Programme-Global Environment Facility (UNEP-GEF) biosafety development process. In South Africa, GM plants are being grown under a general release permit.

Two countries, South Africa and Zimbabwe, have GM legislation and a functioning biosafety framework. Seven other countries are formulating legislation, while forty-three countries are in the UN Environment Programme-Global Environment Facility (UNEP-GEF) biosafety development process. In South Africa, GM plants are being grown under a general release permit.

It is clear that delivery of GM products to smallholder farmers in Africa will be expensive. For example, it is estimated that the regulatory costs alone will be $10 million for each new transgenic product.

Current Support for Agriculture in Africa

The trend in donor assistance for agriculture continues downward. This decline has been most severe in Africa where assistance per agricultural worker is now only 25% of the peak 1982 level. Compounding this reduction in support is evidence that the assistance is not reaching the countries most in need. External assistance is significantly higher in countries where undernourishment is the lowest (over $25/worker in countries with <5% undernourishment, but less than $10/worker in countries with >35% undernourishment).

Clearly, in the competition for declining funding, the poor are neglected. FAO (2004), recognizing the role that NGOs play in advocating for the poor, suggested that they should advocate for increased funding for agriculture research, both conventional and biotechnological. They went further, recommending that specific advocacy groups be developed to lobby for public biotechnology research funding for the poor, and that this should include purchasing the right to use private-sector technology on behalf of the poor. This should raise the alarm that increased funding for biotechnology will come at the expense of conventional research technology transfer and that the benefits will be captured by more advanced developing countries and by larger and richer farmers.

Current Support for GM Crops in Africa

Currently, a number of institutions in Africa are focused on developing and promoting biotechnology for farmers (CBI, 2003). A search of the Internet presents a plethora of Web-sites dedicated to biotechnology for Africa. Foundations, international organizations (including NGOs), and national governments are promoting the potential benefits of biotechnology in addressing the critical need to increase food production in Africa. Several research networks have been established to

Several research networks have been established to promote biotechnology research in crops such as cassava, sweet potato, and cowpea that can benefit the poorest farmers in Africa.

promote biotechnology research in crops such as cassava, sweet potato, and cowpea that can benefit the poorest farmers in Africa. Donor initiatives are promoting research and development of biotechnology products with public/private-sector partnerships, and donor and international organization initiatives will strengthen biosafety-regulation and technical expertise in developing countries to enhance the application of biotechnology products. The United States and Germany are funding projects to enhance biosafety research, policy, and the scientific/technical capacity for African countries in biosafety and to help countries develop laws and regulatory structures to ensure that GM crops pose no threat to human or environmental health. Currently, one regional body in southern Africa and eight countries are involved in regulation of GM food (especially food aid) and seeds (Organic Consumers Association, 2003).

Perceived Benefits of Biotechnology for Resource-Poor Farmers

The FAO (2004) survey concluded that biotechnology has potential benefits, but only if the technologies are appropriate for poor farmers in poor countries and there is access on sustained and profitable terms. This means that research and development of biotechnology products needs to be part of a well funded comprehensive program, with public and private sector investment. Regulation should be strong and rationalized with transparent, predictable, and science-based evidence. While the FAO report provided a comprehensive review of the role of research and development in the application of biotechnology, technology transfer and dissemination aspects were assumed to be of secondary importance. However, the report (page 87) apparently contradicted this in stating that "the paradigm for research and technology delivery that made the Green Revolution possible has broken down." Technology transfer is critical, complex and expensive. To the extent that it continues to function, NGOs have assumed a lead role. Effective biotechnology transfer will require increased commitment, capacity and donor support for NGOs. These should not be assumed.

While African countries are open to the potential benefits of biotechnologies for their farmers, there is consensus that improving food security and agriculture will require more than technology. Rosset (2000) concluded that it is not a lack of technology that limits productivity and keeps farmers in poverty. Rather, the persistent injustices and inequalities in access to resources, such as land, credit, markets, and anti-poor policy biases are responsible. Therefore, farmers do need greater resources targeted to research, development, and dissemination of pro-poor technologies in order to overcome diseconomies of scale, such as agroecology and farmer organization. In addition, an agro-enterprise approach is needed that enables farmers to access and benefit from market opportunities.

Role of NGOs in Technology Transfer

NGOs, such as CRS, have a long history of transferring new technologies to poor farmers. Agricultural recovery from disaster programs have typically included the delivery of "seed and tools" packages. When available, this has been of commercial seed of new varieties. These same packages have been promoted in development contexts, often combined with training programs on new farming methods such as row planting, animal traction, and other "improved farming system options." The main objective of these programs has been increased productivity and production. They have been supported by technical assistance from international and national research programs. A range of approaches has been used, including farmer-evaluation plots, demonstration plots, and more recently, mother-baby trials and farmer field schools.

The strength of these partnerships with NGOs has been their established presence in the community and their logistical capacity to deliver the seeds and conduct the trials.

These activities are important opportunities to transfer new technologies to smallholder farmers to contribute to reducing poverty. Similar programs will enhance the adoption of GM products. The strength of these partnerships with NGOs has been their established presence in the community and their logistical capacity to deliver the seeds and conduct the trials. However, NGOs have significant weaknesses including:

- lack of capacity to conduct scientifically sound testing programs,
- rapid staff turnover,
- short-term nature of programming and funding, and
- diverse social and cultural objectives contributing to low priority assigned to agricultural development.

Although NGO-based technical transfer is feasible, it requires effective research support for training, activity design, implementation, data collection, analysis, reporting and follow up. These requirements are needed even more for the testing and delivery of GM varieties with which there are biosafety concerns.

Assessing and Accepting GM-Crop-Associated Risk

CRS supports farmer evaluation of a wide range of crops including maize, pearl millet, sorghum, chickpea, pigeon pea, cassava, bean, sweet potato, rice, sesame and groundnut. All of the available varieties come from public institutions, either directly from the International Agricultural Research Centers (IARCs) or through national agricultural research system (NARS) programs and have been tested over a period of years in regional or international trials. These tests are done as part of larger research programs, and potential productivity and stability of specific traits are determined prior to decisions to proceed with farmer evaluations. This process has resulted in high probability of farmer acceptance. Risk is rarely explicitly assessed in the technology-transfer process. Rather, it is assumed that it will be considered by farmers themselves prior to adoption. Risks—nutritional, human health, environmental, agronomic, marketability, *etc*.—are inherent in all breeding programs. However, there is increased risk with GM crops because of:

- possible transmission of trangenes to other varieties or to wild relatives,
- possible health implications,
- social and ethical acceptability, and
- market acceptability due to these same concerns on the part of the consumer.

The questions for CRS and other NGOs will be who should assess and who should accept the risk: the developer of the technology, the international and national research programs, the NGOs, or the farmers?

The questions for CRS and other NGOs will be who should assess and who should accept the risk: the developer of the technology, the international and national research programs, the NGOs, or the farmers? These questions, not asked in traditional technology transfer, must be addressed in GM-crop programs.

The FAO (2004) report reviewed the status of risk to human and environmental health from GM crops and raised these key questions:

- Who bears the risk and who stands to benefit?
- Who evaluates the harm?
- Who decides what risks are acceptable?

Risk is a product of the hazard, its probability, and its consequence. There are a number of direct and indirect food-safety concerns with GM crops, the assessment of which is based on the precautionary principles of risk assessment, risk management, and risk communication. The principles of risk assessment state that the food derived from GM plants should be compared with its conventional counterpart. It states that the risk-management measures should be proportional to the risk. Risk communications are based on the ideal that they are effective and transparent. Participatory process should be used to communicate at all phases of the risk analysis. The risk analysis of GM crops for farmers in Africa needs to be carefully considered on a case-by-case basis depending upon the particular species, trait, and agro-ecosystem.

The assessment of risk can be based on various sources of data and on various assumed uses. In addition, assessment of traditional food-use risk will need to be addressed, including home-use preference as well as human-health concerns. The marketability of GM commodities will also need to be assessed within local markets for local food uses. The overall impact of the introduction of the GM crop to the complex agroecology of traditional farming systems will need to be assessed, especially as it relates to the intercropping systems used by farmers. These assessments will be needed prior to the introduction of a GM crop to farmers or there is a risk that the trials will be used as local seed sources, as was the case for *Bt* cotton in Gujarat, India. As with evaluation of conventional varieties, farmers will grow and save seed prior to official release. This would be a significant risk for NGOs when testing GM varieties that are still in the development stage. Formal approval and release will be needed, therefore, before initiation of testing and promotional programs in conjunction with farmers.

The increased risk and cost involved in the development and release of GM varieties, and the need for a mechanism and institutions to insure that farmers have long-term sustained access to these products, will impede their distribution to poorer farmers. In order to ensure that these increased costs and regulations are worthwhile, economic studies will be needed to measure the value of these varieties to farmers versus the cost, including the cost of risk. The process of release and promotion needs to address environmental concerns, health concerns, cultural concerns, economic concerns, and long-term sustainability concerns. The cultural concerns include questions of who will access the technology, how will they access it, how will seed be exchanged and how will seed be regulated. Economic concerns include the cost:benefit aspects of the technology in comparison with alternative options, impact of the adoption of the technology on trade or market potential and the impact of the adoption on credit burden. The long-term sustainability issues include predictable access to seed and to markets and impact on crop and variety diversity.

Risk has been addressed through international conventions and agreements. The Convention on Biological Diversity deals with the management of risk to biodiversity from the introduction of GM crops. It protects and promotes the conservation of the local biodiversity, and led to the Biosafety Protocol. The crops currently grown by poor farmers in Africa are covered by this Convention, which obligates signatory countries to develop legislation to protect and conserve biodiversity. These same countries have agreed to follow general rules laid out in the Biosafety Protocol for development of regulations within their countries for the introduction, testing and release of the products of biotechnology. To date, these regulations have been established in very few of the least-developed countries of the world.

The Biosafety Protocol, ratified in September 2003, is an agreement on rules that govern international trade in GM organisms. It allows developing countries to control the importation of GM crops and their products. A number of issues impact the promotion and dissemination of GM crops by NGOs (Christian Aid, 2004). One of the main issues is that social and economic concerns should be explicitly included in risk analysis, in particular the impact on the livelihoods and food security of smallholder farmers. A second issue is that only GM seed is covered by the Protocol and not their products, for advanced informed consent. This is a concern because GM products could be used for seed as well as for food and/or feed. There is a third issue of liability for damages and labeling. These regulations are necessary to ensure that any risk to environmental and human health is avoided or minimized. Strategies to manage risk can be developed, but these need to be adhered to and considered prior to product release. All of this requires research and testing. Adherence requires enforcement of government regulations. The absence of enforcement of regulations increases risk and compromises farmer recourse. It is possible that farmers would find themselves assuming all the risk and NGOs would find themselves assuming responsibility for enforcing regulations post-release; the developer of the research products, research institutions and government would bear little of the risk.

The Cost of Technology Transfer

The products of conventional breeding programs are the result of a process that begins with early-generation testing, usually on-station. In the final years of testing, the varieties' overall productivity, adaptation and stability are evaluated at multiple locations, including farmers' fields, often with NGO assistance. The final stage of testing occurs when the value of the variety has been determined, but its acceptability to farmers and the market is not yet certain. The cost of most of this process is borne by the IARCs and national programs. This testing, which can be expensive, results in the identification of recommendation domains.

The testing of a GM variety has additional steps due to concerns over risk to environmental and human health.

The testing of a GM variety has additional steps due to concerns over risk to environmental and human health. This includes stricter field-testing protocols, more extensive testing for human-health issues, and assessment of risk of transfer of the trangene(s) to other varieties, wild relatives, or other organisms in the environment. This results in greater cost and time to make the GM products available for testing by farmers. The cost of this testing will have to be borne by the developer since it requires greater control and stricter guidelines, regardless if the developer is a private company, IARC, or a national program. The broader testing and promotion that occurs with the partnership of the NGOs cannot be undertaken until environmental and human health risks have been assessed and determined to be minimal and manageable. Post-release strategies to manage risk will need to be considered in partnership with the NGOs to ensure that they can be adhered to by resource-poor farmers. This may include consumer-acceptability and market analyses. Clearly, one of the major constraints to the release of GM crops to farmers by NGOs is the increased costs involved. Thus, benefits from these new varieties will need to significantly outweigh their increased cost and risk.

Commercial seed companies are compelled to apply measures to prevent or discourage seed-saving by farmers.

Seed Issues

The private-sector profit on investment in conventional and GM varietal development comes from recurrent seed sales. This is not a significant issue with hybrids, with which farmer seed saving comes at a cost of reduced performance. However, this is not the case for other crops in Africa, most of which are either self-pollinated or vegetatively propagated. For these crops, commercial seed companies are compelled to apply measures to prevent or discourage seed-saving by farmers. These include use of a terminator gene, a patent and legal injunction, and misinformation (*e.g.* an unsubstantiated claim of loss of performance with seed saving). Based on the Catholic Social Teaming principle of the universal destination of good, CRS opposes these three measures (Warner, 2001). Terminator genes are harmful to smallholder farmers in Africa. Punitive legal injunctions are difficult and costly to apply. Misinforming growers results not so much in farmer decisions to purchase seed annually as in loss of credibility for NGOs and other information brokers. In addition, CRS opposes the appropriation of the responsibility for seed production by commercial seed companies, when farmer seed production is both effective and efficient. This is counter to the Catholic Social Teaching principle of subsidiarity.

Farmers continually experiment with new varieties, obtained from relatives, neighbors, the local market or from development projects. They adopt a new variety when they have determined it is of value to the household. Adoption does not always imply abandonment; they may grow new varieties and continue to plant their own landrace varieties, because of different uses in the home or in the cropping system. Once obtained, farmers in traditional cropping systems in Africa depend on home-saved seed for future needs.

In many cases, lack of access to seed of new varieties is a constraint to technology adoption in the remote, rural areas of Africa. It is a concern of many agricultural recovery programs implemented by NGOs. Continuous movement of seed into and out of the home is referred to as seed flow. Production of own seed can result in the transfer of genes from other varieties of the crops grown by the household with cross-pollenation. The pollen from the farmers' variety can also cross with wild relatives in the field or adjacent areas. This is referred to as gene flow. This practice can result in the incorporation of new genes from other varieties, including new improved GM varieties. The consequences of traditional seed saving and seed exchange are an additional risk with GM varieties and will need to be considered in the release and promotion of GM seeds to smallholder farmers.

The responsibility for regulating the use of GM seed by farmers and the need to meet their need for affordable seed will have to be clarified before NGOs consider the promotion of these varieties.

Seed flow in the farmer-seed system is very informal and can be used to disseminate new varieties where formal seed systems do not exist. This is the case for most of the crops (maize is an exception) grown by poor farmers in Africa. Although discouraged for the new publicly available varieties, farmers have not found affordable reliable options for access to these varieties while being able to retain their traditional approaches. The release and promotion of new varieties with legal protection will add a new complication to this issue. Farmers might be restricted from saving seed and told to obtain new seed each year. This restriction on seed saving will be compounded by the higher cost of GM seed. The responsibility for regulating the use of GM seed by farmers and the need to meet their need for affordable seed will have to be clarified before NGOs consider the promotion of these varieties.

Issues for CRS

The promotion of the products of biotechnology is an opportunity to introduce and assist farmers to grow crops that will contribute to poverty alleviation through enhanced agricultural development in Africa. The GM plant is a technological innovation that carries new challenges in introduction, evaluation, adoption, and sustained use. The potential benefits of this new technology are great, but so also are the costs and risks. NGOs must confront the following opportunities, risks and challenges to ensure that smallholder farmers, benefit.

Farmer and NGO Participation in Decision-Making

Farmers and NGOs need to be involved in policy and donor-fund allocation discussions that affect them. The tendency to first make a decision to invest in biotechnology and to allocate funding and then bring in farmer and NGO stakeholders needs to be reversed. The costs of investing in biotechnology need to be compared with costs of investing in alternative means of agricultural development.

Biosafety

National and international regulations to ensure environmental and human health, and to address cultural, economic, and sustainability issues need to be in place before technologies are recommended to farmers. Varieties made available to NGOs must have all the necessary assessments to ensure their safe use by farmers. The need for risk management of these GM crops, such as refuges, will need to be developed and training programs for farmers developed and implemented.

Benefits from GM Crops for Resource-Poor Farmers

There is a need for clear evidence that the improvements offered in these biotechnology products outweigh the risk of their introduction and use. There needs to be a clear, transparent assessment of the risk, including factors that are unique to traditional tropical cropping systems. Farmers need to have redress options for any damage to environmental or human health or their economic well-being caused by GM crops.

Freedom to Save and Exchange Seed

The issues of long-term access to affordable seed and planting material need to be addressed. The farmer seed system is of vital importance to African agriculture. As is the case with the products of formal breeding, farmers must have the right to save and multiply seed for further planting. Furthermore, research must support NGOs and farmers to improve the effectiveness of seed saving.

The focus of the IARCs on the science of the problem and the focus of CRS on the delivery of the solution can lead to conflicts and disappointments. Transparent partnerships are required that place value on both research and development. Partnerships with the private sector will be new and require new mechanisms of interaction and funding.

Partnerships and Capacity Strengthening

NGOs will need strong partnerships to effectively deliver this biotechnology to farmers. They need access to technical expertise from the national programs, IARCs, and the private sector on biosafety concerns, intellectual property and license agreements, and risk management. CRS currently has partnerships with IARCs and national programs to deliver new varieties and other improvements. These partnerships have constraints, such as the need to claim success to attract donor funds, which result in conflicts on equitable sharing of credit and costs. The focus of the IARCs on the science of the problem and the focus of CRS on the delivery of the solution can lead to conflicts and disappointments. Transparent partnerships are required that place value on both research and development. Partnerships with the private sector will be new and require new mechanisms of interaction and funding.

References

Christian Aid/World Development Movement (2004) The Biosafety Protocol—Controlling trader in GMO's. Policy Brief/Position Paper. http://www.christian-aid.org.uk/indepth/003bios/biosafet.htm.

Food and Agriculture Organization (FAO) (2004) Agricultural biotechnology. Meeting the needs of the poor? In: The State of Food and Agriculture 2003–2004. Rome: FAO.

Council for Biotechnology Information (CBI) (2003) Biotechnology transfer: Sharing innovation with the developing world. http//www.whybiotech.com/index.asp?id=3650.

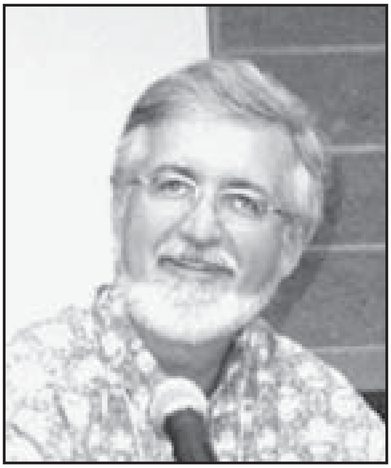
Council for Biotechnology Information (CBI) (2004) Regulation of Biotech Crops and Foods in the United States and Canada. http://www.whybiotech.com/index.asp?id=3993.

Organic Consumers Association (2003) Africa Developing Biosafety Regulations for GMO's. http//www.organicconsumers.org/ge/africa102703.cfm.

Rosset P (2000) Genetic engineering of food crops for the third world: An appropriate response to poverty, hunger, and lagging productivity? In: Proceedings of the International Conference on Sustainable Agriculture in the New Millennium—The Impact of Modern Biotechnology on Developing Countries. Brussels: Friends of the Earth Europe. http//www.foodfirst.org/progs/global/biotech/Belgium-gmo.html.

Warner KD (2001) Are life patents ethical? Conflict between Catholic Social Teaching and agricultural biotechnology's patent regime. Journal of Agricultural and Environmental Ethics 14 301–319.

Zidenga T (2003) The Status of Biosafety in Africa. ISB News Report July.



Tom Remington grew up in Madison, WI, and received BS and MS degrees in horticulture from the University of Wisconsin. He has worked in Africa for over twenty-five years, beginning as a Peace Corps volunteer in Mali in 1977. He received his PhD from the University of Wisconsin in 1990 in agronomy for work with women rice farmers in western Gambia.

Dr. Remington has served as agriculture advisor with Catholic Relief Services (CRS) since 1994. Currently he is responsible for Eritrea, Ethiopia, Sudan, Uganda, Tanzania, Kenya, Rwanda, and Burundi. He has helped CRS articulate a comprehensive agriculture strategy consisting of innovative means of recovery from disaster; increasing farm-family income and resilience; facilitating farmer access to new technologies through linkage with national and international research institutions; integrating domestic and productive uses of water; and improving nutrition through biofortification.

He collaborates with international research centers on farmer evaluation of new crop varieties, including the International Potato Center (Peru, sweet potato), the International Institute of Tropical Agriculture (Nigeria, cassava), the International Center for Crop Research in the Semi-Arid Tropics (India, chickpea, groundnut, and pigeon pea), the International Center for Tropical Agriculture (Colombia, common bean), the International Maize and Wheat Improvement Center (Mexico, maize) and the Africa Rice Center (Ivory Coast, rice).

Agricultural Biotechnology and Quality of Life: What Counts as Quality?

RUTH CHADWICK
Lancaster University
Lancaster, United Kingdom

> *Every act and every inquiry, and similarly every action and pursuit, is thought to aim at some good; and for this reason the good has rightly been declared to be that at which all things aim.*
>
> —Aristotle

Aristotle began the *Nichomachean Ethics* with the statement that there is some good at which all things aim, and proceeded to delineate the good for man. His teleological view included two versions of the "good for man," in his term "eudaimonia" which is commonly expressed as "flourishing"—the moral life and the life of contemplation. For Aristotle, however, certain things could be taken for granted, like the meeting of the basic physical necessities of life, and indeed slaves to cater for the needs of Athenian citizens. Nevertheless, the teleological aspects of his ethical thought continue to be very influential in thinking about quality of life. Andrew Edgar, in his article on quality of life indicators, suggested that "it may not be an exaggeration to suggest that talk of one's quality of life makes an implicit appeal to the degree to which one's life approaches one's personal image of an Aristotelian good life" (Edgar, 1998). If we can agree that human beings have a telos, then it should facilitate further agreement on what the elements of that are and the instrumental steps towards it.

Barriers to agreement about this derive from competing conceptions of human nature, or disagreements as to whether there is such a thing as a universal human nature. I shall argue that quality-of-life arguments are inevitably going to be beset by pluralism, but that this is not necessarily a bad thing. In particular, some accounts of quality of life may be described as "end state" conceptions: others as "process" accounts. By an "end state" conception I mean an account of quality of life that depends on an assessment of the impact of a particular development on a group or population: by a "process" account I mean an account that includes an

Achieving food security is a necessary condition of quality of life, and improvements in this may at the same time constitute an improvement in quality of life, but they are not sufficient. Quality of life, which is distinguishable from "standard of living," cannot be reduced to food security or to discussions of wealth and poverty. Even on a well-being account of quality of life, there are other factors to consider.

assessment of, for example, how much control they had over the process of getting to that state. Arguably, between the different accounts I shall consider, there will be some consensus, *e.g.* on the desirability of food security, defined by the FAO as freedom from hunger and fear of starvation. Achieving food security is a necessary condition of quality of life, and improvements in this may at the same time constitute an improvement in quality of life, but they are not sufficient. Quality of life, which is distinguishable from "standard of living," cannot be reduced to food security or to discussions of wealth and poverty. Even on a well-being account of quality of life, there are other factors to consider. It is interesting to note, however that recent discussions of "quality time" and "time poverty" in rich societies have themselves used the language of poverty.

My aim in this paper is to discuss the link between agri-biotech and quality of life, with a view to informing the debate about the likely success of different strategies for improving quality of life. I want to stress that while it may appear that the disagreement between proponents and opponents of agri-biotech is about the relevant means to achieve food security, an end on which they agree, on the contrary there are deeper disagreements about what counts as quality of life, disagreements that may not always be recognized. The question of the likely contribution of agri-biotech to food security does not settle the question of its significance for quality of life.

Quality of life, food and health

As Andrew Edgar noted, in ordinary language usage "quality of life" suggests the general satisfaction that one has with one's life, and it will thus depend on factors such as housing, the environment in which one lives and works, and social relationships, but the concept of "quality" remains difficult to elucidate (Edgar, 1998). Related concepts include that of a life worth living, which Jonathan Glover explored in *Causing Death and Saving Lives* (1977). Having thought about trying to draw up a list of elements of a life worth living, however, he gave up the task, coming to the conclusion that a person's wish to go on living was good *evidence* for their having a life that is worth living. I mention this point for two reasons. First, Glover's conclusion is an instance of a more general point that stresses the importance of the perspective of the person or persons whose [quality of] life is at issue; secondly, because Glover was writing primarily about the medical context, but I would argue that there are insights to be drawn from that context for the agri-biotech context. Food and health are closely connected and in the biotech sphere growing closer with the introduction of functional foods and nutrigenomics.

. . . three main approaches to quality of life in relation to agri-biotech, the well-being approach, the capabilities approach and the justice approach.

Alongside the attempts to explain the ordinary language use of "quality of life" there are attempts to develop tools of measurement to compare the impact of various interventions on quality of life of individuals or populations. One of the best-known instances of a quantifiable version of this is in the health-care context, the quality-adjusted life year, or QALY. Though the aim might be to produce a neutral tool of measurement, any given tool will inevitably be supported by some value perspective so it is important to examine the presuppositions on which they depend. For example, critics of the QALY have pointed out that things look rather different to those who are suffering from a condition as opposed to those who are not. Some of these elements are included in what I regard as the three main approaches to quality of life in relation to agri-biotech, the well-being approach, the capabilities approach and the justice approach. The capabilities approach, for example, is presented not only as an account of the meaning of quality of life, but also as a means of comparison. I want to set my account, however, in the context of that provided by the UK Food Ethics Council (2003) in its recent report *Engineering Nutrition*, so I shall begin by saying something about that.[1]

Engineering Nutrition takes as an example for discussion Golden Rice™, and questions the ways in which the issues are framed by scientific experts. They point out that the proponents of GM crops are no longer portraying them as *the* answer to world hunger as in the discredited example we saw in the 1990s. Their target is a subtler version of the argument that holds that GM crops have the *potential* to help increase food security, given appropriate conditions. Their objections to the framing assumptions and to the argument that greater investment should be put into GM crops include the fact that the framing assumptions built

[1]The author is a member of the Food Ethics Council.

into the decision-making processes in rich countries are not commensurate with the values of society at large in those countries most affected, specifically:

- they take no account of social risks in the risk-assessment process,
- they overlook the importance of assessing food-security strategies for their effect on the whole diet, taking into account social dimensions of food insecurity, rather than concentrating on single nutrient solutions such as Golden Rice™,
- utilitarian considerations are given primacy over considerations of justice,
- consumer "choice" comes in too late in the research and development process.

The report is right to point out the importance of framing assumptions, but it does not itself discuss the different framings of the notion of quality of life itself. Quality of life as a term is mentioned in the "ethical matrix" (Table 1) around which previous reports of the Food Ethics Council have been structured, including their earlier report on GM foods, *Beyond Nuffield* (1999). The ethical matrix is a structured approach to a pluralistic method of decision-making, including the ethical principles of well-being, autonomy and justice. A similar principled approach, but not the matrix itself, was employed by the first report of the Nuffield Council on Bioethics (1999) on GM crops. Designed by Ben Mepham, it addresses technological developments by assessing their impacts on different groups of stakeholders with reference to these three principles. The point to which I want to draw attention is that in the ethical matrix as illustrated in *Engineering Nutrition* "quality of life" only appears in connection with the *well-being* principle as applied to consumers. This is what I call an "end state" account of quality of life. Mepham understands well-being in the matrix to be based on the utilitarian tradition and so the judgment of quality of life here will be based on some assessment of the utility status of those affected. While *Engineering Nutrition* does not limit itself to a utilitarian outlook—far from it—it is instructive that the other principles are not *explicitly* related to quality-of-life issues.

TABLE 1. THE ETHICAL MATRIX DEVELOPED BY BEN MEPHAM.

Respect for	Well-being (Health and welfare)	Autonomy (Freedom/choice)	Justice (Fairness)
Farm animals	Animal welfare	Behavioral freedom	Intrinsic nature
Agricultural and food industries	Satisfactory income and work	Freedom to adopt or not to adopt	Fair treatment in trade and law
Citizens	Availability of safe food. Quality of life	Respect for democratic, informed choice	Availability of affordable food
The ecosystem	Conservation of the biota	Maintenance of biodiversity	Sustainability

In many instances, the improvements that can be achieved through GM crops may reduce much of the effort required in subsistence agriculture.

As far as well-being is concerned, the Nuffield Report (2004) makes the following claim:

> *Poverty has many causes…Poor efficiency of agriculture is one of them. It is also clear that the efficiency of agriculture has considerable impact on the standard of living of people involved in work on small-scale farms in developing countries. This is most notable in Africa, where the majority of the population lives and works in small farms in rural areas…Moreover, it is particularly true with respect to improving the situation of women, who make up the majority of the world's resource-poor farmers…In many instances, the improvements that can be achieved through GM crops may reduce much of the effort required in subsistence agriculture.*

In disagreeing with Nuffield, *Engineering Nutrition* accepts that proponents such as Nuffield recognize that the first generation of GM crops has been for the benefit not of such communities but of rich companies in developed countries. Both sides also accept that sweeping generalizations about *all* instances of GM can be unhelpful. Nevertheless, the Food Ethics Council regards the call for a case-by-case approach as potentially harmful because it can overlook cumulative effects on well-being.

Autonomy, and the Capabilities Approach

The autonomy column as Mepham developed it incorporates a cluster of notions such as freedom, rights and dignity, including the freedom to pursue a natural telos. Although *Engineering Nutrition* addressed the issue of freedom of choice, it is arguably others who come closest to explicitly relating such notions to quality of life. An example would be the capabilities approach of Amartya Sen and Martha Nussbaum. From this perspective, what is important in assessing quality life is not what people have but what they can do.

For Sen, well-being and agency are not to be regarded as independent. He argued that "to judge the well-being of a person exclusively in the metric of happiness or desire-fulfilment has some obvious limitations….It can be argued that advantage may be better represented by the freedom the person has, and not by…what the person achieves—in well-being or in terms of agency—on the basis of that freedom. This type of consideration will take us in the direction of rights, liberties and opportunities" (Sen, 1988). Like Sen, Martha Nussbaum used the notion of capabilities to develop a space of comparison in which to compare nations, as a rival to other types of measurement such as *per capita* GDP, but wanted to go further and use the approach as the philosophical basis for fundamental constitutional principles establishing a social minimum or threshold. The idea of a basic social minimum is focused on human capabilities, central human functions that could form the basis of agreement.

To what extent is it right to include autonomy and capability considerations in accounts of quality of life? And to what extent does agri-biotech impact on autonomy? These are not easy questions. It is fair to say that autonomy, and choice, have been paraded as primary considerations both in applied ethics and in policy in recent years. As *Engineering Nutrition* pointed out, however, the "choice" has been largely construed as being that of the consumer to buy the product, not only a very limited but also a westernised interpretation. A report of the Rathenau Institute is also critical of this notion. Asking "Where is the autonomous consumer?" they say: "A somewhat slow consumer is 'activated' with difficulty and is typically a less interested, less involved, conversation partner….However, the ever-critical and oh-so-autonomous consumer is very hard to remove from the discussions on technology development and thus obstructs the creation of a more realistic image" (Rathenau Institute, 2003).

In the context of GM crops . . . the relevant choices are about styles of life rather than choices of products . . . . Thus they are about global life choices rather than local life choices.

In the context of GM crops, however, much more than this is at stake. The relevant choices are about styles of life rather than choices of products, and about the extent to which interventions facilitate the pursuit of the human telos, the good life mediated through the perspective of those affected. Thus they are about global life choices rather than local life choices. Whereas a local life choice might be "Do I want this product now?" a global life choice is "What sort of life do I want to lead?"

Martha Nussbaum's development of the capabilities approach has been particularly focused on the position of women (Nussbaum, 2000). The ethical matrix has not explicitly included the perspective of feminist ethics, which has been critical of a 'principles' approach such as that represented by autonomy, well-being and justice. It would not be sufficient, on this perspective, simply to subdivide by gender the "consumer" row of stakeholders. From the perspective of feminist ethics, it is important to look at power relations and the extent to which certain interventions or developments will differentially affect vulnerable groups. Insofar as autonomy is an important principle to apply, the relevant question is not whether the idealized autonomous consumer can take an informed decision, but the extent to which vulnerable groups have a voice. Attention to the ways in which power relations are relevant to quality of life, however, is connected with consideration of the third principle, and column in the matrix, that of justice.

Justice

A significant problem with addressing questions of justice in this area lies in the fact that these questions do not arise within states, or between states. Onora O'Neill has pointed to the "messiness" of trying to develop principles in what she calls "transnational" justice: to whom are they to be addressed—who are the agents of change? Nevertheless it is impossible to avoid asking the question.

O'Neill made the following points, relevant to quality of life: "One of the more promising strategies concedes that a full account of transnational economic justice might require a complete account of human needs, but claims that less is needed for a discussion that considers basic economic rights. It is not controversial that human beings need adequate food, shelter and clothing appropriate to their climate, clean water and sanitation, and some parental and health care, without which they become ill and die prematurely. These *basic needs* may provide a basis for arguing for *basic rights*. It is controversial whether human beings need companionship, family life, education, politics, or food for the spirit….But these issues do not have to be completely settled for a discussion of hunger and destitution to proceed" (O'Neill, 2000).

O'Neill argued that there are severe difficulties with both utilitarian and rights-based approaches to transnational justice. Specifically, on the right to food, she said that "if the claimants of supposed 'rights' to food or development cannot find where to lodge their claims, these are empty 'manifesto' rights." She argued for a Kantian-inspired account based on obligations, which assumes a picture of human life in which agents with "limited capacities and varied vulnerabilities" interact. A picture of justice has to take account not of idealized autonomous agents, but of the real situations of oppression in which people find themselves. So she argued for a picture of transnational justice that does not depend on the agreement of ideal abstract agents as in the Rawlsian original position, nor upon what people actually would consent to in the real world, which ignores power relations, but on what people *could* consent to. This is abstraction without idealization. In thinking about how this would work in practice, we might "ask to what extent the variable aspects of any arrangements that structure vulnerable lives can be refused or renegotiated by those whom they actually constrain" (O'Neill, 2000). She argued that, in fact, the poor cannot refuse or renegotiate their role in economic structures: Debtors who need further loans for survival cannot make much fuss about the terms creditors offer for purchasing their crops; the most dependent women…are acutely vulnerable both to market factors and to more powerful kin.

. . . stakeholder participation needs to be involved in setting the research agenda and not only at the stage of accepting particular crops or foods, and a greater proportion of research funding be directed towards alternatives.

This account of transnational justice is at odds, then, with arguments about justice in the agri-biotech debate that emphasize the moral urgency of trying to help poor farmers through agri-biotech, albeit on a case-by-case basis. Such arguments, which focus on well-being or even autonomy, frequently fail to take account of the real conditions of choice and in particular leave the entry of "choice"—in other words, areas over which people *have* a choice—to a late stage. In *Engineering Nutrition*, the Food Ethics Council argued that stakeholder participation needs to be involved in setting the research agenda and not only at the stage of accepting particular crops or foods, and that a greater proportion of research funding be directed towards alternatives. If this is not the case, then the stakeholders have no effective possibilities of refusal or renegotiation. In this sense, they are implicitly at least in line with O'Neill's account.

Food security is a richer concept than the individual right to food, as it is good for society as a whole. Knowledge is said to be an archetypal public good, and genomics as a type of knowledge is in principle therefore, arguably, a global public good.

Ownership and Global Public Goods

Being treated justly is clearly highly relevant to an assessment of quality of life, and this applies both to individuals and population groups. Another aspect of justice, however, which is germane to the present context, is sharing of the benefits, and this is where issues of private and public goods become relevant.

Food security is considered by the United Nations Development Programme to be a global public good, defined as a good that is enjoyable by all without detriment to others; it is non-rivalrous and non-exclusive. Food security is a richer concept than the individual *right* to food, as it is good for society as a whole. Knowledge is said to be an archetypal public good, and genomics as a type of knowledge is in principle therefore, arguably, a global public good. But whether or not knowledge is a public good is not independent of social and political arrangements. *Engineering Nutrition* however pointed out that the proponents of "pro-poor" agri-biotech have argued for public-private partnerships as the way forward, and are highly critical of this: "We question whether a science that depends on privatising public goods to sell at premium prices can make a realistic promise to generate food security, which depends on public goods (Food Ethics Council, 2003).

Rice is one of five crops constituting 75% of food in developing countries, and 70% of the patents for modification of these crops are owned by five biotechnology companies.

The report also highlighted the concern that poor countries are being "bullied" into abiding by patent rules that do not apply to them. This worry again is consistent with the concept of transnational justice developed by O'Neill. Rice is one of five crops constituting 75% of food in developing countries, and 70% of the patents for modification of these crops are owned by five biotechnology companies (Rathenau Institute, 2003). The Rathenau Institute suggested that research should be encouraged into so-called "orphan" crops that are not seen as commercially interesting. The way towards global sustainable food security must, therefore, proceed through the local varieties from the Third World, otherwise the Third World countries will only get on their plates the "crumbs" from production in the west.

The Food Ethics Council recommends that research should be directed to public-good projects. In the present context, it is difficult to accept the argument that genomics *is* a public good, but the deployment of the public-good argument may be regarded as a useful strategy towards improvement of quality of life.

Our understanding of what counts as quality of life must be pluralistic.

CONCLUSION

Our understanding of what counts as quality of life must be pluralistic. Even if we can establish a global "telos" for human beings, this must be mediated through local understandings. In other words, there will be a plurality of ways of pursuing it. Food security is a necessary condition of quality of life, but not sufficient. Thus the debate over the extent to which agri-biotech helps to answer food security problems does not settle the question of its relevance to quality of life.

Different perspectives on ethics emphasize different aspects of quality: well-being, living autonomously, and being treated justly. In ethics and political philosophy, the debate about the priority of liberty and equality is an issue, but I have not attempted to settle that question here. Rather it has been my intention to demonstrate the different contributions of the different principles to making judgments about what constitutes quality of life and means to improving it. There is a considerable amount of consensus in the debate that well-being is insufficient, at least insofar as consequentialist or utilitarian interpretations of well-being are concerned. Process is arguably at least as important as the end state. An expanded notion of well-being, to include meaningful choice, has more support, but choice itself has tended frequently to be interpreted in an impoverished way, in terms of the ideal autonomous consumer. Attention at least to global dimensions of choice is required. This is not unconnected with justice, which directs our attention to both power relations and distribution of benefits. It has been shown that choice is relevant here too insofar as there are issues about the relevant bargaining power of the parties. In terms of courses of action for improving the situation, two things stand out: moving stakeholder involvement upstream in the research-priority-setting process, and encouraging fair and equitable sharing of benefits through appropriate infrastructure and ownership arrangements. Thus the concept of global public goods remains an important strategy in addressing the issues concerning improvement of quality of life.

References

Edgar A (1998) Quality of life indicators. In: Encyclopedia of Applied Ethics (Chadwick R Ed) San Diego: Academic Press 759–776

Food Ethics Council (1999) Beyond Nuffield. Brighton: Food Ethics Council.

Food Ethics Council (2003) Engineering Nutrition. Brighton: Food Ethics Council.

Glover J (1977) Causing Death and Saving Lives. Harmondsworth: Penguin

Nuffield Council on Bioethics (1999) Genetically Modified Crops: the Ethical and Social Issues London: Nuffield Council on Bioethics.

Nuffield Council on Bioethics (2004) The Use of Genetically Modified Crops in Developing Countries. London: Nuffield Council on Bioethics

Nussbaum MC (2000) Women and Human Development: The Capabilities Approach. Cambridge: Cambridge University Press.

O'Neill O (2000) Bounds of Justice. Cambridge: Cambridge University Press.

Rathenau Institute (2003) Genes for Your Food: Food for Your Genes: Societal Issues and Dilemmas in Food Genomics (Working Document 92). The Hague: Rathenau Institute.

Sen A (1988) On Ethics and Economics. Oxford: Blackwell.

Ruth Chadwick is professor of bioethics and director of the Economic and Social Research Council Centre for Economic and Social Aspects of Genomics at Lancaster University, Lancaster, United Kingdom. Prior to her arrival at Lancaster in 2000, Dr. Chadwick held positions at the University of Liverpool, the University of Wales, Cardiff, and the University of Central Lancashire, Preston.

She has coordinated a number of projects funded by the European Commission, including the Euroscreen projects (1994–1996; 1996–1999) and co-edits the journal *Bioethics*. She is chair of the Human Genome Organization Ethics Committee, and member of the Food Ethics Council, the Advisory Committee on Novel Foods and Processes, the Standing Committee on Ethics of the Canadian Institutes for Health Research, and the Medical Research Council Steering Committee on DNA Banking. Chadwick was editor-in-chief of the award winning *Encyclopedia of Applied Ethics* (1998) and is an academician of the Academy of the Learned Societies for the Social Sciences.

Her current research funding includes a grant from the Wellcome Trust Electronic Bioethics Resource (jointly with the Universities of Oxford and Sheffield). She is a partner in the North West Genetics Knowledge Park (NoWGeN) at St. Mary's Hospital, Manchester, UK.

How Much is the Quality of Life Being Regulated?

Joel I. Cohen and Patricia Zambrano
International Food Policy Research Institute
Washington, DC

Worldwide, genetically modified (GM) crops comprise mainly four species in five countries (James, 2003), produced with GM technologies that have been developed mostly by the private sector in the developed world. Although an active public sector in the developing world is engaged in crop biotechnology (Atanassov *et al.*, 2004), little so far has reached smallholder farmers. Thus, when we discuss biotechnology in the developing world, we can only speak of "potential." Many of the technologies under development have the potential to generate agronomic and environmental benefits or to enhance the nutrition of people in the developing world and to increase income and improve overall well-being. Most of the evaluations of benefits from GM crops in the developing world have been based on *ex-post* data for insect-resistant cotton, which has been approved for use in several countries.

Genetically modified food crops have not met with general acceptance, contrasting sharply with the widespread adoption of high-yielding varieties during the Green Revolution that were regulated under seed- and plant-protection laws still in place today. In the mid-1970s in India, despite a "paralysis that beset the public servants and politicians" (Hopper, 1987, 1999), farmers accessed, traded and sold the goods of the Green Revolution. The impact and longer-term effects of these high-yielding varieties have been studied (Evenson and Gollin, 2003), and their debatable qualities are being modified, some through biotechnology.

Genetically modified cotton and soybean—two of the four major crops grown—have had similar "farmer-first" adoption in developing countries as had the high-yielding varieties of the 1970s. Farmers sought and obtained access to *Bt* cotton before the Indian regulatory system had officially approved it, and interest is increasing in areas where cultivation of GM crops is not yet approved (Sharma, 2004). In fact, approval came months after the GM cotton had been harvested. In Brazil, a similar situation occurred with the planting of an estimated 4 million acres of GM herbicide-tolerant soybean that had not been approved for planting.

Safety standards for crops, as for all food and agricultural products, should not be compromised. However, GM crops now have new regulatory regimes or require additional scrutiny beyond those of conventional crops. The need to identify/evaluate long-term health or environmental effects of GM crops arises in part because the transgenes are new to agricultural systems. Although they function the same as genes introduced through plant breeding, hybridization, introgression, and wide crosses, they are treated differently in terms of management, monitoring and evaluation.

Regulatory decisions on GM crops have been made with varying familiarity as to crop and trait, and with varying uncertainty with respect to risk. So far, they have been deemed safe in a number of global reports (FAO, 2004; Nuffield, 2004), have few negative environmental or health effects, and in certain environments have been proven efficacious.

Regulatory decision making is done country by country and on a case-by-case basis, with little sharing of knowledge, delaying the regulatory and hence adoption process. Additionally, countries adhering to the Cartagena Biosafety Protocol have the option to deny approval for import or use of GM crops by using the precautionary approach, if generally not satisfied with existing scientific knowledge.

These complexities translate to the delaying the approval of GM crops, even in cases where quality-of-life improvements are anticipated. Such improvements potentially include:

- reduction in pesticide use that could benefit farmers and their communities not only for the direct effect of decreasing expenditure in this input, but also by reducing overall health and environmental risks associated with their use,
- increase in yields that can boost local production of food, benefiting local economies and reducing reliance on imports or food shipments,
- implementation of promising technologies that minimize the effects of biotic or abiotic stresses on crop development, such as salt resistance and drought tolerance that are major constraints on marginal lands where many poor farmers are localized,
- delivery of alternative compositions and forms of carbohydrates and fats,
- improved provision of vitamins, with new avenues of reaching the poor.

Timeframes for realizing such benefits from GM food crops may be from 5 to 15 years. Like conventionally developed crops, those considered as genetically modified must pass agronomic and safety evaluations. Field evaluations begin with confined trials, often conducted at experiment stations or commercial research facilities, where environmental risk and exposure are minimized, and where seed production/collection can be controlled. Promising lines are advanced to more-open evaluations and multi-location trials and, eventually, are released to farmers.

Safety assessments are inherent to risk assessment and biosafety. Whether these reviews are carried out through a coordinated framework using existing regulatory agencies, through specially created agencies for GM crops, or through national biosafety committees, the same questions arise as to safety and risk. Therefore, it is essential that regulators in neighboring countries facilitate exchange of data, understand where areas of uncertainty and perceived risk exist, and are cognizant of potential benefits.

However, safety considerations generally do not take into account potential benefits including life-enhancing possibilities.

However, safety considerations generally do not take into account potential benefits including life-enhancing possibilities. Commercial entities and public research institutes in developing countries are often ill-equipped to ensure adequate risk assessment. A consequence of research devoted to regulatory requirements is the additional cost, which means that only a few traits are researched and developed, and even fewer reach confined testing in developing countries. Countries may also decide to set multiple regulatory requirements to avoid a decision, rather than approve an unfamiliar trait where risk is uncertain. If 100% confidence in risk assessment is not achieved, the precautionary approach may result in cessation of the approval process.

Purpose of this Paper

The purpose of this paper is to review GM crops under development and their regulation, potential benefits and cost of lost opportunities, and the social implications of biosafety. The study of GM crops focuses on potential quality-of-life traits under research by the public rather than private sector in developing countries. Regulatory necessities for GM crops are considered, comparisons with prior crop developments are made, the current state of regulation among developing countries is conveyed, and a Conceptual Framework for biosafety systems is introduced. Alternative sources for helping rural communities are interjected, and specific concerns regarding the GM approach are discussed. Suggestions are made for achieving new models for regulation with benefits for public, as well as private, research. Difficulties encountered within a regulatory system, as well as those external to it are described, and aspects of opportunity, costs, benefits and risk are discussed.

Can Public GM Research Produce Crops with Quality-of-Life Benefits?

Currently, for-profit industry is the most successful provider of GM crops in developed and developing countries alike. For this reason, such production is a significant concern in developing countries. Using only commercially derived GM crops may result in inability to save seed, loss of control over costs and other unwanted effects of monopoly control. Arguments have been made for developing countries to consider biotechnology as part of their public-sector agricultural research agenda (Pinstrup-Andersen and Schioler, 2000). This research could provide the foundation for alternative sources of GM crops free of strong commercial control. However, until recently, no reliable data were available regarding such public research or its regulation.

A recent study (Atanassov, 2004; Cohen, 2005) indicated that public research on GM crops has targeted species and traits of importance to developing countries; it identified forty-six successfully transformed crops being tested in developing countries (Table 1). The percentages of these transformation events—distributed by phenotype—are presented in Figure 1. Over half of the 209 events involved single genes that confer either viral or insect resistance. In eleven events, multiple (stacked) genes are being tested for phenotypic combinations, such as insect resistance with herbicide tolerance.

Table 1. Number of transformations (Atanassov *et al.*, 2004).

Region	Country	Number	Sub-total of events
Africa	Egypt	17	
	Kenya	4	
	South Africa	28	
	Zimbabwe	5	54
Asia	China	30	
	India	21	
	Indonesia	24	
	Malaysia	5	
	Pakistan	5	
	Philippines	17	
	Thailand	7	109
Eastern Europe	Bulgaria	8	8
Latin America	Argentina	21	
	Brazil	9	
	Costa Rica	5	
	Mexico	3	38
All			209

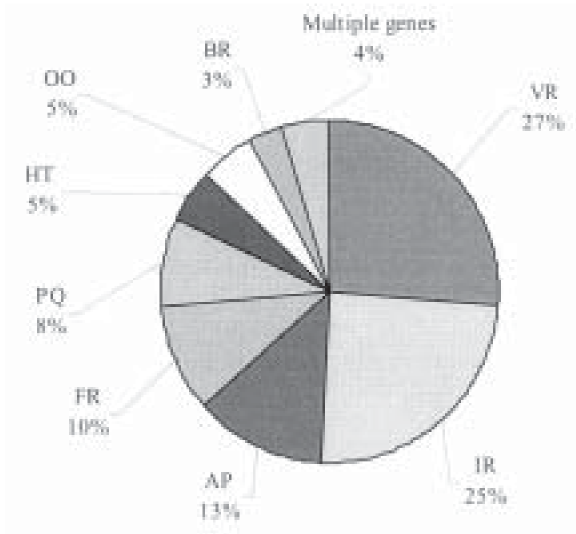


Figure 1. Phenotypic distribution and percent of total events (Atanassov *et al.*, 2004).
AP–Agronomic properties; BR–Bacterial resistance; FR–Fungal resistance; HT–Herbicide tolerance; IR–Insect resistance; OO–Other; PQ–Product quality; VR–Virus resistance.

Transformation events grouped by crop type are shown in Figure 2. Although cereals predominate, significant numbers of fruits, roots and tubers, and vegetables are represented, with each group containing diverse species. Progress in transforming indigenous crops is also significant. Although almost half of all transformation events are for rice, potato, maize, papaya, and tomato, the other half are spread over forty-one other crops, most of them indigenous, including pearl millet, papaya, mung bean, common bean, chickpea, cowpea, lupin, cacao, and coffee.

These combinations of crops and traits have great potential in areas not reached by the Green Revolution and in cases where such crops have been affected by new types of pests, water shortages, and/or where crops better suited to environmental constraints are needed. Benefits for poor farmers are directly related to the degree to which such cultivars can substitute for chemical inputs. Furthermore, the products of public research carry the advantage of being free of restrictive proprietary controls set by commercial providers.

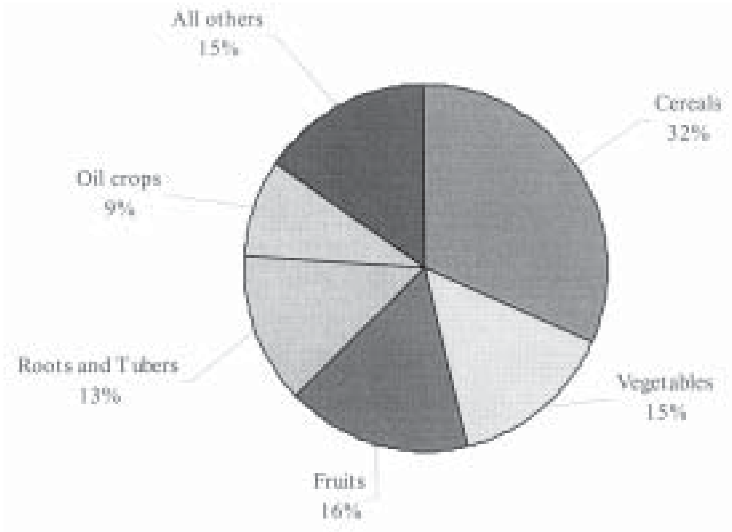


Figure 2. Percent transformation events by crop group (Atanassov *et al.*, 2004).

Many of these GM crops under development target very specific quality-of-life priorities in the countries where they are being developed. In Table 2 we included only those crops that have the greatest potential to improve people's well-being. Strictly we could broaden this to all events, as all the technologies under development by the public sector have at least an indirect effect on producers' or consumers' well-being, which is the purpose of all public research. For example, all fifty-one insect-resistance events under development will have an effect on farmers' quality of life, but we included only the thirty-five specifically developed for lepidoptera as they will have the greatest effect in reducing the impact of insecticide use.

The crops under development are in various stages of regulatory review in their respective countries. The total number of events decreases as lines are cut that do not convey sufficient agronomic efficacy, or if safety requirements cannot be met.

Despite this progress, the primary source of GM crops continues to be the private sector. Multinational companies have invested significant resources in guiding technologies through regulatory processes to production. With the exception of China, public-research products lag behind, eliciting concern because private funds are not being invested in countries, crops, traits or technologies that are most relevant to small-scale, resource-poor farmers.

TABLE 2. QUALITY-OF-LIFE RELATED EVENTS (COHEN, 2005)

Category 1	Category 2	No.	Subtotal
Insect-pest resistance	Lepidoptera	35	35
Disease resistance	Bacteria	8	84
	Fungi	21	
	Viruses	55	
Abiotic-stress tolerance	Drought	7	11
	Salinity	4	
Quality improvement	Nutritional and other	9	15
	Enhancing shelf-life	6	
Other	Vaccines	9	9
Subtotal		154	154
All events			209
% Subtotal over all			74

It is clear that Asia in particular has made a significant commitment to GM-crop research (ADB, 2001). This region contains the largest number of countries engaged in such research as well as the highest percentage of events in the testing phase. Africa, with the exception of South Africa, is seriously lacking in capabilities and resources to consider such research (Alhassan, 2003; UN ECA, 2002); many countries are exploring implications and are considering whether to invest in research on, or importation of, GM crops. Research capacity and potential markets are evolving (*e.g.* for insect-resistant cotton), albeit subject to uncertainties regarding the use of, and trade in, GM crops.

Developing countries are reacting in a precautionary manner regarding approvals of GM food crops, and justifying this approach by referring to the options articulated in the Convention for Biological Diversity and the Cartagena Protocol on Biosafety.

PUBLIC GM RESEARCH AND REGULATORY CONSIDERATIONS

Developing countries are reacting in a precautionary manner regarding approvals of GM food crops, and justifying this approach by referring to the options articulated in the Convention for Biological Diversity (CBD, 2004) and the Cartagena Protocol on Biosafety (Cohen and Paarlberg, 2004). Approaches to regulation that are consistent with the Cartagena Protocol are supported through the United Nations Environment Program Global Environment Facility (UNEP-GEF) program on biosafety, which provides training in regulatory policy, frameworks, legislation and capacity building (Briggs, 2001; UNEP-GEF 2004). While significant progress has been made in building regulatory capacity and developing guidelines, biosafety decision-making remains complicated, lacking transparency.

A Conceptual Framework[1] (McLean *et al.*, 2002) has been developed to bring together regulatory policy, procedures and capacity (Figure 3). It starts by acknowledging that no single biosafety regulatory system fits the needs of all countries. This is shown as countries adopt different approaches for implementing biosafety systems, regulations and policies[2]. Individual countries have different capacities and needs for biosafety regulation. One of these needs is to become compliant with the articles of the Cartagena Biosafety Protocol that one-hundred and ten countries have ratified.

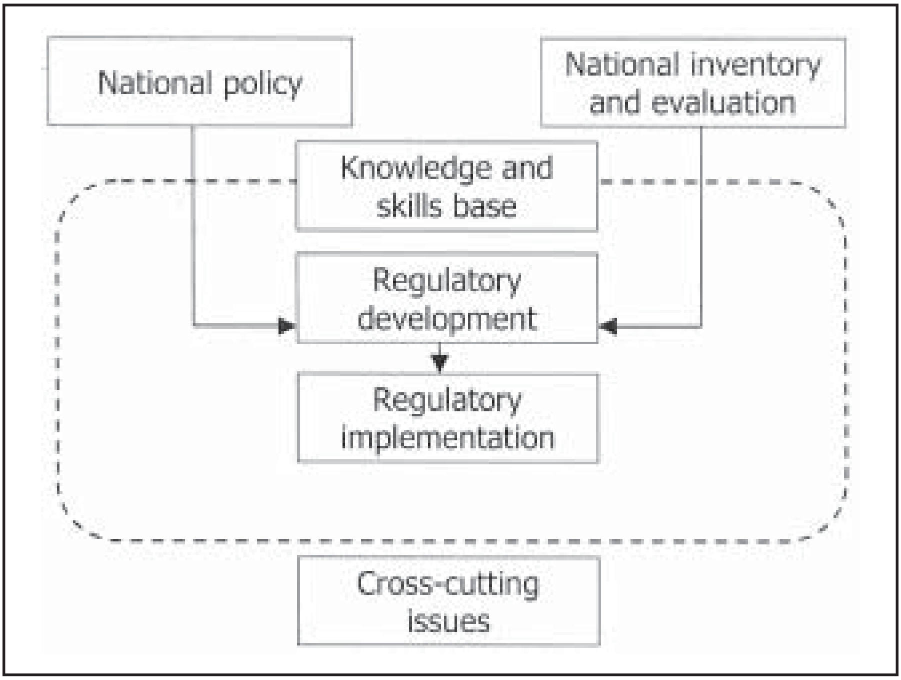


Figure 3. Basic elements of a Conceptual Framework for implementing biosafety frameworks and their interconnections (McLean *et al.*, 2002).

[1]The Conceptual Framework recognizes five elements central to a regulatory system: policy, national inventory, knowledge and skills base, regulatory development, and regulatory implementation.

[2]Major differences between countries are explained by overall economic development level, available human and technical resources, governments' implicit or explicit perspective on biotechnology and genetically modified organisms (GMOs), and whether policies governing the use of GMOs are promotional, permissive, precautionary or preventive.

The Cartagena Protocol on Biosafety speaks both to risk management and to risk assessment (Article 16, and Annex II and III) by which regulators can assess safety, but also consider (explicitly or not) the levels of risk they are willing or able to tolerate. Little data are available to help regulators balance risk analysis and risk perception with the advantages of releasing a promising new technology, and with analysis of cost of regulation. In addition, the Protocol does not specify the different requirements for confined or limited testing versus approvals for commercial release. This tends to confuse both the scientists and the regulators as per the type of trial requested.

For this reason, regulatory stage categories were defined and used to group each transformation event recorded in the study of public sector GM-crop research. Respondents were asked to indicate the stage of regulation for their respective events. Those in the experimental stage contain stable research products derived from multiple generations, beginning in the laboratory and moving to the greenhouse. In this stage, the stable expression of the gene of interest is confirmed.

Fifteen traits remain stable in small-scale, single or multi-location confined trials. These trials are contained to prevent any environmental damage, thus the regulatory standards are different from those established for subsequent stages.

The scale-up stage occurs when products advance from confined to pre-commercial trials, requiring the ability to increase seed amounts and larger areas for testing purposes. These tests may be conducted for environmental safety purposes or to examine agronomic efficacy, or both. Finally, products are made available to farmers after commercial release, through privately or publicly owned seed companies or other institutional mechanisms. The data show a total of 127 events at the experimental stage, forty-four are in confined trials, twenty-two are in scale-up testing (mostly in China), and seven are at the commercial release stage (Figure 4).

Events at the stage of confined testing represent the most promising public research on GM crops. These forty-four events will decline in number during their evaluation. Of those listed, only five countries have five or more such trials in place. However, the public sector must go beyond confined trials for safety and efficacy. It must also guarantee seed supplies to evaluate product performance on a large scale, and include experiments designed specifically for safety evaluation. However, many of the events recorded have been in multiple years of testing and now await approvals for scale-up or pre-commercial trials.

For these crops, regulatory decision-making is needed for advancement and approval. To efficiently review public GM crops, it is necessary to first analyze and then strengthen regulatory decision-making. This necessitates actions internal and external to the biosafety system itself as described in the Conceptual Framework. Efficient processes essential for timely application review can be neutralized by external factors, including political, trade and activist positions, and, especially, difficulties when encountering European markets that are essentially closed to GM imports or use (Cohen and Paarlberg, 2004).

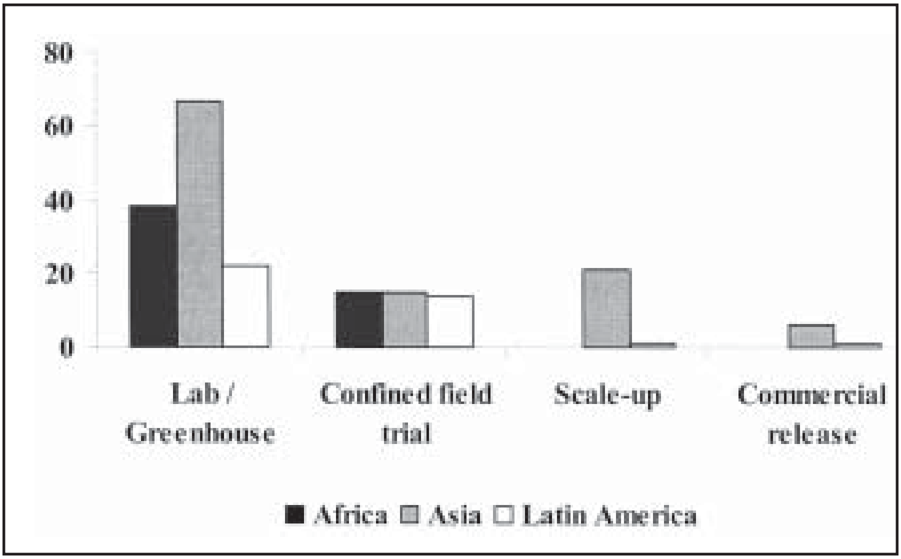


Figure 4. Public events classified by regulatory stage and region (Atanassov *et al.*, 2004)
Note: Eight transformation events for Bulgaria are not included, as the regulatory stages were not disclosed at the time of survey.

No uniform roadmap is available for working externally, facing political, trade, environmental concerns, anti-GM lobbies, moratoriums, and non-governmental or activist influence.

Developing actions that will impact on advocacy voices external to the regulatory system is difficult. No uniform roadmap is available for working externally, facing political, trade, environmental concerns, anti-GM lobbies, moratoriums, and non-governmental or activist influence. Informed discussion regarding biotechnology's benefits and potential risks is needed—in the context of specific GM crop examples, political governance and advocacy concerns, and including farmer perspectives.

Social and Opportunity Costs for Biosafety Systems

There are at least three consequences for countries using alternative paths to implement biosafety systems. First is the potential for lack of coordination between neighboring countries, creating a patchwork of regulatory systems that hinders trade and discourages technology transfer. Second is the potential for duplication of effort coupled with resource depletion. Third is the potential for jurisdictional arbitrage to seek those countries with the least stringent environmental regulations. Therefore regional regulatory approaches offer the possibility of creating greater efficiency and safety. Even the most dissimilar of biosafety systems will have in common the need for scientific expertise; ability to distinguish confined from open trials, communications infrastructure, appropriate facilities, and suitably educated personnel.

The challenge is to ensure safety while facilitating new opportunities for farmers. Such an outcome recognizes that there is a real social cost for not having efficient biosafety regulatory systems in place.

Regulatory systems are required that, while addressing safety, take account of national agricultural objectives, implications of international treaties [WTO-Sanitary and Phytosanitary (SPS) Agreement and the Cartagena Protocol on Biosafety], and potential to facilitate regional harmonization. On a more technical level, using a country's own interim processes[3] can keep the regulatory process moving, particularly for authorization of confined/experimental field-testing.

A new initiative addressing these matters—the Program for Biosafety Systems (PBS)[4]—will use regionally focused discussions regarding specific commodities, knowledge of existing regulatory systems, and a sub-set of multi-sector issues for analysis. This will explore trade-offs between options and decisions involved in the design of a biosafety regulatory process from a multi-country perspective, identify specific areas where data and regulatory approval can be shared, and guide the development of these areas over the life of the project. This analysis will ultimately help shape new models for biosafety regulatory systems that take into account likely opportunity costs and variations of the risk-benefit-cost calculation. The ideas discussed look for participatory development of new models for biosafety systems to be implemented in a local context of expertise, resources, regulations, political and social realities, and trade constraints.

Policymakers will have an opportunity to examine the consequences of having a biosafety process that is too lengthy or expensive, to look at how this can reduce opportunities for domestic companies and public-sector R&D institutes to reach

[3]Interim processes can be defined as steps that allow countries to manage issues of immediacy while providing policymakers with experience that can be used to guide the development of a rational statutory process under either new or adapted legislation.

[4]PBS management is based at the International Food Policy Research Institute. Further details in its policy approach to regulation are under development. http://www.ifpri.org/themes/pbs/pbs.htm.

the farmers' hands, and to examine how this can bias the system toward multinational firms. The use of interim processes offers one way of achieving a new model for regulatory implementation. These processes offer a way to reduce lag time for the introduction of biotechnologies, while formal legislation is being formulated.

Two philosophies about risk assessment and management currently prevail in relation to transgenic organisms: the benefit-cost approach, and the precautionary principle.

Assessing Risk and Loss Calculations

Two philosophies about risk assessment and management currently prevail in relation to transgenic organisms: the benefit-cost approach, and the precautionary principle, as used by the European Union (Vogel, 2001) and by the Cartagena Biosafety Protocol. However, both these approaches have generally agreed on the same scientific criteria to be used in risk decision-making for transgenic organisms. The PBS will analyze the implications of these different approaches and develop decision models using a new methodology that integrates benefit-cost and risk analysis. Under this approach, the EU's precautionary approach becomes a special case with zero or negligible risk.

The development of new decision models for PBS involves integrated quantitative risk assessments and benefit-cost analyses. These two approaches are used in a complementary manner, providing different information about decisions to release transgenic organisms. Integration of both approaches is needed to assess where to implement costly regulations for small benefit in terms of reduced risk.

The analysis will be conducted around a series of country case studies of crop-trait combinations and will involve an assessment of the costs, benefits and risk of these combinations under the regulatory conditions existing within each country. The country-specific biosafety regulations will affect the costs (opportunity, timing, *etc.*) incurred and the level of risk assumed

Therefore, changes to the regulatory environment can be assessed as far as they impact the receipt of benefits, or the increase in costs and various potential risks.

Can Quality of Life Come From Elsewhere?

GM research requires human, institutional and financial resources. Each country determines if it is able to make and sustain such commitments in the face of competing claims for funding. Such funds could otherwise be invested in irrigation, organic production methods, clean water development, or human disease prevention and eradication.

Furthermore, GM-free zones are being widely advocated or forced on countries by trade agreements. Consequently, at this time, GM-crop production may not be timely; rather it may be more advisable for countries to focus on enhancing food distribution, infrastructure and markets (Oxfam, 1999).

One industry developer has seen its regulatory costs reach between $10 million and $20 million for each crop event. These costs have grown substantially since the developer began GM research in the early 1980s.

Safety is key for the deregulation of GM crops. However, one industry developer has seen its regulatory costs reach between $10 million and $20 million for each crop event. These costs have grown substantially since the developer began GM research in the early 1980s. Overall, this means that crop research using GM technologies is *a priori* severely limited and such production costs can be justified only with crops with the highest potential profit. The same considerations apply to public research; ways must be found to meet the costs of addressing safety and regulation.

Another issue is whether a GM approach should even be considered, as it may be naively seen as a panacea for increasing national food security or productivity. Such a philosophy dictates that GM approaches be dropped as they may result in precipitous development and adoption of GM crops, avoiding full appraisal of potential or presumed risks (ISP, 2003).

Closing Statement

Safety is a foremost concern while we develop a track record of familiarity with GM crops and traits. However, the Cartagena Biosafety Protocol presents a precautionary approach when science is new. Among concerns over process, procedures, compliance, and trade, quality-of-life benefits can be unclear. While many farmers benefited immediately from Green Revolution varieties and, more recently, from insect-resistant GM cotton, their voices within regulatory circles and in the Conference of the Parties for the Cartagena Protocol on Biosafety have been otherwise absent.

All of the research and regulatory issues ahead leave developing countries at a difficult juncture, as complexities exist to approve either confined or larger trials. This complexity means that, presently, there is little chance of public GM food crops reaching the farmer. Without such access, determining if quality of life can be more than just a "potential" is not possible. Without such impact, many will argue that there are more certain and successful alternatives to improve quality of life or livelihoods than agricultural biotechnology.

References

Alhassan, W.S. (2003) Agrobiotechnology Application in West and Central Africa (2002 Survey Outcome). Ibadan: IITA.

Asian Development Bank (ADB) (2001). Agricultural Biotechnology, Poverty Reduction, and Food Security. Working Paper. Manila: Asian Development Bank.

Atanassov AA *et al.* (2004) To Reach the Poor. Results from the ISNAR-IFPRI Next Harvest Study on Genetically Modified Crops, Public Research, and Policy Implications. EPTD Discussion Paper 116. Washington, DC: International Food Policy Research Institute. http://www.ifpri.org/divs/eptd/dp/eptdp116.htm.

Briggs, C. (2001) Planning for the Development of Nearly 100 National Biosafety Frameworks. Paper presented at the international consultation A Framework for Biosafety Implementation – A Tool for Capacity Building, organized by the International Service for National Agricultural Research (ISNAR) and Virginia Polytechnic and State University, Washington, DC, July 23–26.

Cohen JI (2005) Poorer nations turn to publicly developed GM crops. Nature Biotechnology 23 27–33.

Cohen JI and Paarlberg R (2004) Unlocking crop biotechnology in developing countries – a report from the field. World Development 32(9): 1563-1577.

Convention on Biological Diversity (CBD) (2004) The Cartagena Biosafety Protocol. http://www.biodiv.org/biosafety/signinglist.aspx?sts=rtf&ord=dt.

Evenson RE and Gollin D (2003) Assessing the impact of the green revolution, 1960 to 2000. Science 300: 758–762.

Food and Agriculture Organization of the United Nations (FAO). (2004) The State of Food and Agriculture 2003-04. Rome: FAO.

Hopper WD (1987) An interlude with Indian development. In: Policy and Practice: Essays in Honour of Sir John Crawford (Evans LT Miller JDB Eds), Sidney: Australian National University Press.

Hopper WD (1999) Introduction, The Future: Social Research. Pages 1-4. New School for Social Research in association with The Gale Group and LookSmart.

Independent Science Panel (ISP) (2003) The Case for A GM-Free Sustainable World. http://indsp.org/ISPreportSummary.php.

James, C. (2003) Preview: Global Status of Commercialized Transgenic Crops. International Service for the Acquisition of Agri-biotech Applications (ISAAA).

McLean MA *et al.* (2002) A Conceptual Framework for Implementing Biosafety: Policy, Capacity and Regulation. ISNAR Briefing Paper 47. The Hague: The Netherlands.

Nuffield Council on Bioethics. (2004) The Use of Genetically Modified Crops in Developing Countries. London: Nuffield Council.

Oxfam (1999) Biotechnology in Crops: Issues for the developing world A report compiled for Oxfam GB by Laura Spinney. http://www.oxfam.org.uk/what_we_do/issues/livelihoods/biotech_gm.htm.

Pinstrup-Andersen P Schioler E (2000) Seeds of Contention. World Hunger and the Global Controversy over GM Crops. Baltimore: Johns Hopkins University Press.
Sharma AB (2004) Demand for Bt cotton takes root. The Financial Express (India) May 12.
United Nations Economic Commission for Africa (UN ECA) (2002) Economic Report on Africa 2002. Tracking Performance and Progress.
United Nations Environment Program Global Environment Facility (UNEP-GEF) (2004) Project on Biosafety. http://www.unep.ch/biosafety.
Vogel D (2001) Ships Passing in the Night: The Changing Politics of Risk Regulation in Europe and the United States. EUI Working Papers RSC No. 2001/16. San Domenico, Italy: European University Institute.

Joel Cohen is a Senior Research Fellow, as of April 2004, in the Environment and Production Technology Division of the International Food Policy Research Institute (IFPRI). He is also Director of the Program for Biosafety Systems, an international consortium enhancing regulatory policy and system development in Africa and Asia that was founded in May, 2003. This appointment followed eleven years as project leader in Management of New Technologies for Agricultural Research at the International Service for National Agricultural Research (ISNAR). Simultaneously, he served as director of ISNAR's Biotechnology Service.

Dr. Cohen recently authored papers on the public production of genetically modified (GM) crops in sixteen developing countries and their regulatory implications; the policy setting for food-safety assessments in the developing world; regulatory concerns and GM crops; and, realities/possibilities for crop biotechnology to mitigate or cope with effects of climate change.

Prior to joining ISNAR, Cohen worked for the US Agency for International Development as senior biotechnology specialist in the Office of Agriculture, before which he was with Dekalb Plant Genetics. His doctoral degree was in plant breeding and molecular genetics from the Department of Plant and Soil Sciences, University of Massachusetts, Amherst. He also served as a rural extension agent in Nepal, as part of his Peace Corps volunteer experience.

Patricia Zambrano is a Senior Research Assistant at IFPRI. A native of Colombia, she joined IFPRI as a senior research assistant in 1999. Her work focuses on biotechnology and research and development policy issues. Zambrano earned an undergraduate degree in economics from the Universidad de Los Andes, Bogotá, Colombia, and an MA in economics from the University of California, Davis.

Module III—Improving Quality of Life

Q&A

Moderator: Nancy Cox
University of Kentucky
Lexington, KY

Alan Wildeman (University of Gueph, Guelph, ON): A question for Dr. Chadwick. Is the matrix you talked about equally applicable in Africa and the United States or the United Kingdom or Canada for example? Or does the matrix need to be prioritized in different situations?

Ruth Chadwick: Ben Mepham, who developed the matrix, recognizes that it has drawbacks. However, it can be a useful way of structuring a discussion and looking at the different ethical dimensions of a problem. However, I think that it is true that the three principles, well-being, autonomy and justice, are principles of western ethical traditions and so it may very well be the case that it omits a lot of important considerations. Well, I mentioned one important consideration that it does omit and that's the perspective of feminist ethics, for example. And so yes it may very well need to be adjusted. If you think that that type of approach is useful it may very well need to be adjusted for different cultural contexts.

John McDermott (International Livestock Research Center, Nairobi, Kenya): I want to raise some issues regarding public and private goods—how they are developed and disseminated. First of all, in the general area of biotechnology most of the work we do in public research institutions doesn't lead to GM crops, for example. It leads to conventional breeding solutions sometimes or to other solutions. The second thing is: the nature of the goods. They are usually a mixture of public and private. For example, a new vaccine for animals could have important implications as a public good in terms of control or even eradication of disease for a whole country. It could have important social equity aspects. But it could also be used by individual farmers as a private good for safeguarding the health of their animals. Another issue we struggle with is—as a public research institute—we are not very good at the final stages of vaccine release. A lot of proprietary technology expertise with regulatory mechanisms is held in the private sector. So, my issues are how do we mix these public/private-good goals? One of our approaches has been to safeguard, as much as possible, the intellectual property in the public sector. But, my biggest problem as a research director is not that we safeguard intellectual property, but that we don't get products to farmers in a way that helps them; the research actually doesn't produce anything at the end of the day. We actually need some kind of private-sector collaboration.

Chadwick: Yes, that is very interesting. Certainly the distinction between public and private is much more complicated than it might appear. But, I was trying to outline the position of the Food Ethics Council, which is very concerned about proposals—what needs to happen in this area is more public/private partnerships. They see the way forward as encouraging more public-good projects. Not just in terms of thinking about products, but in thinking about genomics itself as a public good in terms of knowledge and development of infrastructure to enable people in developing countries to take advantage of that knowledge and develop their own projects. It's important to find ownership arrangements that do make that possible. That's the main point: ownership- and benefit-sharing arrangements are needed to facilitate that kind of development.

Joel Cohen: John, let me add that I didn't have the opportunity to present data on partnerships that we also collected in this sampling of public research. Over 60% of these institutions are working without any partnerships. Another 23% are working public to public and less than 10% are working with some kind of collaboration with the private sector, as follows:

Public-sector partner	Number of events	%
No partner	129	62
Foundation/Private	1	0.5
Private	13	6.2
Private/Public	5	2.4
Foundation	1	0.5
Foundation/Public	8	3.8
IARC	3	1.4
Public	49	23

It's a real indication that while that need is there—it's argued for, it may exist—there is virtually no experience with it now in the developing world. Institutions working alone are at a great disadvantage because they don't get the global expertise and knowledge that could help with their research.

Allan Eaglesham (NABC, Ithaca, NY): Dr. Remington may have an inside track on this. I'm referring to a situation that prevailed in Zambia recently. Although there was hunger—possibly even starvation—aid from the United States in the form of corn was declined because it was genetically modified.

Tom Remington: Fortunately I don't cover Zambia. But, it's a very interesting point. CRS was caught between a rock and a hard place. In particular, the Zambian Catholic Conference of Bishops came down very strongly in opposition to GMOs. There is a Social Peace and Justice Commission in Zambia that is very strong and very active and doing excellent work, headed by Peter Henriot. He has taken Catholic Social Teaching farther than anybody. However, I think he made a mistake in not focusing on the social justice issues. In trying to address the health issues—the issues of compromising exports to Europe, *etc*.—they, CRS, came down behind the Zambian Bishops on this one. I think that was a mistake. I think there was an undercurrent that Europeans were making suggestions that this could compromise exports to Europe. I never could figure out where the beef exports from Zambia to Europe were coming from; clearly they are not smallholders. So what's the big deal? Are these large South African farmers? I never figured that one out. So, it's a complex issue. We, CRS, are the largest mover of US-food aid. The US government refuses to label whether it is genetically modified or not. Why not? They don't want to because essentially all the maize and soy is GM. So the assumption is it's all genetically modified. It's a big issue and it's an issue that we don't know how to deal with. One last point: I heard the Minister of Agriculture being confronted by the BBC on how he could do this and put his people at risk. The point was made that Americans eat GM corn all the time with no health affects. The Minister said, "Look—they eat a bowl of corn flakes once a week, we eat meali-meal three times a day." I thought that was compelling logic from his point of view, so I don't have an answer. But, based in part on that experience, I try to concentrate on where I think NGOs—and CRS in particular—should be focusing and leave the health and environmental issues to those people who are better placed.

Audience Member: We've heard a lot about the precautionary principle. That doesn't sit very well in Canada as a useful standard. Certainly we support a precautionary approach. We look at Europe and it seems to be a bureaucratic quagmire where things get lost for years and years intentionally. Good scientists say that biotechnology is safe; we've done the testing, other countries have done the testing. But there doesn't seem to be any harmonization globally—that point has been made today. How do you respond to the comment that this is just a bureaucratic way of protecting the domestic market that it's basically a trade issue in a lot of ways—a non-tariff trade barrier?

Chadwick: I am involved in the regulatory system in the United Kingdom—at least I sit on the Advisory Committee on Novel Foods and Processes, which looks at safety and assesses the applications to put novel foods on the market. Yes, we do apply the precautionary principle. We also have the risk-assessment process that is based on purely scientific evidence. As a participant in that process, I don't have any sense of it being as you described. But then, I suppose you could argue that since I'm implicated in the system I would say that. Wouldn't I?

Audience Member: Especially in the UK there is a great deal of bias to protect the organic industry and this seems to be sacrosanct, from what I've read or observed. Organic is regarded as the ideal; everything has somehow to meet that standard. That seems to be politically motivated, perhaps because of Prince Charles. But not everybody worships organic food—there's a great deal of risk there as well.

Chadwick: Well, yes. You may be right that Prince Charles does have some influence, but he's not as great an influence as you might think. In my opinion, the present government is very pro-GM. I don't see it as supporting the organic movement in particular.

Kanayo Nwanze (Africa Rice Center, Abidjan, Ivory Coast): My question is for Tom Remington. If I heard you correctly, you indicated that the task of biosafety risk assessment will fall on the NGOs who have only a weak capacity to analyze data. Why does this responsibility fall on the NGOs and not on national systems in the countries that you referred to?

Remington: I wonder why also. It's just that there is a creative tension between those sorts of research and, in this case, the NGOs who are doing the extension work. I'll give you an example. The research institutions came up with a wonderful paradigm called "mother and baby" trials. I must admit that they took me in. It sounded really nifty: an on-farm multi-location trial involving hundreds of babies, fully replicated and statistically analyzable. Well, we were tasked to do this, to collect all the data. We failed miserably, to the great consternation and disappointment of our research partners. I said, "What we need to learn from this is that we don't have the quantitative capacity." If we want to do mother and baby trials—conventional varietal work—you need to come a lot farther down to our level and help us with it. Partnership yes, but you need to get closer to the field. We discovered the limit of our capacity and of our partner's capacity. Speaking of biosafety I must admit I'm a bit ignorant: how long does biosafety monitoring continue at the farm level? Does it continue? Or once a GM variety is released, once it's in the hands of the farmer, is there need for continued monitoring? If that's the case, then my concern is less.

Nwanze: Okay. The last part of your answer pacifies me. I was worried when you said that NGOs would take responsibility for risk assessment. How would GM plants come into a country if the national system does not officially provide clearance? This emphasizes what you said regarding the weak capacity for NGOs to do that. We need to be very cautious. If I may say so, the issue at stake here is that we should assist national programs or systems to increase capability, to assume the necessary responsibility to do the job. Otherwise, it will fall to institutions such NGOs, albeit of weak capacity, to do what national systems themselves should be doing.

Remington: In their recent paper, the FAO actually suggested that NGOs should actively support the GM process and should actively advocate for increased funding for GM crops, which got me wondering and worrying about what else NGOs would be tasked with doing. But, again, we won't be bringing GM plants into the country. It would be at the point when it reaches the farmer. At that stage, the farmer is usually involved in participatory evaluation. As Joel mentioned, that's the point at which farmers are coming over and grabbing hold of the product and saying thank you very much, I think this is good stuff. I don't see how you can have an on-farm pre-release without that being a *de facto* release, if the stuff is good.

Marc Saner (Institute on Governance, Ottawa, ON): I feel compelled to clarify the use of the precautionary principle in Canada. In a previous question it was said that few people in Canada are interested in it. Historically Canada was quite important in the design of the Convention on Biological Diversity and previous Prime Minister Brian Mulroney was the first one to sign it. So Principle 15 was endorsed by Canada. It entered legislation in Canada. It's in the Canadian Environmental Protection Act and also in the Oceans Act under two different names. In one case as "precautionary principle" and in other case as "precautionary approach." And I also believe it's in the newest version of the Pest Control Products Act. And finally our Privy Council Office, which is the central agency that ensures consistency of decision-making and policy-making has written up a guideline on how to use the precautionary principle after a very lengthy interdepartmental exercise. So, there is plenty of usage in Canada of the precautionary principle.

John Radin (USDA, Washington, DC): Dr. Cohen, I'd like to commend you for identifying some things that could be done and should be done fairly quickly regarding regulatory aspects in the less-developed countries. Are you aware of movement to try to initiate collaboration to simplify the highly segmented process?

Cohen: That is something that we are doing now. We are trying to reengage that process. Unfortunately, there have been scattered attempts before that have not come to fruition. It's difficult because the initiative comes from the agricultural sector through regional bodies that do not include regulators. So, we are trying to build regional and national consortia to look at that. Our entry points are modest—it's a long-term hope.

Ann Oaks [University of Guelph (retired), Guelph, ON]: In Canada, the Wheat Board tests the quality of wheat that comes from different farmers. It's a public enterprise, and it's something that industry south of the border complains about constantly. Is this the way we should be thinking, regarding the issue of testing being done by NGOs? There is distrust of industry because of its track record—the tobacco industry, for example. And there is secrecy because of patents. I think that testing and setting standards have to be at the public level, but sufficiently organized and sophisticated so that people can believe in it.

Remington: Obviously, quality assurance is very important. In East Africa, seed certification—originally intended to protect consumers—has been perverted; it's used really to protect commercial seed companies. It's now a barrier to entry by farmer seed entrepreneurs and small seed companies. So, I would agree with you in principle, but in practice quality assurance can be perverted and fail to serve the intended purpose. I can see I didn't answer your question.

Oaks: It seems to me that there needs to be a central place where the testing can be done, whether it's for quality or safety or whatever.

Tony Shelton (Cornell University, Geneva, NY): I'd like to get a point of clarification from Dr. Chadwick. The council of which you are a member, that makes these decisions: you said that you use the precautionary principle and then also a risk/benefit analysis. Can you clarify that? As Dr. Cohen explained it, there was really much more of a separation between the two.

Chadwick: Well, in making decisions about whether to allow something onto the market, the only thing we are allowed to look at is safety, really. It's based on a scientific assessment of whether there are any concerns about safety. It's not a risk/benefit analysis in that sense because we're not really looking at benefits. It's not within our remit to look, for example, at whether a functional food that claims health benefits has any benefits or whether it's likely to be effective.

Shelton: Or a crop that is insect resistant, whether that really has any benefit, your council focuses on the risk but not the benefit?

Chadwick: That's right.

Shelton: Okay. I just wanted that clarified. Although the principles that you outlined would be the same, or should be the same, throughout the world, in a developing country would you find that you would emphasize some of the principles more than others? That is to say, would you be more inclined to look at risk/benefit analysis in a developing country versus the United Kingdom or Europe where hunger is not a major concern?

Chadwick: We need to be clear about different spheres of operation here. The Advisory Committee of Novel Foods and Processes is purely part of the regulatory process in the United Kingdom and there are clear lines within which we can operate. When I'm talking about the principles in the ethical matrix, then that is within the sphere of general ethics. Although the Food Ethics Council has used that matrix, it doesn't have any regulatory status; it's an independent body that thinks about ethical issues in foods and agriculture. It was asked earlier whether the principles in that have global application, well this is a discussion in theoretical ethics because some people argue that they do have global application because everyone everywhere ascribes to the importance of well-being, choice and justice although they might interpret them differently. So, I'm not sure that one could say that any particular principle has greater priority in a particular part of the world. There is an ongoing debate about the priority of liberty as opposed to equality, and liberty and well-being, so I guess in certain conditions it would be more important to put an emphasis on basic needs rather than, say, on liberty.

Shelton: Right. I wonder if cultural aspects would profoundly influence the principles that you have listed there though? I don't know the answer to that, but I wonder if that would occur and what the ramifications would be for putting GM crops into developing countries that way.

Chadwick: Well, discussions I have had with bioethicists in China, for example, have led to the idea that although there might be pragmatic agreement on some of these principles, the underlying reasons that people might have for agreeing with them might be rather different because of different traditions. So, yes, I think there are important cultural differences to take into account.

Module IV—Ensuring Safe and Health Food

Module IV—Ensuring Safe and Health Food

Introductory Remarks

Spencer Henson
University of Guelph,
Guelph, ON

This session is titled *Ensuring Safe and Healthy Food* and we have already touched upon issues of safety and the healthfulness of food and of diets. Presumably healthy diets and safe food are common goals that everyone would agree upon. There are clearly differences in terms of priorities across the world although some would argue that those priorities are becoming more common. For example, obesity rates—notoriously high in Canada, the United States and in the United Kingdom—are also increasing very dramatically in many lower-middle-income countries. So, for example, the estimate that I saw from the International Food Policy Research Institute (IFPRI) was that the rates of clinical obesity, even in Latin American and Caribbean countries are now at 10% and increasing. Even in some countries of sub-Saharan Africa they are at 5%. So, we are seeing movement towards even more common priorities.

Health and safety are, as well as scientific constructs, also social constructs.

We have talked a lot about causes of food insecurity. The FAO estimates there are 842 million under-nourished people in the world and the number of food-insecure is clearly a lot bigger than that. And we have discussed the reasons, demand-side and supply-side factors—I have to get those words in, being an economist—and where we position biotechnology within that framework; I think that's a very important issue. And another issue that we have hinted upon, which for me at least is an interesting thing and a good thing, is that health and safety are, as well as scientific constructs, also social constructs. So, what represents healthfulness and safety is not only defined in terms of rates of obesity and in terms of gastrointestinal infections for example, but about how people feel in terms of what is healthy and what is safe. That creates many challenges in terms of dialogue and in terms of communication, but also in terms of setting priorities. What may be regarded as safe and healthy to an Indian consumer may be different from the opinions of a Canadian consumer to some extent.

A few days ago, when thinking about this conference I came across an interview with Hugh Grant, CEO of Monsanto, in the *Financial Times*: "We've Bet the Farm On This." Grant is from a Scottish farming family and in the article the challenge of heading Monsanto, particularly given its history, comes across. It contextualizes some of the discussions we've been having here. He asks: "Is a skeptical and frequently cynical audience prepared to listen? The mistake that companies like mine have made, but we're not exclusive in the mistakes category, is the belief that good science will prevail." Grant says that much of society doesn't speak "science." The debate has to move on and take account of the fact that we are shifting from what Grant calls a "trust-me" to a "show-me" society. A "trust-me" society is a paternalistic society that says, "Don't worry about it, it'll be fine, I know best. We have your interests at heart, this will work." According to Grant, the "show me" society says, "I might not understand the data and that's okay if I don't. But I want to know that I can access it at any time and I want to know that my views are relevant to this debate."

I don't necessarily agree with everything he says. I'm not sure what the term "good science" means, for example. But, his context and the challenges he articulated are interesting.

Ensuring Safe and Healthy Food has three eminent speakers: Edilberto Redoña, Florence Wambugu, and Suzanne Harris.

Rice Biotechnology for Developing Countries in Asia

Edilberto D. Redoña
Philippine Rice Research Institute
Science City of Muñoz, Philippines

Rice (*Oryza sativa* L.) is the staple food for more than three billion people, over half the world's population. It provides 27% of dietary energy and 20% of dietary protein in the developing world. Rice is cultivated in at least 114, mostly developing, countries and is the primary source of income and employment for more than 100 million households in Asia and Africa (FAO, 2004). Of the 840 million people suffering from chronic hunger, over 50% live in areas dependent on rice production. About 80% of the world's rice is produced on small farms, primarily to meet family needs, and poor rural farmers account for 80% of all rice producers (FAO, 2004). Less than 7% of the world's rice production is traded internationally (Maclean *et al.*, 2002) and with this small marketable surplus, prices fluctuate widely with droughts, floods, and typhoons (Hossain, 1997).

Rice is the dominant crop in Asia where, in many countries, it covers half of the arable land used for agriculture (Cantrell and Hettel, 2004). The Asian continent, host to 56% of humanity including 70% of the world's 1.3 billion poor people, produces and consumes around 92% of the world's rice (Papademetriou, 1999). Nine of the top-ten rice-producing countries in 2003, namely, China, India, Indonesia, Bangladesh, Vietnam, Thailand, Myanmar, the Philippines, and Japan are in Asia. China and India combined account for more than half of the world's rice area, and, along with Indonesia, consume more than three-fourths of the global rice production (Hossain, 1997; Maclean *et al.*, 2002).

In addition to being the world's most popular staple—cultivated for more than 10,000 years—rice provides a symbol of global unity and cultural identity for many countries where its cultivation is intertwined with religious observances, festivals, customs, folklore, and other traditions. Cognizant of this, the United Nations launched the International Year of Rice in 2004 with the theme Rice is Life, the first time a year has been dedicated to a single crop, to underscore the enormous implications of rice for human nutrition, global food security, and alleviation of poverty (FAO, 2004).

The Challenge to Increase Rice Productivity

Record rice-production increases occurred during the last three decades of the twentieth century, beginning with the Green Revolution. In many Asian countries, yield levels doubled or tripled from the pre-Green Revolution average of 1.9 tons per hectare (t/ha) (Figure 1). Between 1966 and 2000, populations of low-income countries increased by 90%, while rice production increased by 130% from 257 million tons (Mt) in 1966 to 600 Mt in 2000. Average per-capita food availability was 18% higher in 2000 than in 1966 (Khush, 2004). About 84% of the rice-production growth has been attributed to modern farming technologies such as varieties that are semi-dwarf, early maturing, non-photoperiod sensitive (and can, therefore, be planted more than once per year), and responsive to nitrogen (N) fertilizer (Maclean *et al.*, 2002). More than 2,000 modern varieties have been commercially released in twelve countries of South and Southeast Asia over the past 40 years (Cantrell and Hettel, 2004). Gradually, resistances and tolerances to biotic and abiotic stresses were incorporated into many of these varieties, thereby extending their cultivation and productivity potential. As a consequence, rice-production cost per unit output was reduced by 20 to 30%, which translated to reduced rice prices at the consumer level from about US$450/t unmilled rice in the early 1950s to less than US$300/t by 1999 (Maclean *et al.*, 2002). Furthermore, these productivity gains have allowed production to more than double and fulfill the demand of a population that grew by 80% in the same period. This has helped to reduce world market rice prices by 80% over the last 20 years (Cantrell and Hettel, 2004).

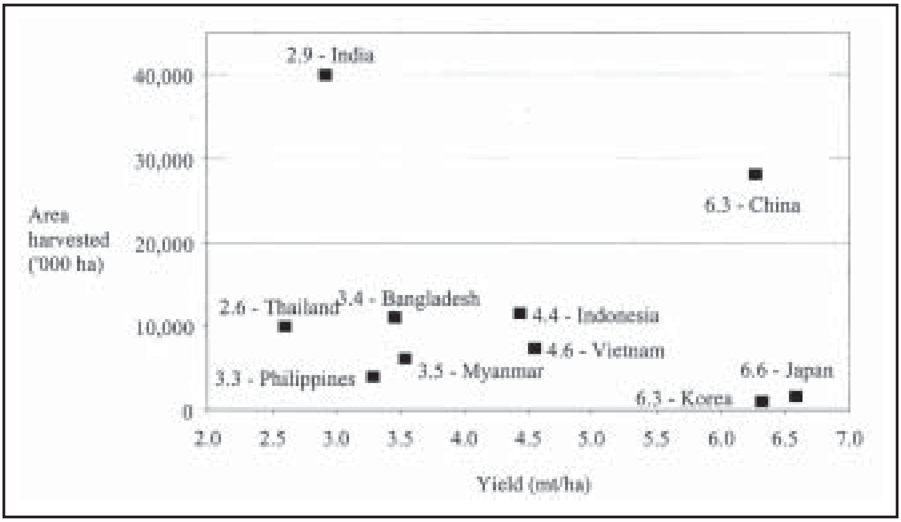


Figure 1. Area harvested and yield levels in major Asian rice-growing countries (FAO, 2004).

There is tremendous pressure, however, to further improve rice productivity in order for it to keep pace with population growth. In Asia, it is projected that demand for rice will increase by 70% over the next 30 years, driven primarily by population growth that, excluding China, is expected to increase by 51% (Hossain, 1997). The Asian population is expected to increase from 3.7 billion in 2000 to 4.6 billion in 2025 (Cantrell and Hettel, 2004). The urban population will nearly double from 1.2 billion to 2.0 billion, as people move from rural areas to the cities in search of employment.

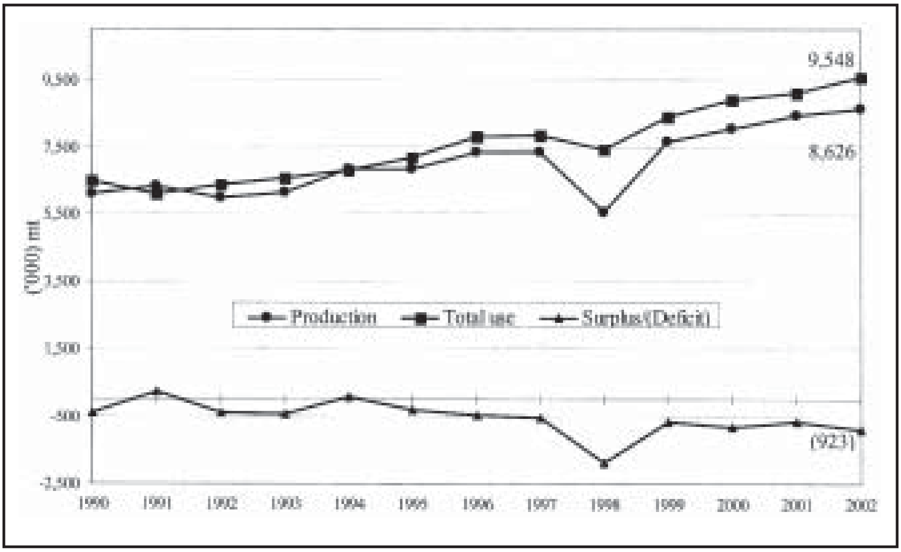


Figure 2. Trends in rice production, utilization, and importation in the Philippines, 1990–2002.

In the Philippines, 65% more rice, relative to present levels, has to be produced by 2025 to keep pace with demand by a projected population of about 107 million, growing by 2.3%/year (Figure 2). To keep up with projected demand, rice-production growth must be sustained at 3%/year, if importation is to be avoided, as espoused by many Asian governments. Given that annual rice-production growth rates have been decelerating to less than 2% per year, and the land frontier—the primary source of growth in recent years—is closing (Table 1), major technological progress has to be achieved in the next two decades for the population demand for rice to be met locally. Against the backdrop of decreasing land, labor, and water that can be devoted to rice production due to increasing competition from non-farming sectors, the challenge to increase rice productivity is indeed enormous.

TABLE 1. SOURCES OF GROWTH OF RICE PRODUCTION IN THE PHILIPPINES, 1970-2001.

Source of growth	All		Wet season		Dry season	
	1970–86	1986–01	1970–86	1986–01	1970–86	1986–01
	(%)					
Area	–0.18	0.96	–1.0	–0.89	1.4	2.9
Yield	3.9	0.67	3.9	0.71	3.5	0.66
Production	3.6	1.6	2.9	–0.18	4.9	3.6

CONSTRAINTS IN ASIAN RICE PRODUCTION

Rice productivity and quality are severely compromised by pests, diseases, and physiological and environmental factors. The crop is the world's single largest market for agrochemicals, consuming around US$3.7 billion annually, with agrochemical costs and crop losses amounting to tens of billions of dollars per year (DFID, 2004). Furthermore, rice cultivation per se is hobbled by resource constraints such as scarcity of water and scarcity of land. Clearly, therefore, technological progress is required in both the biotic and abiotic fronts.

There is a need to increase water productivity of rice.

Scarcity of Water

Rice is a moisture-hungry crop. It consumes twice the water needed to grow corn or wheat. Producing 1 kg of rice requires from 3,000 to 5,000 L of water (Cantrell and Hettel, 2004). In Asia, 90% of the total diverted freshwater is used for irrigated agriculture and, of this, 50% is used to grow rice (IRRI, 2001). By 2025, however, a "physical water scarcity" is expected in Asia's more than 2 million hectares (Mha) of irrigated dry-season rice and 13 Mha of irrigated wet-season rice, and most of Asia's 22 Mha of irrigated dry-season rice will be hampered by "economic water scarcity" (Tuong and Bouman, 2002). As drought is one of the main constraints to high yields also in rainfed-production systems in both the lowlands and the uplands, there is a need to increase water productivity of rice (Cantrell and Hettel, 2004).

Scarcity of Land

Due to competition from non-farming sectors, the land devoted to rice production is decreasing in many Asian countries. In the Philippines, for example, about 10,000 ha of prime rice land is lost annually to the urban and industrial sectors. With water resources becoming limiting and enormous resources required to construct irrigation facilities, there appears to be little room for future expansion of irrigated areas in developing countries. Hence, the contributions of fragile environments such as the rainfed lowlands, uplands, and salinity-prone areas to rice productivity growth will be increasingly important. Technologies, therefore, will be required not only for increasing rice productivity in these environments, but also for preventing resource and environmental degradation in marginal areas.

Pests and Diseases

Intensive and continuous cultivation makes rice vulnerable to various pests and diseases. Although breeding for resistance, coupled with popularizing integrated pest management, has contributed to managing pest populations and minimizing damage levels in many Asian countries, a wide range of viral, bacterial, and fungal diseases still causes economic losses in farmers' fields. For example, tungro, the most destructive viral disease in Southeast Asia, results in crop losses worth more than US$1.8 billion annually (DFID, 2004). On the other hand, aside from causing damage by direct feeding, insect pests also act as vectors for various important rice diseases. Among the most important in the Philippines, are tungro, bacterial leaf blight, sheath blight, and rice blast, while the important insect pests are brown planthopper, whiteback planthopper, and green leafhopper, the latter being the vector for the tungro virus.

Constraints and Yield Loss

Yield losses due to biophysical constraints have been extrapolated for Asia by Hossain (1997) and Evenson *et al.* (1996) (Table 2). In the irrigated ecosystem, yield losses due to technical constraints accounted for 20% (962 kg/ha) of the average yield, with soil-related problems being the most significant. On the other hand, yield losses due to technical constraints accounted for 33% of average yield in rainfed lowland and flood-prone ecosystems, with submergence being the most important, while it was more than 40% of the average yield in the upland ecosystem, with drought being the most significant. Overall, all technical constraints caused a total yield loss of about 23% or 833 kg/ha in Asia, with abiotic factors being more important than biotic for all ecosystems. Climate-related constraints like submergence, drought, and cold resulted in yield losses that ranged from 227 kg/ha (20% of average yield) for upland to 429 kg/ha (28% of average yield) for flood-prone ecosystems. Yield losses due to pests and diseases, on the other hand, were most significant in the rainfed ecosystem while those due to weeds were most important for the upland environment.

Tropical Hybrid Rice

In addition to China, a number of countries in tropical Asia, notably, India, Vietnam, the Philippines, Indonesia, Bangladesh, and Sri Lanka have launched national programs aimed at commercializing hybrid rice. These programs aim to exploit the phenomenon of heterosis or hybrid vigor, which provides about 1 to 1.5 t/ha (15 to 20%), higher yields than those obtained using the best inbred varieties under irrigated conditions. The associated seed-production technology that must accompany commercialization promotes the development of seed industries that provide additional rural employment. Already a commercial success in China,

TABLE 2. YIELD LOSS DUE TO TECHNICAL CONSTRAINTS IN THE RICE ECOSYSTEMS OF ASIA (EVENSON *ET AL.*, 1996).

Constraint	Irrigated	Rainfed lowland	Flood-prone	Upland	Average loss for Asia	
			(kg/ha)			(%)
Biotic						
Diseases	69	146	18	70	83	3.1
Insects	108	166	16	65	110	2.3
Other pests	29	88	21	120	52	1.4
Abiotic						
Water	400	288	429	227	358	9.9
Soil	356	75	13	80	229	6.4
Total	962	763	496	563	833	23
Loss of yield (%)	20	33	33	40	23	

In the Philippines, the commercialization of hybrid-rice technology has been embraced as the government's banner program for agriculture.

where 15 Mha (50% of the total rice area) are planted to hybrid rice varieties, about 1 Mha were estimated to be planted to hybrids in tropical Asia in 2003 (Virmani, 2003). In the Philippines, the commercialization of hybrid-rice technology has been embraced as the government's banner program for agriculture, with 200,000 ha planted to seven commercially released hybrids in 2004 (Redoña *et al.*, 2003). Results of the program from 2001 to 2003 showed an average superiority in the yield of hybrids of 1.59 t/ha or 36% over that of modern inbred varieties.

New Plant Type

In the early 1990s, IRRI started developing "new plant type" (NPT) rice that is expected to reach farmers' fields during this decade. With redesigned plant architecture that increases total biomass and harvest index, these "super" varieties—intended for direct seeding—are expected to yield about 20% more than current modern varieties. Several NPT lines with yields >10 t/ha have already been distributed, *e.g.* to Indonesia and the Philippines, for adaptation trials and three NPT varieties have already outyielded popular modern varieties in China by more than 1 t/ha (Cantrell and Hettel, 2004). NPT rices trace their lineage to both the indica and japonica subspecies and are, therefore, also valuable sources of genetic diversity in breeding for higher yield potential and heterosis.

"Aerobic" Rice

To strategically address the projected water scarcity, IRRI has also developed an "aerobic rice" technology that aims to significantly reduce the crop's water requirement below current levels. Patterned after the rice grown in irrigated upland areas of Brazil, the "aerobic" plant for tropical Asia is expected to yield 6 to 7 t/ha under a crop-management system that will provide only half as much water as rice requires today (Cantrell and Hettel, 2004). In China, where "aerobic" rice has been tested on 190,000 ha, yields of 6 to 7 t/ha have been obtained, while, in the Philippines, several varieties with yield potentials of approximately 6 t/ha have been identified for use under "aerobic" conditions (Bouman, 2003).

Integrated Crop Management

Following the successful promotion of an integrated pest management program across Asia, an even more comprehensive rice-crop management system—designed to close the yield gap—is being piloted in Vietnam, Thailand, Indonesia, and the Philippines, with the support of the United Nations Food and Agriculture Organization (FAO). It is referred to as "rice integrated crop management" (RICM). Similar to the Rice Check system that has been dubbed a major contributor to increases in rice yields in Australia, from 6 t/ha in 1987 to 9.7 t/ha in 2000 (Nguyen, 2002), it provides a platform for the integration of different production technologies and decision-making support tools that should allow farmers to move closer to the practice of real-time precision rice agriculture. In the Philippines, a Rice Check prototype that involves eight key checks throughout the growing season was piloted on-farm beginning in 2004.

Rice-Based Farming Systems

In line with the Asia's aim to improve the profitability of rice farming, alleviate poverty, and achieve food security at the household level, particularly in marginal or fragile environments where the poorest of Asia's farmers live, diversified systems that integrate crop, livestock, and fish components are being developed in several countries. In the Philippines, for example, crop relays that result in the highest profits have been identified for the rainfed lowland ecosystem, planting calendars based on agroclimatic data have been formulated for adoption by farmers, and GIS suitability maps have also been developed for use of local government units in the prioritization of agricultural programs.

Beginnings of Biotechnology in Rice

In modern parlance, "biotechnology" generally refers to genetic manipulation at the DNA level. However, it is important to note that not all biotechnology involves genetic engineering or recombinant DNA techniques that result in transgenic plants or genetically modified (GM) organisms. In the strictest sense, biotechnology could also refer to specialized fermentation processes, *in-vitro* culture techniques such as embryo rescue and double haploidization, and protein engineering. For the purpose of this paper, however, "biotechnology" will imply manipulations at the level of DNA.

The potential of plant biotechnology to contribute greatly to the world's fight against hunger and malnutrition, poverty, and environmental degradation—despite claims to the contrary—has already been generally acknowledged. In Asia, agricultural biotechnology has been recognized as having the potential to:

- increase crop and animal productivity,
- improve nutritional quality of food,
- broaden tolerance of crops for drought, salinity, and other abiotic stresses, and
- increase resistance of crops to pests and diseases (ADB, 2001).

Applied to problems of poor farmers, biotechnology holds the greatest promise for increasing yield potential and quality in many crops. This in turn should enhance the attainment of sustainable household and national food security and proper human nutrition, while increasing profits and reducing farming costs, thereby contributing to poverty alleviation, especially in fragile environments, where most of Asia's poor live.

One of the most comprehensive assessments of the potential that biotechnology holds for a given crop was made for rice by the Rockefeller Foundation (RF) in the process of developing its International Program on Rice Biotechnology (IPRB) (O'Toole *et al.*, 2001). Culminating in the publication Rice Research in Asia: Progress and Priorities (Evenson *et al.*, 1996), a series of studies identified the top-twenty priority traits for biotechnology research intervention, balancing research costs *vis-à-vis* the benefits from expected increases in rice productivity or value (Table 3). With clear research priorities in place, in the mid-1980s RF supported a 17-year program that laid the scientific foundation for rice biotechnology as we know it today. At about the same time, national agricultural research systems (NARS) around Asia began building capacity for biotechnology. The salient accomplishments of the IPRB include:

- the generation of the first DNA molecular marker map of rice;
- the transformation and regeneration of rice;
- the use of rice-pest genomic information to understand host-plant resistance;
- discoveries that changed the way rice geneticists view breeding objectives, such as insect resistance, abiotic-stress tolerance, and hybrid rice;
- the discovery of rice's pivotal genomic position in the evolution of cereal species;
- the transfer of resulting biotechnologies to institutions in rice-producing and -consuming countries; and
- the strengthening of both physical and human resources in cooperation with national and international rice research systems in Asia, Africa, and Latin America (O' Toole *et al.*, 2001).

Table 3. Importance of rice research challenges measured by equity-weighted net present value (NPV) and potential of biotechnology (BT) to address the challenge (Herdt, 1991).

Challenge	NPV worldwide	Weighted NPV x BT potential
Brown planthopper	1,944	1,944
Tungro virus	1,726	6,905
Gall midge	1,292	2,583
Greater lodging resistance	1,228	1,228
Cytoplasmic male sterility	1,161	2,322
Upland drought/blast	1,085	1,962
Yellow stem borer	945	3,781
Submergence (flash flood)	842	1,685
Weeds	718	359
Seedling vigor	540	1,080
Birds	412	206
Cold at seedling	310	310
Drought at anthesis	288	575
Apomixis	275	275
Bacterial blight	274	137
Waterlogged	262	524
Coastal saline/acid	256	256
Sheath blight	168	336
Storage insects	158	158
Ragged stunt virus	155	621

More than 400 rice scientists, primarily from Asia, were trained in advanced laboratories around the world.

The last item involved international collaborative research-cum-training that successfully linked emerging national rice biotechnology efforts directly to advanced research institutes in the United States, Europe, Japan, and Australia, resulting in the training of more than 400 rice scientists, primarily from Asia, in advanced laboratories around the world. At least seventy-three institutions in twelve Asian countries have received research grants and had up to twenty scientists funded for formal training, including: PhD fellowships; dissertation fellowships; postdoctoral fellowships; visiting-scientist fellowships; biotechnology career fellowships; and technology-transfer fellowships in advanced laboratories and universities in developed countries (Table 4, O'Toole *et al.*, 2001).

Table 4. Breakdown of number of institutions by country where formal training was sponsored under the Rockefeller Foundation's International Program on Rice Biotechnology (O'Toole *et al.*, 2001).

	Number of institutions according to number of researchers trained[a]						
Country	>20	15–19	10–14	5–9	3–4	1–2	0
Bangladesh	–	–	–	1	1	–	–
China	–	1	4	4	2	6	5
India	1	1	–	5	7	7	3
Indonesia	–	–	–	1	–	1	–
Malaysia	–	–	–	–	–	1	–
Nepal	–	–	–	1	–	–	2
Pakistan	–	–	–	1	–	–	1
Philippines	–	–	1	1	–	–	
South Korea	–	–	1	–	–	–	1
Sri Lanka	–	–	–	–	–	–	1
Thailand	–	–	1	1	–	3	1
Vietnam	–	–	1	2	–	3	–
Latin America	–	–	–	–	–	1	3
Total	1	2	8	17	10	22	17

[a]Column headings reflect the number of scientists trained under IPRB sponsorship.

The Asian Rice Biotechnology Network (ARBN) was formed in 1993, with IRRI as coordinator. It facilitated collaborative research amongst several Asian rice-breeding programs with a primary objective of developing disease-resistant varieties through the application of DNA-marker technology (Leung *et al.*, 2004). Among the major Asian R&D institutions involved were the Indonesian Agricultural Biotechnology and Genetic Resources Institute in Bogor, Indonesia; the Central Rice Research Institute in Cuttack, Orissa, India; the Punjab Agricultural University in Ludhiana, Punjab, India; the Philippine Rice Research Institute (PhilRice) in Muñoz, Nueva Ecija, Philippines; the Agricultural Genetics Institute in Hanoi, Vietnam; and the China National Rice Research Institute (CNRRI) in Hangzhou, Zhejiang, China.

Progress in Rice Biotechnology Applications

With increased activities in biotechnology from the mid-1980s, rice gradually became the "model monocot" in molecular genomics research, and eventually was the first food crop to have its genome sequenced. Among the key advantages that rice offered as a model system were its small genome (~430 Mb) (Arumuganathan and Earle, 1991); the development and availability of a complete genome sequence (Komari *et al.*, 1998; Feng *et al.*, 2002; Goff *et al.*, 2002; Sasaki *et al.*, 2002; Yu *et al.*, 2002; The Rice Chromosome 10 Sequencing Consortium, 2003), its diverse germplasm (84,000 accessions at IRRI); and the development of a number of key resources for genomic mapping research (Chen *et al.*, 2002; McCouch *et al.*, 2002; Wu *et al.*, 2002). The progress achieved in biotechnology applications for rice improvement in two major areas—the use of molecular markers for identifying and introgressing favorable genes and gene combinations within the rice species, and the use of transgenic technologies to incorporate traits for herbicide tolerance, biotic-stress resistance, abiotic-stress resistance, and nutritional value into rice—was recently summarized by Coffman *et al.* (2004).

Use of Molecular Markers

The development of the first rice molecular map in the late 1980s (McCouch *et al.*, 1988) sped up molecular genetics research in rice. Among the early molecular marker applications for rice improvement were:

- construction of dense genetic maps using different populations,
- tagging and/or introgression of major genes and those underlying quantitative traits, referred to as quantitative trait loci (QTL),
- high-resolution characterization and fingerprinting of germplasm,
- assessment of the diversity of germplasm pools, and
- map-based gene cloning.

Molecular markers offered great potential for increasing the precision and speed of rice breeding as, among other advantages over phenotypic markers, they provided the ability to screen breeding populations regardless of growth stage; they permitted screening for traits that were extremely difficult, expensive, or time consuming to score phenotypically; and they distinguished the heterozygous condition without need for progeny testing (Coffman *et al.*, 2004). Molecular markers provided geneticists with powerful tools to dissect the inheritance of economically important traits, many of which are quantitatively inherited and complex in nature. Thus, studies dealing with QTLs were carried out on seedling vigor and tolerance to a variety of environmental stresses including drought, submergence, salinity, and mineral deficiencies and toxicities (Champoux *et al.*, 1995; Redoña and Mackill, 1996; Xu and Mackill, 1996; Flowers *et al.*, 2000; Gregorio, 2002; Price *et al.*, 2002). These traits were considered primary targets for molecular marker-aided selection (MAS) as breeding for them using conventional techniques often proved to be difficult.

MAS, or the selection of traits based on the presence or absence of a molecular marker (in *lieu* of phenotype) has already received a lot of emphasis in rice. The development of simple and less-costly marker systems based on the polymerase chain reaction (PCR) such as the simple sequence repeats or SSRs (McCouch *et al.*, 2002) contributed greatly to the use of MAS in various laboratories in developing countries. For example, at PhilRice—the NARS for rice in the Philippines—MAS studies are conducted to develop varieties resistant to bacterial blight, including the pyramiding of two to three bacterial-blight-resistance genes in a common genetic background, both for inbred and hybrid rice breeding. Gene pyramiding is expected to provide durable resistance against insect pests and diseases; early attempts in this direction were focused on bacterial blight and rice blast diseases and the brown planthopper. Introgressing genes from wild relatives into cultivated rice has also been accomplished with the aid of molecular markers, such as the bacterial-blight-resistance gene from *Oryza longistaminata* (Ronald *et al.*, 1992), and the yield traits from *O. rufipogon* (Thomson *et al.*, 2003). Markers have also been used to minimize the linkage drag that occurs in wide crosses and to obtain the desired recombinants in fewer generations during backcrossing (Blair *et al.*, 2003; Takeuchi *et al.*, 2003). Whole-genome, marker-based selection fosters new opportunities and makes efficient use of genetic variation both in cultivated rice and its wild relatives.

One of the most significant developments aided by the use of molecular markers in rice was the map-based cloning of Xa 21 and its subsequent use in developing varieties with broad-spectrum resistance to bacterial blight (O'Toole *et al.*, 2001). Starting with the genetic mapping, using RFLP markers of the Xa 21 locus in 1990 (Ronald *et al.*, 1992), the gene was cloned using map-based cloning techniques and a bacterial artificial chromosome library was made by 1995 (Song *et al.*, 1995; Wang *et al.*, 1995). By 1997, the gene had been pyramided with other Xa genes using PCR-based MAS (Huang *et al.*, 1997) and, by 1998, Xa 21 had been transformed into elite lines (Zhang *et al.*, 1998); field trials were conducted in China, India, and the Philippines by 1999. By 2000, a hybrid rice parental restorer line had been improved through MAS, resulting in resistant hybrid rices under field conditions (Chen *et al.*, 2000).

The IRRI-coordinated ARBN, supported by the Asian Development Bank (ADB) and the RF, played a key role in developing capacity for marker-aided analyses of pathogens and host-plant resistance in several national breeding programs. This network approach was found essential for the sharing of resources and providing sustained training in the adoption of new biotechnology tools and genetic knowledge in individual breeding programs of various NARS in Asia (Leung *et al.*, 2004). As a result of ARBN activities, elite or commercial rice lines with multiple disease-resistance genes have been developed in several participating countries (Table 5).

TABLE 5. MARKER AIDED SELECTION-IMPROVED VARIETIES AND THEIR CORRESPONDING INCREASES IN YIELD DEVELOPED BY RESEARCH TEAMS FROM ASIAN NARS (LEUNG *ET AL.*, 2004)

Country	Background commercial/ Yield standard	Released (R)/ Near-release(NR)	Yield (t/ha)	Gain over yield standard (%)
Philippines	IR64	AR32-19-3-2 (NR)	5.1	0
	IR64	AR32-19-3-3 (NR)	6.7	31.4
	IR64	AR32-19-3-4 (NR)	6.1	19.6
	BPI Ri10	AR32-4-3-1 (NR)	6.0	17.6
	BPI Ri10	AR32-4-58-2 (NR)	6.5	27.5
	PSB Rc28	Yield standard	5.1	–
Indonesia	IR64	Angke (Bio-1) (R)	5.4	20.0
	IR64	Conde (Bio-2) (R)	5.4	20.0
	IR64	Yield standard	4.5	–
India	PR106	IET17948 (PR106-P2) (NR)	8.2	22.4
	PR106	IET17949 (PR106-P9) (NR)	7.9	17.9
	PR106	Yield standard	6.7	–
China	Zhong 9A/ Zhonghui 218	Hybrid Guofeng No. 2 (NR, R)	7.8	11.4
	II-3A/ Zhonghui 218	Hybrid II You 218 (NR, R)	8.3	18.6
	Shanyou 46	Yield standard	7.0	–

No transgenic rice has yet been commercialized in an Asian country. However, two GM varieties, both with herbicide tolerance, have passed the regulatory approval processes in the United States: the Liberty-Link™ rice of Aventis Crop Science (now Bayer CropScience) and CLEARFIELD™ rice from BASF, Inc.

Use of Transgenic Technologies

No transgenic rice has yet been commercialized in an Asian country. However, two GM varieties, both with herbicide tolerance, have passed the regulatory approval processes in the United States: the Liberty-Link™ rice of Aventis Crop Science (now Bayer CropScience) involving phosphinothricin (PPT) herbicide tolerance, specifically ammonium glufosinate, and CLEARFIELD™ rice involving imidazolinone herbicide tolerance from BASF, Inc. (AgBios, 2004). Ten trials on 11 ha and twelve trials on 45 ha were conducted in 2002 and early 2004, respectively, 90% of which involved Monsanto (Jia *et al.*, 2004). To indirectly gauge the extent of use of GM technology Coffman *et al.* (2004) utilized information on patent applications and classified these into the areas of:

- herbicide tolerance,
- biotic-stress resistance,
- abiotic-stress resistance; and
- nutritional traits.

Up to 2002, 307 patents had been filed in rice biotechnology from 404 different groups (Brookes and Barfoot, 2003). The largest number of patents was held by DuPont/Pioneer (sixty-eight), followed by Monsanto (thirty-three), Syngenta (thirty-two), Bayer (nineteen), public sector institutions in Japan, and Japan Tobacco.

***For abiotic-stress tolerance, transgenic rice plants that produce trehalose at three to ten times the normal rate—resulting in tolerance to drought and/or salinity—have been developed by introducing the otsA and otsB genes for trehalose biosynthesis from* Escherichia coli.**

Amongst various traits, herbicide tolerance has been the major focus for the private sector. In the United States, Monsanto and Bayer were responsible for 80% of GM-rice field trials, primarily addressing herbicide tolerance (Brookes and Barfoot, 2003). Other countries in which herbicide-tolerant GM rice has been field tested include Italy, Brazil, Argentina, and Japan, and possibly China (Coffman *et al.*, 2004). Biotic-stress resistance, on the other hand, has been the primary focus for public-sector research institutions including those in Asia (Brookes and Barfoot, 2003). Specific traits being worked on using GM technologies include resistance to bacterial blight using the Xa21 gene, rice blast, rice hoja blanca virus, rice tungro spherical virus, rice yellow mottle virus, rice ragged stunt virus, the brown planthopper, and yellow stem borer, the latter—using *Bt* technology—being the closest to commercialization. For abiotic-stress tolerance, transgenic rice plants that produce trehalose at three to ten times the normal rate—resulting in tolerance to drought and/or salinity—have been developed by introducing the otsA and otsB genes for trehalose biosynthesis from *Escherichia coli* (Garg *et al.*, 2002).

Perhaps one of the most promising, albeit controversial, applications of transgenic technology in rice has been the development of vitamin A-enriched varieties, popularly known as Golden Rice™ due to the slightly yellow color conferred to the endosperm (Potrykus, 2000; Figure 3). Beginning as a collaborative project in the early 1990s between the Swiss Federal Institute of Technology (ETH-Zurich) and the University of Freiburg, Germany, with Ingo Potrykus and Peter Byer, respectively, as lead collaborators, the Golden Rice™ project drew financial support from ETH-Zurich, the European Commission, and the Rockefeller Foundation.

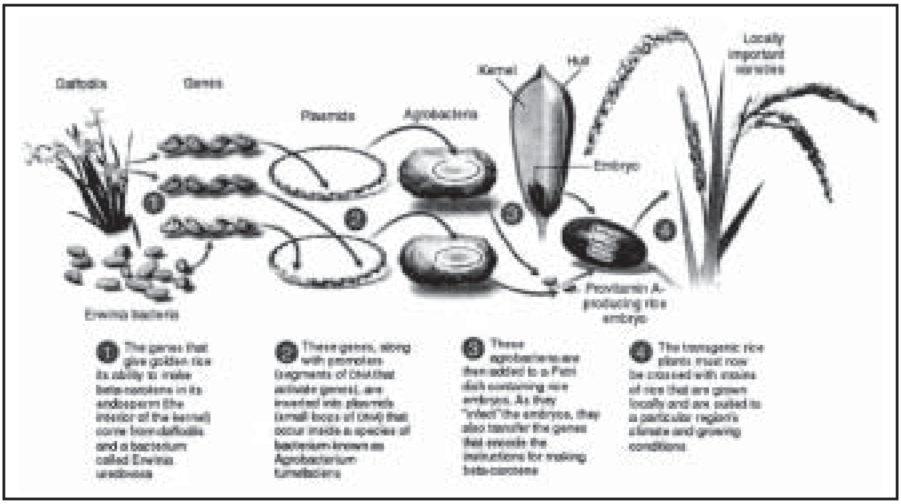


Figure 3. Development of Golden Rice™ (ISAAA, 2004a).

Vitamin A is considered essential for children and women of childbearing age and, worldwide, nearly 134 million children are at risk for diseases related to vitamin-A deficiency (VAD), including some 3.1 million preschoolers who suffer from eye damage, and nearly 2 million under 5 years of age who die each year from diseases linked to persistent VAD. In Southeast Asia alone, 5 million children become at least partially blind every year due to VAD. Golden Rice™ has the potential to improve the supply of vitamin A in the human diet, thereby, alleviating the suffering and death of millions of people, especially those who cannot afford diet diversification (ISAAA, 2004a).

With the proof of concept for rice to produce and accumulate pro-vitamin A (beta-carotene) in the seed endosperm tissue through genetic engineering already demonstrated (Beyer *et al.*, 2002), new vitamin-A enriched materials are now in the pipeline, including several popular Asian indica varieties such as IR64. Some of these new materials are said to contain ten times more pro-vitamin A than the original Golden Rice™ material that was eventually found unsuitable for commercialization as they were in a genetic background (japonica) not grown in most Asian countries. Reported to involve "clean" events, without cross-border transfers or antibiotic markers, the new materials are being readied for backcrossing and stability and field testing in 2004, while vitamin-A absorption and bioavailability tests are underway or planned in the Philippines, China, and the United States (Datta *et al.*, 2003; Coffman *et al.*, 2004; Cantrell and Hettel, 2004).

Another promising use of transgenic technology to improve human nutrition is in combating iron deficiency. One of the most common micronutrient deficiencies, it affects about 3.5 billion people worldwide and causes anemia, heart problems, neurological disorders, *etc.* The ferritin gene from *Phaseolus vulgaris* has been introduced into rice, resulting in doubling to tripling of the iron content in the endosperm, even after polishing the grain (Vasconcelos *et al.*, 2003). To improve the bioavailability of iron, since it is usually complexed with phytic acid, genes from *Aspergillus fumigatus* encoding a thermotolerant phytase protein and a cysteine-rich metallothionein-like protein were also introduced into rice resulting in a seven-fold increase in cysteine level and a 130-fold increase in phytase level (ISAAA, 2004b).

Only the Philippines has so far approved the commercial release of a transgenic food crop: a **Bt*****-enhanced corn.***

Many NARS in rice-growing countries of Asia that are endowed with universities and agricultural research institutes with biotechnology research capacity are actively involved in research on transgenic technologies, encouraged by supportive government policies. In a recent study by the International Food Policy Research Institute (Atanassov *et al.*, 2004), 209 transformation events were reported to have already been done in seventy-six scientific institutes in sixteen countries. Of these, 109 (52%) were done in seven Asian countries, namely, China (thirty), Indonesia (twenty-four), India (twenty-one), Philippines (seventeen), Thailand (seven), Pakistan (five), and Malaysia (five). Of these countries, however, only the Philippines has so far approved the commercial release of a transgenic food crop: a *Bt*-enhanced corn. Although the highest number of transformation events for any crop was reported for rice (18%), followed by potato (11%), maize (8.6%), and papaya (6.2%), a GM rice variety has yet to be commercialized in Asia.

To hasten public acceptance of biotechnology, a massive public-education campaign uses the tri-media as well as various public fora, and involves the government, private, NGO, and religious sectors.

In the Philippines, both IRRI and PhilRice have on-going biotechnology programs employing molecular marker and transgenic technologies, as well as other more conventional techniques such as *in-vitro* culture and wide hybridization. With the Philippine government declaring a supportive policy, the use of biotechnology is embedded as a strategy for achieving the goals set by the irrigated lowland, direct-seeded, rice for fragile environments, and hybrid rice multidisciplinary R&D programs of PhilRice. GM technology, in particular, is being used to improve high-yielding varieties, including NPTs and hybrid parental lines (Aldemita *et al.*, 2004). The Philippine focus is on tungro, sheath blight, blast, and bacterial blight diseases, as well as on insect stem-borer, and tolerance of salinity. Genes procured from laboratories around the world and modified for *Agrobacterium tumefaciens*-mediated transformation, are being used to generate transgenic plants. A number containing chitinase and glucanase genes have already been produced and tested under controlled screenhouse conditions. Moreover, PhilRice has conducted the first and only contained field trials for any GM rice in the Philippines; transgenic IR72 plants containing the Xa21 gene for bacterial-blight resistance showed complete resistance to nine Philippine races of the pathogen. Furthermore, transgenic plants with the pin2 gene are being developed to improve stem-borer resistance, while a coat-protein gene from the rice tungro bacilliform virus is being used in *A. tumefaciens*-mediated transformation. PhilRice, a member of the Golden Rice™ Network, has undertaken backcrossing work on discarded original Golden Rice™ materials. To expedite the availability of vitamin-A enriched rice to consumers, PhilRice hopes to continue its active participation in this network, which involves other Asian countries such as Indonesia, Vietnam, India, Bangladesh, and China, as well as partners in developed countries such as the United States, Germany, the United Kingdom, and Switzerland. Already, guidelines on the national testing of GM rice prior to commercialization are being prepared. To hasten public acceptance of biotechnology in general, and GM rice in particular, PhilRice, along with other Philippine government agencies, has spearheaded a massive public-education campaign using the tri-media as well as various public fora, and involving the government, private, NGO, and religious sectors.

Work in Progress

The availability of the complete rice-genome sequence offers opportunities to further our understanding of natural genetic variation and the effects of alleles and their interactions, particularly for traits that are of importance in rice breeding, using specific genetic backgrounds and under specific environments. At IRRI, for example, biotechnologists are systematically assessing the array of phenotypes resulting from the disruption of putative gene sequences in mutants, near-isogenic lines, permanent mapping populations, and elite and conserved germplasm through an initiative on functional genomics (Hossain *et al.*, 1997; Leung *et al.*, 2004). However, these gene-discovery and allele-mining efforts require the annotation of the rice genome and the subsequent construction of databases and information resources. The use of information and communication technology and bioinformatics, such as the IRIS (Bruskiewich *et al.*, 2003; http://www.icis.cgiar.org/) and GeneFlow (http://www.geneflow.com) databases, should make the accumulating information more easily accessible to scientists, especially breeders in rice-growing countries.

Other work in progress includes attempts to transfer the C_4-photosynthetic pathway and leaf anatomy genes of maize to C_3 rice in order to improve the latter's radiation-use efficiency while reducing transpirational water loss and N-fertilizer requirement, and studies aiming to more thoroughly understand genetic variation for drought tolerance using genomics and bioinformatics tools in order to identify the exact genes involved (Cantrell and Hettel, 2004). Another promising area is the genetic engineering of N_2-fixation capacity into rice; attempts to engineer the nif-regulon into the chloroplast genome have the objective of making rice only partially dependent on external N and able to provide additional N during the grain-filling period to maintain the photosynthetic apparatus for a longer period of time (Potrykus, 2000). Over the medium and long terms, apomixis research, started earlier at IRRI, needs to be vigorously pursued using biotechnology in order to capture—and make available to resource-poor farmers—the benefits of heterosis.

Issues, Concerns, and Opportunities

Setting Biotechnology R&D Priorities

It may be argued that most of the earlier rice biotechnology activities, particularly in the public sector, and on transgenic technology applications, were more science-driven than attuned to the needs of ordinary farmers. A case in point is the development of Xa 21-enhanced IR72, a variety that, while high-yielding, is of little economic importance to farmers. In this regard, it is important to note that for GM rices to be useful, at least in the short term, and to gain rapid acceptance amongst resource-poor farmers, it is best that they be derived from varieties already widely grown and suited to specific agroenvironments (DFID, 2004). Ranged against the challenges confronting rice cultivation in most Asian rice-growing countries today, it is clear that, trait-wise, to have the greatest impact, international as well as NARS biotechnology research should focus, on one hand on the most important diseases and pests, and physiological and environmental factors that reduce productivity and quality as discussed earlier, and on the other hand on increasing yield potential. An example of trait prioritization, has been advanced by Hossain *et al.* (1997, Table 6) for achieving the greatest impact on the lives of poor rice farmers and consumers, while being complementary to conventional rice-improvement efforts. Obvious from their analysis is the treatment of biotechnology not as a be-all solution to existing problems but as a tool or strategy complementary to conventional breeding efforts. To ensure relevancy of the biotechnology R&D agenda, a bottom-up approach is needed in the crafting of priorities, with farmers' and other stakeholders' needs and concerns adequately addressed. Such an approach should benefit from the rich indigenous knowledge of local farming communities on specific rice-production constraints, while facilitating public acceptance and ensuring the "trickling down" of benefits from biotechnology-derived products.

It is incumbent upon the public sector to develop a "pro-poor" biotechnology R&D agenda.

Need for More Public Investments

There remains an imbalance in R&D investments in rice biotechnology that tends to favor developed countries, thus impacting on the potential of biotechnology to boost agriculture in the developing world and to alleviate the plight of resource-poor rice farmers. The concentration of biotechnology R&D in developed countries and the limited private-sector effort in developing countries, particularly in Asia, has raised concerns over the economic concentration of biotechnology in favor of developed countries and multinational companies (ADB, 2001). As the private sector is unlikely to undertake rice biotechnology research based primarily on the pressing needs of resource-poor farmers—due to difficulties in recouping costly investments—it is incumbent upon the public sector to develop a "pro-poor" biotechnology R&D agenda. Furthermore, public research products would have to gain similar approval as those developed by the private sector if transgenic research products and their concomitant potential benefits are to reach the poor.

While scientists in Asian countries have demonstrated the capacity to successfully undertake biotechnology R&D relevant to the needs of resource-poor farmers, the desired phenotypes have been few when compared to traits being developed by multinational firms and advanced research institutes in the developed world (Nuffield Council on Bioethics, 2004). One noteworthy aspect, however, has been the case of Thailand, which established the National Center for Genetic Engineering and Biotechnology (BIOTEC) in 1983. BIOTEC has supported biotechnology R&D in six areas, including the improvement of disease resistance in rice, particularly against rice blast. This disease affected 200,000 ha of rice in Thailand in 1993, causing serious economic loss and resulting in government intervention to

TABLE 6. PRIORITIZATION OF TRAITS FOR BIOTECHNOLOGY INTERVENTION IN DIFFERENT RICE-GROWING ENVIRONMENTS (HOSSAIN *ET AL.*, 1997).

				Preferred approaches*		
Priority traits		Target environment	Available products	Conventional breeding	Marker-aided selection	Transgenic
Stress tolerance	Bacterial blight	Rainfed lowland	Genes, markers, transgenic lines	++*	++++	++++
	Sheath blight	Irrigated, high yield	Transgenic lines	+	+	++++
	Blast	Upland	Markers	+++	+++	+
	Stemborer	All	Transgenic lines	+	0	++++
	Drought	Rainfed lowland, upland	Under development	++	+	+
	Salinity	Coastal		+++	+	++
Nutritional value	Vitamin A	areas	Gene constructs, transgenic lines	+	0	++++
	Fe		Gene constructs	+++	0	+++
	Zn			+	0	?
Yield enhancement		All ecosystem	Elite lines	++++	++	++

*The more "+" marks, the higher the priority; 0 = not applicable.

With field testing of various transgenic rices in progress since 1998, and with 53 ha planted in 2003, China is poised to becoming the first country in the world to commercialize transgenic rice.

assist stricken farmers, costing about US$10 million. Since then, BIOTEC has supported research for the molecular genetic characterization of local blast isolates and mapping of blast-resistance genes, with focus on aromatic varieties for Thailand's export rice market. In 1999, BIOTEC also provided US$3.7 million to fund the "Rice Genome Project Thailand," particularly for the sequencing of rice chromosome 9, which contains a QTL for tolerance of submergence, a very important concern of Thai farmers (Tanticharoen, 1997). Most rice-growing countries in Asia, with the exception of China and India (Atanassov *et al.*, 2004), however, have yet to launch similarly focused government initiatives on rice biotechnology R&D. In China, investments on public-sector biotechnology research have risen dramatically to $1.2 billion for 2001–2005, a 400% increase over 1996–2000 levels, with about $120 million allocated for transgenic rice R&D (Jia *et al.*, 2004). With field testing of various transgenic rices in progress since 1998, and with 53 ha planted in 2003, China is poised to becoming the first country in the world to commercialize transgenic rice.

Importance of Collaboration

Given the varying capacities for biotechnology research among rice-growing NARS and the limited resources allocated for biotechnology research in the public sector—unintentionally abetted by the phasing out of the Rockefeller Foundation's IPRB (O'Toole *et al.*, 2001), the constraints in NARS R&D budgetary allocations, and the reduction of funding support for international agricultural research centers (IARCs) including IRRI (Cantrell and Hettel, 2004), the need for biotechnology R&D practitioners to collaborate has become paramount. Collaborations need to be pursued at the individual, institutional, governmental, bilateral, regional, and international levels to ensure not only that the highest returns for R&D investments are attained, but also to facilitate regulatory approvals and biotechnology product commercialization. At the national level, the creation of a coordinating body such as BIOTEC in Thailand (Tanticharoen, 1997) should provide a mechanism for increasing efficiency in the use of limited national R&D budgetary allocations through the avoidance of research duplication and through sharing of in-country research capacity. On the other hand, a regional collaboration approach, as exemplified by the ARBN (Leung *et al.*, 2004), should be able to develop a biotechnology R&D agenda focused on the shared needs of rice farmers in the region and, where possible, pool human, scientific, and financial resources or, alternatively, parcel out the research portfolio as was done in the rice-genome-sequencing initiative. One type of formal collaboration that is yet to be explored involves bilateral arrangements between countries. In the development of transgenic technologies, such South-to-South collaboration would facilitate learning and sharing of common approaches, genes, germplasm, regulatory trials, and biosafety-related information (Atanassov *et al.*, 2004). Already established broad-based regional cooperative efforts, such as the Association of Southeast Asian Nations (ASEAN) and the Asia Pacific Economic Conference (APEC) should be tapped to support these regional biotechnology undertakings. At the international level, programs that help rice scientists from developing countries to train, further hone their capacities, and maintain ties with advanced laboratories at the IARCs and in developed countries need to be supported.

IARCs and the Private Sector

With many NARS still not fully able to undertake, solely by themselves, activities spanning the whole biotechnology research, development, and commercialization spectrum, IRRI and similar international institutions will continue to contribute as technology and knowledge providers, as well as builders and enhancers of biotechnology capacity. Of particular importance for IRRI is the provision of strategic research outputs that, already, several NARS in Asian countries are capable of transforming into applications and products. These include protocols, gene constructs, and markers for traits relevant to local problems, but prohibitively expensive for NARS to develop single-handedly. Alternatively, IRRI should be able to complement its strategic research program with a product-development thrust, focusing on biotechnology-derived advanced breeding lines and varieties, with traits commonly of high relevance amongst Asian countries. The product-development portfolio includes varieties that are tolerant of drought, of high nutritional value, and are resistant to major diseases such as tungro and bacterial blight. The role of IRRI as facilitator in the transfer of useful technology and products amongst NARS through the sharing of hardware, knowledge, and experience needs to be strengthened. Equally important is its role in facilitating the formation of effective NARS/public-sector and private-sector collaborations, so that NARS may access private-sector-held intellectual property (IP) on rice biotechnology and products. IRRI can also serve as a clearinghouse for IP-protected technologies from both the public and private sectors to facilitate access by NARS scientists. Training support by IRRI and similar institutions for NARS should now include those designed to advance NARS capacity on the science and management of biotechnology, IP rights, biosafety and food-safety regulations, and international negotiations. As Cantrell and Hettel (2004) argued, with IRRI's strengths, it can serve as the unbiased broker and facilitator amongst the rice NARS, advanced research institutions, and the private sector.

Other international organizations, such as the FAO, can help expedite progress in rice biotechnology in Asia by promoting and supporting networking mechanisms such as the South-to-South cooperation model. They can also help in developing and supporting infrastructure for public-good agricultural research, providing knowledge and training to NARS researchers, enabling interactions amongst stakeholders through dialogue and similar fora, facilitating access to relevant IP, sensitizing policymakers on biotechnology-related issues, and assisting governments in the crafting of biotechnology-related policies. As the primary source of GM crops continues to be the private sector, technology transfer between the private and public sectors—in terms of products as well as experience in regulation, commercial development, and release of GM crops—would greatly benefit NARS. This technology transfer could be facilitated by private foundations such as the International Service for the Acquisition of Agri-Biotech Applications (ISAAA).

In total, seventy intellectual and technical property rights belonging to thirty-two companies and universities were used in product development and for which "freedom-to-operate" situations had to be applied for in order for NARS to begin using Golden Rice™ in further breeding and in de-novo transformation activities using locally adapted varieties

---

Intellectual Property Rights

The impact of IP rights on biotechnology research is often imbedded in discussions on public- and private-sector partnerships. There is a need to balance the fact that, on one hand public-sector institutions, due to limited resources, cannot fully avoid accessing private-sector-held IP during the development of their own products and, on the other hand, the private sector has to avail itself of IP rights protection to be able to safeguard its investments and commercial interests and to enable sharing of its IP with other sectors without fear of exploitation. The development of Golden Rice™ is a case in point. In total, seventy IP rights and technical property (TP) rights belonging to thirty-two companies and universities were used in product development and for which "freedom-to-operate" situations had to be applied for in order for NARS to begin using Golden Rice™ in further breeding and in *de-novo* transformation activities using locally adapted varieties (Potrykus, 2000). Several modalities, however, are still open to the public sector, providing access to genes and technologies from the private sector. These include licensing, the fact that patents have time limits, confidentiality agreements, and the purchase of genes for incorporation into local germplasm. New types of IP agreements

Compliance costs for regulatory approval could be prohibitive for many developing-country institutions.

have also evolved, such as the donation of IP facilities and "humanitarian"-use type agreements as were done with Golden Rice™, with the threshold for humanitarian versus commercial use being a $10,000 income from the technology. As the issue of IP rights becomes increasingly important, strenghthening of capacities of governments and science sectors of many developing countries will be needed to understand, deploy, and negotiate regarding biotechnology. Rice biotechnology practitioners in Asia need to be trained on the intricacies of modern IP rights systems and on negotiating with institutions and companies for the purpose of accessing IP, and applying for IP protection. Alternatively, research institutions could establish IP units, not only for negotiating with other institutions and sectors, but also for registration of their own biotechnology processes and products.

Regulatory Requirements

National biosafety committees in developing countries have made impressive progress in the drafting and implementation of biosafety regulations for the importation and testing of transgenic crops; regulations for field tests are already in place in rice-growing countries such as China, India, Thailand, and the Philippines (Atanassov *et al.*, 2004). A looming issue, however, revolves around the compliance costs for regulatory approval: they could be prohibitive for many developing-country institutions. In the various studies cited by Atanassov *et al.* (2004), annual compliance costs, including those for initial greenhouse and field screening, field testing for environmental impact, and food safety, but excluding technology development costs, ranged from US$140,000 for a virus-resistant papaya in Brazil to US$830,000 for a virus-resistant potato in South Africa. For rice, an annual regulatory compliance cost of US$680,000 was estimated for a virus-resistant variety in Costa Rica (Sittenfeld, 2002) covering tests on molecular characterization and epidemiology, transgenic field trials, biosafety, IP rights, food-safety deployment, and gene flow. Given reduced NARS budgets, this could pose a major hurdle in the commercialization of rice biotechnology products from the public sector. It is hoped, however, that as knowledge and experience are gained by regulatory agencies, approval costs may decrease, both by reducing the number of required tests, and by shortening the length of experimentation. The latter would also avoid the risk of biotechnology products becoming irrelevant to farmers' needs due to long delays in approval (Atanassov *et al.*, 2004). In this regard, continuous training of personnel in regulatory bodies of developing countries on new biotechnology developments and approaches is necessary for them to make educated recommendations, as is envisioned in the Cartagena Biosafety Protocol (CBD, 2000). A well functioning regulatory system can hasten acceptance of biotechnology products by instilling public confidence that risk assessments are carefully done, science-based, and, therefore, reliable.

Biosafety and Food Safety

The benefits that biotechnology confers upon the environment include reduction in the use of agrochemicals and preservation of presently uncultivated and marginal lands and concomitantly of biodiversity due to increases in productivity in currently used arable lands. To sustain the rice agriculture resource base and avoid environmental disturbance, it is important to match new genes and biotechnology-derived varieties to the target environments (Atanassov *et al.*, 2004). In 2003, GM crops commercialized in the developing world were largely limited to insect-protected cotton in Argentina, China, India, Mexico, and South Africa (James, 2003, Figure 4); experience remains limited on safety assessments of GM food crops such as rice. Among developing countries, only four have approved a single transgenic event in a food crop (soybean in Brazil, the Czech Republic and Uruguay; and maize in the Philippines), two have approved two events (soybean and tomato in Mexico; soybean and maize in South Africa) and one (Korea) has approved three events (one in soybean and two in maize) (Atanassov *et al.*, 2004). Therefore, the sharing of experiences and knowledge from food-safety assessments done in these countries should be valuable for developing countries with rice-biotechnology products in the pre-commercialization stages. As rice is a food,

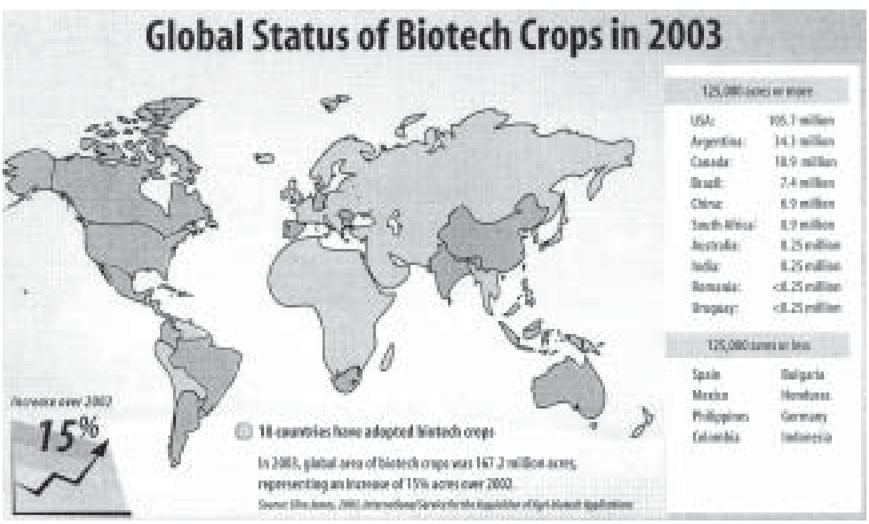


Figure 4. Global status of biotech crops in 2003 (James, 2003).

and *per-capita* consumption varies both within and among countries—from less than 100 kg/yr in China and India to over a 200 kg/year in Myanmar (Maclean *et al.*, 2002)—careful food-safety experimentation must be done in the case of nutrient-enhanced GM rice to remove any potential health dangers related to over-dosages; alternatively, effective GM-rice deployment strategies need to be developed.

Given all of these issues and challenges, lessons can be learned from the saga of Golden Rice™, as to the confluence of factors necessary for a rice-biotechnology product to be developed and commercialized for maximum impact. As detailed by Potrykus (2000), the Golden Rice™ project was made possible because of enabling factors such as:

- an environment supportive of independent research,
- strong institutional collaborative research partnerships,
- availability of the needed genes,
- support from donor institutions for strategic research for developing countries, and
- a highly motivated team of scientists willing to work on a pro-poor R&D agenda.

Potrykus further noted that the Golden Rice™ experience should:

- facilitate greater public acceptance of GM technology,
- encourage research investments in projects without guarantees of success,
- motivate research to be more food security- and less industry-focused,
- encourage free licensing for enabling technologies if used for humanitarian purposes, and
- motivate scientists to undertake projects relevant to the poor.

Rice production in Asia must increase from its current level of 545 Mt to 700 Mt by 2025 in order to feed an additional 650 million consumers while ensuring profitability for countless resource-poor farmers. Biotechnology—which has progressed rapidly to a point where transgenic rices are about to be commercialized—can help address these major challenges of guaranteeing food security while alleviating poverty in Asia.

Conclusion

Rice production in Asia must increase from its current level of 545 Mt to 700 Mt by 2025 in order to feed an additional 650 million consumers while ensuring profitability for countless resource-poor farmers. Biotechnology—which has progressed rapidly to a point where transgenic rices are about to be commercialized—can help address these major challenges of guaranteeing food security while alleviating poverty in Asia. New processes and second- and third-generation products of greater relevancy are also in the pipeline, expected to gain rapid acceptance both by farmers and the rice-consuming public. It is important to note, however, that biotechnology is not a panacea for achieving food security and sustainability of rice-based agricultural systems in Asia. The technology must address the existing and projected problems of small rice-farming communities and, at the same time, the dietary and health needs of more than half of the world's population. Furthermore, products must be designed so that they complement rather than replace existing practices, and enrich rather than disrupt the agroenviroments for which they are targeted for deployment.

The tasks ahead are gargantuan and the future—particularly for transgenic rice in Asia—remains uncertain. Full engagement of and dialogue amongst all stakeholders are needed at all levels, in the public, private, NGO, and other relevant sectors of society. New modalities of collaboration need to be explored. Asia must draw its lessons from cumulative experience in the developed world. Programs that stimulate open discussions and enable concerted and cooperative efforts to be made on the safe and relevant use of rice biotechnologies must be supported. Only then can the impact of science in general, and biotechnology in particular, be maximized for the benefit of the poor in Asia, through the attainment of stable and sustainable rice-based agriculture and household food and economic security.

References

AgBios (2004) Global status of approved genetically modified plants. http://www.agbios.com/dbase.php?action =Synopsis.

Aldemita RR *et al.* (2004) Biotechnology for rice improvement. PhilRice Technical Bulletin 8 15–22.

Arumuganathan K Earle ED (1991) Nuclear DNA content of some important plant species. Plant Molecular Biology Reporter 9 208–218.

Asian Development Bank (ADB) (2001) Agricultural Biotechnology, Poverty Reduction and Food Security. Manila, Philippines: Asian Development Bank.

Atanassov A *et al.* (2004) To Reach the Poor—Results From the ISNAR-IFPRI Next Harvest Study on Genetically Modified Crops, Public Research and Policy Implications, EPTD Discussion Paper No. 116. Washington DC: International Food Policy Research Institute.

Beyer P *et al.* (2002) Golden Rice: Introducing the beta-carotene biosynthesis pathway into rice endosperm by genetic engineering to defeat vitamin A deficiency. Journal of Nutrition 132 506S–510S.

Blair M *et al.* (2003) High resolution genetic mapping and candidate gene identification at the xa5 locus for bacterial blight resistance in rice (Oryza sativa L.). Theoretical and Applied Genetics 107 62–73.

Bouman BAM (2003) Examining the water-shortage problem in rice systems: water-saving irrigation technologies. In: Rice Science: Innovations and Impact for Livelihood (Mew TW Eds). Beijing: Chinese Academy of Engineering and Chinese Academy of Agricultural Sciences, Los Baños: International Rice Research Institute.

Brookes G Barfoot P (2003) GM Rice: Will this Lead the Way for Global Acceptance of GM Crop Technology? Brief No. 28. Los Baños: ISAAA.

Bruskiewich R *et al.* (2003) Linking genotype to phenotype: the International Rice Information System (IRIS). Bioinformatics 19 163–165.

Cantrell RP Hettel GP (2004) New Challenges and Technological Opportunities for Rice-Based Production Systems for Food Security and Poverty Alleviation in Asia and the Pacific. Presented at the FAO Rice Conference, FAO, Rome, Italy, February 12–13.

Champoux MC *et al.* (1995) Locating genes associated with root morphology and drought avoidance via linkage to molecular markers. Theoretical and Applied Genetics 90 969–981.

Chen M *et al.* (2002) An integrated physical and genetic map of the rice genome. Plant Cell 14 537–545.

Chen S *et al.* (2000) Improvement of bacterial blight resistance of 'Minghui 63', an elite restorer line of hybrid rice, by molecular marker-assisted selection. Crop Science 40 239–244.

Coffman R *et al.* (2004) Potentials and Limitations of Rice Biotechnology. Presented at the FAO Rice Conference, FAO, Rome, Italy, February 12–13.

Convention on Biological Diversity (CBD) 2000. Cartagena Protocol on Biosafety to the Convention on Biological Diversity. Montreal: Secretariat to the Convention on Biological Diversity.

Datta K *et al.* (2003) Bioengineered "golden" indica rice cultivars with beta-carotene metabolism in the endosperm with hygromycin and mannose selection systems. Plant Biotechnology Journal 1 81–90.

Deparment for International Development (DFID) (2004) Rice Biotechnology: Towards Sustainable Agriculture in the Developing World. Bangor: DFID. http://www.dfid-psp.org/publications/biotech/RiceRpt.pdf.

Evenson RE (Eds) (1996) Rice Research in Asia: Progress and Priorities. Manila: International Rice Research Institute and Wallington: CAB International.

Food and Agriculture Organization (FAO) 2004. Rice is Life. Italy: FAO. http://www.fao.org/newsroom/en/focus/200436887/ index.html.

Feng QY *et al.* (2002) Sequence and analysis of rice chromosome 4. Nature 420 316–320.

Flowers TJ *et al.* (2000) QTL: their place in engineering tolerance of rice to salinity. Journal of Experimental Botany 51 99–106.

Garg AK *et al.* (2002) Trehalose accumulation in rice plants confers high tolerance levels to different abiotic stresses, Proceedings of the National Academy of Sciences 99 15898–15903.
Goff SA (2002) A draft sequence of the rice genome (Oryza sativa L. ssp. japonica). Science 296 92–100.
Gregorio GB (2002) Progress in breeding for trace minerals in staple crops. Journal of Nutrition 132 500S–502S (review).
Herdt RW (1991) Research priorities for rice biotechnology. In: Rice Biotechnology (Khush GS Toenniessen GH Eds). Wallingford: CAB International and Los Baños: International Rice Research Institute, 19–54.
Herdt R (1997) The Future of the Green Revolution: Implications for International Grain Markets. Bozeman: Trade Research Center, Montana State University.
Hossain M (1997) Rice supply and demand in Asia: A socioeconomic and biophysical analysis. In: Applications of Systems Approaches at the Farm and Regional Levels (Teng PS *et al.* Eds). Dordrecht: Kluwer Academic Publishers.
Huang N *et al.* (1997) Pyramiding of bacterial blight resistance genes in rice: marker-assisted selection using RFLP and PCR. Theoretical and Applied Genetics 95 313–320.
International Rice Research Institute (IRRI) (2001) Water. In: Rice research: The Way Forward, IRRI Annual Report, 2000–2001. Manila: International Rice Research Institute, 17.
International Service for the Acquisition of Agri-biotech Applications (ISAAA) (2004a) GM Rice/Golden rice. Manila: ISAAA. http://www.isaaa.org.
International Service for the Acquisition of Agri-biotech Applications (ISAAA) (2004b) GM Rice/Iron-rich rice. Manila: ISAAA. http://www.isaaa.org.
James C (2003) Preview: Global Status of Commercialized Transgenic Crops: 2003, ISAAA Briefs No. 30. Ithaca, NY: ISAAA.
Jia H *et al.* (2004) China ramps up effort to commercialize GM rice. Nature Biotechnology 22 642.
Khush G (2004) Harnessing Science and Technology for Sustainable Rice Based Production Systems. Presented at the FAO Rice Conference, Rome, Italy, February 12–13.
Komari T *et al.* (1998) Advances in cereal gene transfer. Current Opinions in Plant Biology 1 161–165.
Leung H *et al.* (2004) Sustainable Disease Resistance in Rice: Current and Future Strategies. Presented at the 4th International Crop Science Congress, Brisbane, Australia.
Maclean JL *et al.* (Eds) (2002) Rice Almanac. Los Baños: International Rice Research Institute, Bouake; Ivory Coast: West Africa Rice Development Association; Cali: International Center for Tropical Agriculture; Rome: Food and Agriculture Organization.
McCouch SR *et al.* (1988) Molecular mapping of rice chromosomes. Theoretical and Applied Genetics 76 815–829.

McCouch S *et al.* (2002) Development of 2,240 new SSR markers for rice (Oryza sativa L.). DNA Research 9 199–207.

Nguyen VN (2002) Productive and environmentally friendly rice integrated crop management systems. IRC Newsletter 51 25–32.

Nuffield Council on Bioethics. 2004. The Use of Genetically Modified Crops in Developing Countries: A Follow-Up Discussion Paper. London: Nuffield Council on Bioethics.

O'Toole JC *et al.* (2001) The Rockefeller Foundation's international program on rice biotechnology. In: Rice Genetics IV (Khush GS *et al.* Eds). New Delhi: Science Publishers and Los Baños, Philippines: International Rice Research Institute, 39–62.

Papademetriou MK (1999) Rice Production in the Asia-Pacific Region: Issues and Perspectives. Regional Expert Consultation on Bridging the Rice Yield Gap in the Asia and Pacific Region, at the FAO Regional Office for Asia and the Pacific, Bangkok, Thailand, October 5–7.

Potrykus I (2000) The Golden Rice™ Tale. AgBio View: http://agbioview.listbot.com.

Price AH *et al.* (2002) Mapping QTLs associated with drought avoidance in upland rice grown in the Philippines and West Africa. Plant Molecular Biology 48 683–695.

Redoña ED Mackill DJ (1996) Mapping quantitative trait loci for seedling vigor in rice using RFLPs. Theoretical and Applied Genetics 92 395–402.

Redoña ED *et al.* (2003) Hybrid rice development and use in the Philippines, 1998–2001. In: Hybrid Rice for Food Security, Poverty Alleviation, and Environmental Protection (Virmani SS *et al.* Eds). Los Baños: International Rice Research Institute.

Ronald P *et al.* (1992) Genetic and physical analysis of the rice bacterial blight disease resistance locus, XA21. Molecular and General Genetics 236 113–120.

Sasaki T *et al.* (2002) The genome sequence and structure of rice chromosome 1. Nature 420 312–316.

Sittenfeld A (2002) Agricultural biotechnology in Costa Rica: status of transgenic crops. In: Next Harvest—Advancing Biotechnology's Public Good: Technology Assessment, Regulation and Dissemination. The Hague, Netherlands: ISNAR.

Song WY *et al.* (1995) A receptor kinase-like protein encoded by the rice disease resistance gene, Xa21. Science 270 1804–1806.

Takeuchi Y *et al.* (2003) Fine linkage mapping enables dissection of closely linked quantitative trait loci for seed dormancy and heading in rice. Theoretical and Applied Genetics 107 1174–1180.

Tanticharoen M (1997) Thailand: Biotechnology for Farm Products and Agro-Industries. http://www.cgiar.org/biotech/rep0100/Tanticha.pdf.

The Rice Chromosome 10 Sequencing Consortium (2003) In-depth view of structure, activity, and evolution of rice chromosome 10. Science 300 1566–1569.

Thomson M *et al.* (2003) Mapping quantitative trait loci for yield, yield components and morphological traits in an advanced backcross population between Oryza rufipogon and the Oryza sativa cultivar Jefferson. Theoretical and Applied Genetics 107 479–493.

Tuong TP, Bouman BAM (2002) Rice production in water scarce environments. In: Water Productivity in Agriculture: Limits and Opportunities for Improvement. The Comprehensive Assessment of Water Management in Agriculture Series, Volume 1 (Kijne JW *et al.* Eds), Wallingford: CABI Publishing, 13–42.

Vasconcelos M *et al.* (2003) Enhanced iron and zinc accumulation in transgenic rice with the ferritin gene. Plant Science 164 371–378.

Virmani SS (2003) Advances in hybrid rice research and development in the tropics. In: Hybrid Rice for Food Security, Poverty Alleviation, and Environmental Protection (Virmani SS et al. Eds). Los Baños: International Rice Research Institute.

Wang GL *et al.* (1995) Construction of a rice bacterial artificial chromosome library and identification of clones linked to the Xa-21 disease resistance locus. Plant Journal 7 525–533.

Wu J *et al.* (2002) A comprehensive rice transcript map containing 6591 expressed sequence tag sites. Plant Cell 14 525–535.

Xu K Mackill DJ (1996) A major locus for submergence tolerance mapped on rice chromosome 9. Molecular Breeding 2 219–224.

Yu J *et al.* (2002) A draft sequence of the rice genome (*Oryza sativa* L. ssp *indica*). Science 296 79–92.

Zhang S *et al.* (1998) Transgenic elite indica rice varieties, resistant to Xanthomonas oryzae pv. orzae. Molecular Breeding 4 551–558.

EDILBERTO D. REDOÑA is the deputy executive director for research and development of the Philippine Rice Research Institute (PhilRice) in Muñoz, Nueva Ecija, Philippines. PhilRice is the lead national and coordinating agency for all publicly funded R&D rice activities.

An MS and PhD graduate in genetics from the University of California, Davis—through a Rockefeller Foundation fellowship—Redoña is president of the Crop Science Society of the Philippines, and editor of the *Journal* *of Breeding and Genetics*, a publication of the Society for the Advancement of Breeding Research in Asia and Oceania (SABRAO). He chairs the Technical Working Group of the Open Academy for Philippine Agriculture, an alliance of seventeen institutions aiming to empower farmers and extension agents through ICT-based learning approaches.

With 20 years experience in rice research, Redoña's foremost interests include the application of molecular markers and biotechnology in breeding, and development of hybrid rices. His contributions in these endeavors garnered him the Outstanding Young Scientist Award from the Philippine National Academy of Science and Technology, and the Outstanding Researcher and Best Research Awards from the Philippine Department of Agriculture. He leads the commercialization of hybrid rice technology, the Philippine government's banner program for agriculture.

Africa's New Focus in Establishing Food Security

Florence M. Wambugu
Africa Harvest Biotech Foundation International
Nairobi, Kenya

Africa Harvest is the latest member of the biotechnology family. It's an international foundation based in Africa with an African focus but also with a global vision, realizing that biotechnology cannot be done in isolation; it needs the cooperation of all stakeholders. We are a nonprofit foundation with a mission to use science and technology—including the tools of biotechnology—to achieve sustainable agricultural development. We realize that biotechnology is broader than genetic engineering and includes use of molecular markers, tissue culture and many other tools, but we also recognize the power of biotech in terms of genetic engineering.

Although we started just 3 years ago, we are making rapid progress. Two of our board members are here: Kanayo Nwanze and Mary Mackey. We are making various international contributions, including participation in the United Nations Millennium Hunger Task Force, which was started by Kofi Annan after the world summit in Johannesburg, and we provide input to the science board of the Bill Gates Foundation. Across Africa we are involved in the New Partnership for Africa's Development (NEPAD) and the Forum for Agricultural Research in Africa (FARA). With Dr. Nwanze, we are also in the Pan Africa Network, trying to see how we can help our continent. We have been involved by the African Union to talk about how science and technology can be used for economic empowerment of women in Africa in the twenty-first century. But most important are the national programs in which we demonstrate the impact of biotechnology for the poor. When all is said and done, we believe we have to touch people; our national downstream networks are fundamentally important.

In the big picture, according to United Nations standards, 800 million people are classified as hungry of which 200 million are in Sub-Saharan Africa. Africa is the only continent where hunger and poverty are projected to increase by the Food and Agriculture Organization.

The African food-security challenge is that 60% live in absolute poverty—it is estimated at between 60 and 70%—with 40% deemed food secure. There is a direct link between hunger and poverty in that, on average, Africans spend 80% of their income on food. This applies also to city dwellers; much urban poverty results from relatively high expenditure on food.

Challenges

Africa's development challenges may be summed up as follows:

- investment in human development: nutrition, health, education, water, sanitation;
- increasing agricultural productivity by smallholder farmers;
- attaining an adequate threshold of infrastructure: roads, railroads, energy, ports, communications
- gaining access to global markets and fair trade.

In February 2003, I attended an FAO meeting in Johannesburg for discussion of the trade issues that emerged from the Cancun Meetings in Mexico. At the conclusion, President Mbeki of South Africa stated, in a strong speech, that scientists cannot solve Africa's problems alone; political intervention will be necessary especially to address unfair trade. Farmers in Africa who grow coffee, tea or cocoa, get less than 10% of the profit. Most of the money is made by the people who do the processing. It would be a delusion to think that by increasing production, scientists are going to solve the problems of Africa. There has to be political intervention because some of the policies set during the colonial era still apply. Tropical countries are still producing raw material for export and that issue is bigger than science can handle.

Investments are needed in urban infrastructure to establish industries to produce goods for export because young Africans don't want to be farmers. They want to live in the cities, yet jobs are not being created.

Another issue is empowering the poor, especially women, through democratic governance and human rights. We must protect and enhance natural and human-dominated ecosystems, including the urban environment. Urban poverty is destructive to development. Obviously, biotechnology is not going to solve all this; however, although there are bigger issues, that doesn't mean we cannot make significant contributions.

Another challenge facing us is to make smallholder farmers more productive. Population is growing and families are becoming larger, yet family farms are not growing in area. Children orphaned as a result of HIV are taken in by relatives. A family that would otherwise have been composed of husband, wife and five children may now be composed of ten or more. So we have to make each unit of land produce more, not only to provide basic nutrition but to help the family shift from subsistence to income generation.

INITIATIVES

There have been global initiatives to find solutions for Africa, including smallholder agricultural development and food-based safety net programs of the FAO, and the United Nations Hunger Task Force—we are playing a role in the UN Task Force with Pedro Sanchez—making markets work for the poor. Other initiatives have involved the Canadian International Development Agency (CIDA), the International Development Research Council (IDRC, Canada), the US Agency for International Development (USAID), the international centers of the Consultative Group on International Agricultural Research (CGIAR), national agricultural research institutes (NARIs) and non-governmental organization (NGO) programs.

African efforts to reduce hunger and poverty include the Pan African Initiative and this is why I see what I call a new awakening, a new paradigm, a new thinking-through. I see new strong political leadership under NEPAD and the African Union. I see Africans themselves taking political leadership roles in solving their own problems, in contrast to thinking that the World Bank, the International Monetary Fund or another external agency will sort things out. I see also strong science-based leadership; FARA—composed of forty-two African countries—is saying. "We need to identify what we can do as Africans and where we need help. After choosing good leadership, we will look for partners and participate in networks."

African leaders in NEPAD resolved to put 10% of African GDP into agriculture research.

In a significant development in April, 2004, at a meeting in Maputo, Mozambique, African leaders in NEPAD resolved to put 10% of African GDP into agriculture research. In view of the fact that many African countries have traditionally invested less than 5% in agriculture, and in some cases 0%, this is a major initiative. This commitment is now being followed up: rather than depending wholly on donors, investment in our own agriculture can be used as leverage to attract wise investment externally. With investment of our own funds we have tighter control of the research, otherwise research direction is controlled by those who provide funds.

Another new initiative is NEPAD's Comprehensive African Agricultural Development Program (CAADP), which has identified "scaling up success modules" as the best way to progress. Three projects are in progress:

- New Rice for Africa (NERICA).
- Tissue-culture (TC) banana.
- Cassava.

Regarding NERICA—New Rice for Africa—we must recognize the leadership of Kanayo Nwanze; for the first time Africa was nominated for the World Food Prize. Monty Jones is the first African to be a joint winner for his work on NERICA at the Africa Rice Center (WARDA) in the Ivory Coast. NERICA rice has been chosen by NEPAD as a success model to be duplicated in the rest of Africa. Another is tissue-culture banana—which we have been working on—and the cassava program; others will be included in due course. The point is: instead of always starting new projects, we identify those that have worked and scale them up to provide immediate intervention for hunger. Of course, this approach does not preclude continuance of research to identify novel approaches.

Networking within Africa is on the increase, involving national programs, NGOs, universities, and farmer groups. In the past, certain organizations worked with one another, groups within Canada or within the United States of America, whereas networking is now occurring within Africa—sharing information, sharing resources—which I think is the way forward.

Genetic Engineering

The potential exists for genetic engineering technology to contribute to hunger abatement. There are opportunities in biofortification—Golden Rice™ is a good example; we hope to be able to similarly fortify NERICA rice. In the future, we may have fortified sorghum, and so on. *Bt* cotton has had a significant impact in South Africa. Genetically modified (GM) crops have met with success globally and this will apply also to African countries. The fact that the technology is within the seed ensures its delivery to, and use by, smallholder farmers. Packages of information with technologies such as chemical sprays have not worked. Biotechnology is skill-neutral.

The controversial issue of GM-food aid—resulting largely from strictures espoused by European NGOs— must be addressed.

GM Foods

The controversial issue of GM-food aid—resulting largely from strictures espoused by European NGOs—must be addressed. According to FAO, twenty-four African countries currently face hunger, and deficits have been met with GM food from the United States and Canada. However, Zambia and Angola recently declared that they will not accept GM-food aid, which raises complex issues of trade between America and Europe in which Africa is likely to become embroiled. On my way here, I attended the annual conference of the Biotechnology Industry Organization (BIO). One seminar addressed the question, “What does the Cartagena

Protocol mean to us?" This is something that we should be concerned about: the Protocol—heavy in its demands—was negotiated under the assumption that all GM products would come from multinational private-sector companies. It does not consider products from universities and other public-research entities. In my opinion, its objective is to "freeze" big companies. It deals with issues of devising formal agreements, liability, compensation, *etc*. If the costs of regulation are to be minimized, the Cartagena Protocol must be addressed. And on the issue of risk, very few African countries have operational national biosafety committees.

Africa's food-security problems will be solved not with maize, soybean and canola, but by working on African food crops: banana, cassava, sorghum and rice.

We cannot claim that Africa's poor have benefited from GM technology, partly because there is such limited opportunity to access possible benefits. There is no question that the technology has potential, but, of the four major GM crops—maize, soybean, cotton, canola—only *Bt* cotton has shown tangible benefits, in South Africa. Africa's food-security problems will be solved not with maize, soybean and canola, but by working on African food crops: banana, cassava, sorghum and rice.

Challenges to be faced in the introduction of GM-technology include:

- limited human and infrastructural capacity,
- biosafety regulations, particularly in terms of the demands of the Cartagena Protocol,
- public acceptance—pro-biotech funding is limited compared to money being spent to fight biotechnology,
- available products are all from the private sector; public-sector products will promote acceptance.

The Way Forward

African Leadership

Increasing African leadership in project design and implementation is an important new trend. As already stated, in the past, projects have been unduly influenced by the sources of funding. True North/South partnerships are emerging between organizations in Africa and organizations abroad, as well as very profitable South/South partnerships: Africa working with India, China and Argentina. And public/private partnerships must continue because the private sector has the intellectual property rights that we need, as well as technical know-how.

National Funding

Increased national government funding will be essential. We cannot make progress without our governments providing money or, at least, incentives. Funding of scientific consortia will encourage networking within Africa with sharing of resources and expertise.

Safety Policy Development

Biosafety policy development will be essential. Only five or six African countries have such regulatory capacity. Information outreach is very important; biotechnology information availability in Africa has been very limited. The ISAAA briefs provide global figures and statistics, but the average person needs to understand local applicability. Data for China, India or Canada may have little relevance to a national program in Africa. And again, access to markets and fair trade are essential.

Sweet Potato Case Study

Work on GM sweet potato was started in 1991. Part of the problem of bringing improved cultivars to the market is the dearth of organizations in Africa that can do this kind of work. They exist in South Africa and Egypt and in some CGIAR centers, but most national programs do not have the capacity. The scientific staff may possess the necessary knowledge but lack the infrastructure.

For our GM work in sweet potato, we had two years of training and capacity building before the GM product was developed. GM trials are on-going. When we started this work in 1991 there was no transformation system for sweet potato, so we started by developing that system. We are in the process of developing a second-generation product, tailor-made for Kenya.

Whether GM or non-GM, largely the same issues apply in terms of the poor accessing improved plant types.

Emergence from Poverty

In South Africa, *Bt* cotton has generated much excitement. This Monsanto product is the only GM crop we have. *Bt* white maize is under development. Tissue culture banana is not GM, but it exemplifies the challenge of getting a novel technology to the poor. Whether GM or non-GM, largely the same issues apply in terms of the poor accessing improved plant types. Having an improved product through science is not enough. Microcredits to access the technology, good soil fertility, water, and access to good extension services and markets, must be available.

We are working with sigatoka, a fungal disease of banana. Success in transferring GM technology starts with the farmers, bottom up. Again, whether it is GM or non-GM, the issues are the same. You must communicate and have discussions and involve farmers in the generation of information. Otherwise there will be public-acceptance issues. The process must be consultative; it must start with the farmers. Panama weevil spreads the fungus and farmers transplant suckers that already have the disease. We are making lab-produced fungus-free plantlets available. We have successfully used similar approaches with pyrethrum, sugar cane and even with trees. When we started this work in Kenya, only four labs were operational, producing flowers for export to Europe. Kenya and Israel each has a big market share in flower production. When we approached these laboratories to assist in plantlet production, they refused because local crops were viewed as commercially risky. We had to plead with them to work on banana. So, even where laboratories exist, inducing work on local crops is likely to be another challenge because people in business want big markets and even in Africa the private sector must make a profit.

Farmers participate in our field trials; they serve as our best extension workers.

Farmers participate in our field trials; they serve as our best extension workers. Building confidence with farmers is fundamentally important. No longer do we go to the farmer wearing a lab coat and say, "I'm Dr. So-and-so, you must listen to me." We have to literally work together.

Management is also important. The way to get maximum value from a product is via management—desuckering, integrated pest management, *etc.*—new skills may need to be imparted to farmers.

Finally, the product must prove itself. No matter what it is, it must be better than what it replaced. It has to have a proven performance. And with this simple technology, not only good quality is necessary but high standards. If there has been no shedding, then all the bananas come at the same time and you have a small unit of business.

Farmers themselves become distributors. They learn very fast. Even with just a small profit margin, other products can then be considered. Chickens, for example, may be produced from profits from bananas. With some entrepreneurial spirit, the small-scale farmer can obtain greater profit with appropriate handling and packaging of the bananas. By making banana crisps, wine or starch, even more profit is possible from the same product.

A farmer needs only sixty-five tissue-culture banana plants to get out of poverty.

The whole value chain must be considered, with donors encouraged to fund technology-transfer, market development and entrepreneurship to create job opportunities and build prosperity for everyone.

A farmer needs only sixty-five tissue-culture banana plants to get out of poverty. Once the farmer gets credit, (s)he breaks even the first year and thereafter profit accrues every 6 months. After paying back the loan, other money-making projects may be considered.

The TC-banana project is a major success; a half-million small-scale farmers are participating and the number is expanding. The demand for plantlets is great; obtaining credit is the major limitation to continued expansion.

Most importantly, whether dealing with a local GM or non-GM crop: you don't introduce the technology and leave it there. You must work it through to the market, exploring all means of maximizing value. When we started working with donors several years back, they declared that they would fund only research. From 1994 to 1996 no donor in Kenya funded anything beyond research. I asked what happens after the research is done? Things have changed. FARA is now funding market development. We had a major marketing conference in April, 2004, to encourage entrepreneurship among small-scale farmers, *e.g.* turning bananas into juice, into wine or into starch. In so doing, jobs are created for young people who thus learn that farming is not such a bad means of earning a living: in the process, it is possible to become a businessman, an entrepreneur.

The whole value chain must be considered, with donors encouraged to fund technology-transfer, market development and entrepreneurship to create job opportunities and build prosperity for everyone.

Florence Wambugu is a plant pathologist with specialization in genetic engineering for crop protection against viral diseases. Her postdoctoral work involved production of transgenic virus-resistant sweet potato currently being tested in Kenya, which has paved the way for training of African scientists in gene technology.

Dr. Wambugu has been awarded "Woman of the Year" recognition by the American Biographical Institute. Under her leadership, the Biotech Tissue Banana Project won the World Bank Global Development Network Award.

She is a member of the Private Sector Committee (PSC) of CGIAR, DuPont Biotech Advisory Panel-USA, the Board of Trustees IPGRI and she serves as the Vice-Chair of the African Biotechnology Stakeholders Forum (ABSF). She also participates in the Bill and Melinda Gates Foundation as well as the United Nations Hunger Task Force (UN-HTF).

She is a strong believer in the power of biotechnology to boost food production. She has participated in many international forums in support of biotechnology for developing countries. She has (co)authored about sixty papers in local and international journals and publications, and is the author and publisher of the book *Modifying Africa: How Biotechnology Can Benefit the Poor and the Hungry: A Case Study from Kenya* (www.modifyingafrica.com, winner of the 2002–2003 Golden Web Award).

The Goal Is Nutritionally Adequate Diets: How Do We Get There?

SUZANNE S. HARRIS
International Life Sciences Institute
Washington, DC

Biotechnology has been held up as a critical key to solving the world's nutrition problems. Recent worldwide media coverage of "Golden Rice™" fueled the view that changing a few foods would alleviate world hunger. Unfortunately, this is not likely to be reality. Biotechnology can be an important tool in the world's effort to address malnutrition when used in combination with other important tools.

WORLDWIDE NUTRITION PROBLEMS

An important initial step in realizing the benefit of biotechnology is to fully understand the nature of malnutrition in the world today. Undernutrition (*i.e.*, protein-calorie malnutrition and micronutrient deficiencies) remains an important public-health issue in the developing world. The Food and Agriculture Organization of the United Nations estimates using food-supply data that 17% of the populations in the developing world are undernourished (FAO, 2003). Table 1 provides selected examples of undernutrition and current prevalence figures. Undernutrition has a significant impact on development capacity because it reduces education attainment and worker productivity.

TABLE 1. PREVALENCE OF NUTRITION-RELATED HEALTH INDICATORS FOR CHILDREN IN DEVELOPING COUNTRIES.

Nutrition Related Health Problem	Prevalence Estimates in 2005
Underweight children (0–5 years old)	126.5 million (22.7 %)[1]
Stunted children (0–5 years old)	147.5 million (26.5 %)[1]
Vitamin A deficient children (0–5 years old)	127.3 million (25.3 %)[2]
Low birth weight infants	17% of live births[3]
Iron deficient anemic children (0–5 years old)	45%[4]
Overweight children (0–5 years old)	18.5 million (3.4%)[1]

[1]SCN (2004). [2]2002 figure (West, 2002). [3]2004 figure (UNICEF, 2004). [4]UNICEF/MI (2004).

As important as undernutrition is, overnutrition is now taking over the spotlight as the world's primary nutrition problem.

As important as undernutrition is, overnutrition is now taking over the spotlight as the world's primary nutrition problem. The number of overweight and obese individuals is now greater worldwide than the number underweight. This is the first time in human history that such a statement could be made. Unfortunately, the health sequelae of obesity are just as serious as those from undernutrition, and the rising cost of healthcare to manage obese individuals with diabetes and cardiovascular disease is rapidly becoming a significant economic burden in many countries. Many developing countries are seeing both over- and under-nutrition in their populations and are ill equipped to deal with either.

In September 2000, 189 members of the United Nations adopted a series of Millennium Development Goals (MDGs) aimed at reducing poverty and hunger. Nutritional status is an indicator for poverty and hunger in several of the eight goals to be met by 2015 (Table 2).

TABLE 2. UN MILLENNIUM DEVELOPMENT GOALS (UN GENERAL ASSEMBLY, 2001)

Eradicate extreme poverty and hunger
Achieve universal primary education
Promote gender equality and empower women
Reduce child mortality
Improve maternal health
Combat HIV/AIDS, malaria and other diseases
Ensure environmental sustainability
Develop a global partnership for development

Various strategies are available to improve nutritional status, including:

- poverty reduction through food-assistance programs, education and training,
- improved food availability through increased production and enhanced trade,
- enhanced food quality through biofortification, fortification and improved food processing,
- dietary diversification through education and improved food-preparation skills.

These strategies are interrelated and must involve broad segments of the population to ensure their sustainability. Those individuals around the world who are suffering from malnutrition—either under- or over-nutrition—require:

- adequate nutrients and other bioactive compounds,
- adequate quantities of food year-round,
- safe, clean food and water,
- enough—but not too many—calories.

Lessons from ILSI Workshops

The International Life Sciences Institute (ILSI) has been working for more than 25 years to improve the health of people worldwide. Nutrition is one of our primary areas of interest. ILSI is a nonprofit, worldwide foundation that brings together scientists from academia, government, and industry to solve problems with broad implications for the well-being of the general public. Its funding comes from industry, governments and foundations. Additional information is available at http://www.ilsi.org.

The potential of biotechnology to help alleviate malnutrition has been a focus within ILSI, using a variety of approaches including international workshops, creation of databases and development of technical guidance. ILSI has also been involved for some time in developing the science base for safety assessment of food derived from biotechnology and providing training seminars for scientists in government, academia, and industry in developing countries. More information about these activities is available on the ILSI Web-site.

In 2002, ILSI, working with the Joint Institute for Food Safety and Applied Nutrition (JIFSAN) at the University of Maryland and with the Institute for Food Policy Research, sponsored a workshop in Cancun, Mexico, on *Biotechnology-Derived Nutritious Foods for Developing Countries: Needs, Opportunities, and Barriers*. Scientists with expertise in nutrition or plant breeding from developing countries in Asia, Africa, of Latin America were invited to participate in a series of plenary sessions and small-group discussions. The objective was to engender innovative thinking about the nutrition problems faced in these countries and feasible solutions to address them.

The workshop format was particularly important to fostering the innovative thinking needed to develop solutions. The important components of the format were:

- the majority of participants were scientists from developing countries,
- participants were evenly divided in expertise between nutrition and plant breeding,
- there was a mix of plenary presentations and small-group discussions.

The proceedings were published in the *Food and Nutrition Bulletin* (Bouis *et al*., 2002). The small-group discussions generated ideas that the whole group endorsed. These ideas can be segregated into those that relate (i) to the science of improving nutritional status in developing countries and (ii) to the process of utilizing the science base.

The group described modern biotechnology as an array of tools that provide flexibility and new approaches to improving crops. They strongly recommended a total food-systems approach to addressing nutritional problems, rather than focusing on a single crop or nutrient. Biotechnology should be considered along with traditional breeding practices in finding ways to enhance nutrient content.

The answer will not always involve the transfer of genes. Biotechnology offers the ability to quickly screen cultivars for higher nutrient content or needed agronomic traits, such as resistance to drought or pests. Tissue culture, diagnostics, and trait markers are all part of the biotechnology tool kit. Gene transfer is another valuable tool, but should not be the exclusive focus. The output of such research could be an entirely new crop or a locally used crop that has been adapted in a novel way.

The return on an investment of $42 million in conventional breeding would be $4.9 billion over 10 years in improved nutrition and higher agricultural production. Biotechnology could increase this return by speeding the selection process.

Bouis (2002) simulated the cost effectiveness of biofortification using data from India and Bangladesh for iron- and zinc-enhanced varieties of rice and wheat. Using conservative assumptions in his simulations, he demonstrated that the return on an investment of $42 million in conventional breeding would be $4.9 billion over 10 years in improved nutrition and higher agricultural production. Biotechnology could increase this return by speeding the selection process.

The group of experts expressed interest in finding ways to increase the use of indigenous crops that are currently underutilized. The nutritional quality of these crops could be enhanced, agronomic traits could be improved thereby increasing yields, or improvements could be made to enhance food safety. Specific examples given at this and a follow-up workshop held in Bali, Indonesia, in early 2004, included:

- increased lysine and tryptophan in maize,
- increased beta-carotene in sweet potato,
- increased protein, iron and folic acid in cassava,
- improved disease resistance for papaya and cocoa,
- increased iron and zinc in wheat.

All of these examples focus on undernutrition, but there is a need also to identify approaches to modifying the food supply to address growing obesity worldwide.

Of equal importance to these scientific issues in the minds of the participants were those related to exchange of knowledge about biotechnology. It was readily apparent from the workshop that nutrition experts and plant breeders in developing countries do not often interact. Fostering multidisciplinary exchange is essential to improving nutrient availability. Support for so-called "South-South" exchange—scientists in developing countries exchanging practical scientific knowledge—is vital. There is a real need to develop sustainable networks among interested scientists to facilitate knowledge-exchange.

The workshop participants also acknowledged the need in developing countries to continue to foster broader dialogue about biotechnology—what it is and what it is not—with farmers, food processors, consumers and policymakers. Having specific success stories, *e.g.*, increased profits for local farmers and increased availability of affordable, nutritious foods for consumers, is very helpful in building this dialogue.

ILSI followed up on these recommendations by holding the second workshop, in Bali, Indonesia. *Biotechnology-Derived Nutritious Foods—Challenges and Opportunities in Asia* was cosponsored by the Institut Pertanian Bogor in Indonesia and JIFSAN. Participants were primarily from Asian countries and were again a mixture of experts in nutrition and plant breeding. Rice was a major focus of discussion. Need for sustained dialogue within developing countries was again pointed to as an important requirement for progress.

ILSI Crop Composition Database

ILSI has developed two additional tools to help to improve nutrient content of the world's food. The first is the Crop Composition Database, which is comprehensive, up-to-date, globally accessible and searchable (www.cropcomposition.org). It was developed by the ILSI International Food Biotechnology Committee (IFBiC) (Ridley *et al.*, 2004). One of the challenges in understanding nutrient composition is to develop valid estimates for natural variation in concentration. Using data from conventional crops grown for comparison purposes, the IFBiC has compiled composition ranges for nutrients and other bio-active compounds for corn, soybean and cotton. More data will be added as they become available.

With more than 70,000 data points, each linked to the validated, analytical method used to generate it, this database complements existing food and nutrient databases, such as the US Department of Agriculture's National Nutrient Database and the Food and Agriculture Organization's INFOODS database. The IFBiC database provides individual measurements (sample from a single plot at one location) as well as summary data including minimum, maximum and average values. The data are from multiple worldwide locations, collected from 1995 to the present.

Specific requests can be made for comprehensive data—all proximates for all years and all locations—or more refined data, for example, a single amino acid in a particular geography in a single year. Data are available for the whole plant and its parts expressed in terms of fresh and dry weights.

Framework for Nutritional and Safety Assessment of Biotechnology-derived Foods

ILSI, through IFBiC, has also published a framework for *Nutritional and Safety Assessments of Foods and Feeds Nutritionally Improved through Biotechnology* (ILSI, 2004). This document discusses scientific approaches and methods needed for such evaluations and provides scientific underpinnings and recommendations. The framework was developed by an expert working group comprised of international academic experts. Their draft was externally reviewed by a larger group of international experts and presented for comment at an international workshop in Paris in December 2003. The revised document was then published.

The key conclusion presented is that existing comprehensive safety and nutritional assessment processes used for agronomic traits are also appropriate for improved nutritional traits. On a case-by-case basis, additional studies may be needed, such as metabolite analysis or nutrient bioavailability and efficacy data. Comparative assessment provides the framework for identifying similarities and differences between a new food and its conventional counterpart. The identified differences become the focus of additional scientific studies.

ILSI will continue to use these tools in training workshops worldwide to transfer scientific knowledge about biotechnology and its safe use to improve the nutritional adequacy of diets. These efforts, combined with those of many others, generate new ideas and share existing scientific knowledge. More research, which will require more resources—financial and human—will be needed as will the continued involvement of the broader community in areas where diets are not nutritionally adequate.

Biotechnology offers significant potential for enhancing nutritional quality of foods and for improving agronomic characteristics to increase food availability.

Conclusions

Biotechnology offers significant potential for enhancing nutritional quality of foods and for improving agronomic characteristics to increase food availability. Coupled with adequate public-health guidance on scientifically sound dietary patterns and other strategies, real progress can be made toward eliminating malnutrition.

The challenge to make this potential a reality is large, but the benefit is even greater in terms of improving the lives of millions worldwide.

References

Bouis HE (2002) Three criteria for establishing the usefulness of biotechnology for reducing micronutrient malnutrition. Food and Nutrition Bulletin 23 351–353.

Bouis HE *et al.* (2002) Biotechnology-derived nutritious foods for developing countries: needs, opportunities, and barriers. Food and Nutrition Bulletin 23 342–383.

Food and Agriculture Organization (FAO) (2003) State of Food Insecurity in the World 2003: Monitoring Progress Towards the World Food Summit and Millennium Development Goals. Rome: Food and Agriculture Organization of the United Nations.

International Life Sciences Institute (ILSI) (2004) Nutritional and Safety Assessments of Foods and Feeds Nutritionally Improved through Biotechnology. Comprehensive Reviews in Food Science and Food Safety. Washington, DC: ILSI. http://www.ift.org/pdfs/crfsfs/crfsfsv3n2p0035-0104ms20040106.pdf.

Ridley WP *et al.* (2004) Development of the International Life Sciences Institute Crop Composition Database. Journal of Food Composition and Analysis 17 423–438.

Standing Committee on Nutrition (SCN) (2004) 5th Report on World Nutrition Situation – Nutrition for Improved Development Outcomes. Geneva: UN System Standing Committee on Nutrition.

UN General Assembly (2001) Road Map Towards the Implementation of the United Nations Millennium Declaration, Report of the Secretary General A/56/326. New York: United Nations Statistics Division. http://millenniumindicators.un.org/unsd/mi/mi_goals.asp.

United Nations Children's Fund (UNICEF) (2004) The State of the World's Children: Girls, Education and Development. New York: UNICEF.

United Nations Children's Fund Micronutrient Initiative (UNICEF/MI) (2004) Vitamin and Mineral Deficiency, A Global Progress Report. Ottawa: Micronutrient Initiative.

West KP Jr (2002) Extent of vitamin A deficiency among preschool children and women of reproductive age. Journal of Nutrition 132:2857S–2866S.

In January 2004, **SUZANNE HARRIS** assumed the role of executive director for the International Life Sciences Institute, a nonprofit, worldwide foundation established in 1978 to advance the understanding of scientific issues relating to nutrition, food safety, toxicology, risk assessment, and the environment by bringing together scientists from academia, government, industry, and the public sector. She is also executive director of the Human Nutrition Institute (HNI) of the ILSI's Research Foundation, a position she has held since 1989. HNI is the arm of ILSI responsible for implementing long-term nutrition research programs.

Prior to joining ILSI, Harris was the Deputy Assistant Secretary of Agriculture for Food and Consumer Services from 1985 to 1989. While with the USDA, she assisted in the development of national nutrition and consumer policies, as well as in the oversight of the Food and Nutrition Service, the Human Nutrition Information Service, and the Office of Consumer Advisor.

Prior to joining the USDA, she held faculty positions at the University of Alabama at Birmingham where her primary research interest was in vitamin A and bone formation. She holds a PhD in biochemistry from the University of Alabama at Birmingham and a BA in chemistry from Vanderbilt University.

Module IV—Ensuring Safe and Healthy Food

Q&A

Moderator: Spencer Henson
University of Guelph
Guelph, ON

Ann Oaks [University of Guelph (retired), Guelph, ON]: Dr. Wambugu, I really appreciated your talk. I haven't seen such a good overview of the situation in Africa. You mentioned a population increase in Africa, whereas from what I've been reading, HIV/AIDS is causing a decline in numbers. My other comment has to do with nutrition. There are two ways to approach this, one being via agbiotech, the subject of this conference, for vitamin-A deficiency for example. But from my reading, NGOs like CARE and Oxfam are emphasizing small mixed garden plots to encourage families to grow a variety of foods. Sometimes we have a misperception in North America that one food is going to solve all the problems. We want a mixture. Carrots, for example, would supply vitamin A. Is that an alternative to Golden Rice™ and an easier alternative to handle?

You said something about subsistence agriculture and I have a feeling in North America we think that's bad. But really it's food for the people and it should be the first priority. In addition we need a cash crop and you stressed that. Bananas may be the cash crop; each country needs subsistence and cash crops. We don't want importation of food. We want to grow as much as possible. But each country—particularly in the South—have something to export: bananas or coffee or cocoa. I think that this is something that people in developed countries—America and Europe—do not appreciate and it needs to be addressed by the World Trade Organization, International Monetary Fund, *etc*. I wish Dr. Wambugu had brought her book along; I want to buy one. I want to buy ten. Thank you very much for a good talk.

Florence Wambugu: Thank you very much for that compliment. I share it with the rest of the people in Africa Harvest and many others working in Africa. The interesting bit about HIV is certainly there is population decrease, but at the same time it doesn't help because a lot of resources are being used on people who soon die. But, they don't just die in a day. Before they die, a lot of family income is consumed with medicine purchases, or whatever. Thus, poverty is increased by HIV. A large part of the problem is that the children are left. The high-risk population—many of them have several children who are left without anybody. Some people take them on board, so families are increased in size, which exacerbates hunger and poverty. Also those who live in poverty and are undernourished are more likely to succumb to HIV. They are less likely to respond even when retroviral drugs are available. I can't say that there is documented data, but it is very clear that good nutrition helps people who are taking anti-viral drugs.

I am in agreement that—whether it is banana, rice or whatever—there have to be products not only for eating but for generating some income to help the poor emerge from this vicious cycle. The North American countries now are big economies, but they started where we are. You started by farming and then by producing more, people moved to cities. Agriculture is the wheel that generates income that creates urbanization. Without producing surplus you don't have the wheel that drives industrialization.

Edilberto Redoña: Golden Rice™ has been mentioned. However, many rice farmers in Asia in particular, don't have the capacity or the access right now, or can't afford diversification. To cite an example in my country, most farmers plant rice and nothing else, so unless rice farming is profitable it is impossible to diversify. In Myanmar, for example, many people eat over 200 kilos of rice every year: breakfast, lunch, dinner and snacks in between. So while it's a good suggestion and needs to be explored you have also to consider the economies of these countries and access.

Manish Raizada (University of Guelph, Guelph, ON): A quick comment and then a question. To help some of our students and ourselves appreciate some of the realities in Africa or in Asia, I suggest listening to live-stream radio stations on the Internet. A radio station in Ghana called Joy-FM held a contest, and the prize was a sack of rice. When you hear that, it really hits home what the challenges are. I'm a molecular biologist and I would like my lab to assist in the training of future scientists in, lets say, Africa. but I'm also afraid of increasing the brain drain by doing that. Do you have any advice?

Wambugu: Well I don't think I have the answer, but I can offer some comments. It's a difficult issue because of the economies in Africa. It's good to come and take a degree here in Canada, but then the person may be trained with the mentality that the Canadian way is the only way to make things work back in Africa. So, they go back home and they prepare a budget and are grieved to learn that it equals the budget for the whole organization. The people who are needed in Africa are those who will actually generate jobs, those who can use what they have learned here and are able to step it down and be innovative and take pride in their home situation and generate some kind of income or generate some kind of product. And so, sometimes you don't want to bring people to Canada or the United States. I don't have an answer to that.

Kanayo Nwanze (Africa Rice Center, Abidjan, Ivory Coast): There are many ways in which you can help students in Africa. There are programs for student training in biotechnology—affiliated with universities in Africa—and I can help you with that. Rockefeller offers training for young biotechnology scientists. We just had a case where two of those scientists returned to the Africa Rice Center as postdocs. But then you have to obtain funding for employment as postdocs. The budget is about $40,000 a year, including benefits. I mentioned in my presentation a biosciences facility at the International Livestock Research Institute (ILRI). Is John McDermott here? Yes. that is another possibility for you to assist young African scientists—training at the facility in ILRI. And then we have exchange programs with which you can assist young already-qualified African scientists with on-the-job training in techniques and methodologies to enhance their research capacity. This could be summer training, or a specific training course, at the University of Guelph, for example.

Wambugu: I fully support that. Even in our own situation having the biotranformation laboratory in Kenya for GM sweet potato—has helped to bring back a number of people—although we still have some who haven't come back. Again I agree, but there has to be some infrastructure.

Joel Cohen (International Food Policy Research Institute, Washington, DC): A question for Dr. Redoña and a follow-up for Dr. Wambugu. Why has the Philippines been successful in approving and advancing GM food crops in Asia where China and India have not? Second question: I've heard that a well functioning biosafety system is now being looked at in parallel by a UNEP-GEF [United Nations Environment Program Global Environment Facility] effort under the Protocol; why are we examining another system when one is working fairly well? And Dr. Wambugu: the same question to you on food crops—why isn't it in all of Africa? Is South Africa is the only country that has approved food crops for use by its people?

Redoña: This is a very difficult question for me to answer given my perspective, which is pushing and pushing biotech products. The Philippines is considered to have among the strictest biosafety regulations in Asia and it has been successful probably because of strong support at the highest level. I'm referring to the level of the president, enabling commercialization of certain crops. Otherwise it would not have been possible because of the strong NGO position. You say also that China has recently obtained support at the highest level, so I think the situation will change in China. I cannot say why we need to come up with another round of review—it was decided by the Department of Science and Technology. One thing that is good in the Philippines is that biosafety and the regulatory process is not under the wing of government that is generating all the outputs—the Department of Agriculture and the universities. It's done by a separate—like what was referred to earlier—arms-length regulation with NGOs in that case being regulators.

Wambugu: I think John McDermott has an answer to this question. I can only give indicators as to why only South Africa has commercialized GM crops. Let me start by saying that South Africa has 42% of all Africa's GDP. It's the richest country in Africa—42% of all the African wealth is in South Africa. And that's why almost all the companies we have are represented in South Africa because it has ability to purchase, there is money to pay for products. Like China, it has population with purchasing ability, so big companies are there. Now, all the products in South Africa are from the private sector so that doesn't make a difference with other countries, although local universities are also participating in terms of trials, *etc*. Also, before private-sector companies came on board, South Africa had its own scientific expertise in GM technology—people like Professor Jennifer Thompson—who demanded the protocol. It was internally driven. The GMO Act in South Africa was actually initiated by scientists in the country saying they needed such an act because they were already handling plasmids, they were handling DNA, they were handling GM issues. Because it was internally driven and the country already had capacity in biotech, things could be put in place very quickly. It was demand-driven. Then it was easy for companies to come on board with their products because the country had the infrastructure, and they had finances; it's a country that is developing very rapidly.

As far as other countries are concerned, it is necessary to develop regulatory capacity. Biosafety policy cannot develop in a vacuum. The legacy of so many biosector workshops is that they have not produced capacity. Workshops, conferences, do not develop capacity. They help in networking. But, a lot of people who came to Africa thought the way to fix biosafety was to have lectures. People moved from one lecture to another, but it didn't translate to a regulatory setup. The only countries that are making progress in this regard are those with GM expertise. Kenya's was driven by the GM sweet potato. Egypt has been partnering and networking with the North and has developed quickly; they are going to commercialize *Bt* cotton. Kenya will commercialize *Bt* cotton soon; the license has been issued for field-testing. I believe Zimbabwe has conducted some pre-commercialization trials. Nigeria has a protocol. Again, in a nutshell, policy cannot develop in a vacuum. There has to be local capacity on which to build and the country must have the ability to attract significant private investment.

PART V

BANQUET AND LUNCHEON SPEAKERS

Frankenfoods: What to do When the Devil Has All the Good Songs

Peter Calamai
Toronto Star
Toronto, ON

I would like to congratulate delegates at this conference for their contributions to helping reverse the erosion of "social capital." You may have heard of the idea of social capital in the context of a best-selling book entitled *Bowling Alone: The Collapse and Revival of American Community*. The author Robert Putnam (2000) defined social capital as the fabric of our connections with each other in a society. He argued that evidence showed social capital had plummeted in the United States, impoverishing lives and communities. Americans signed fewer petitions, belonged to fewer organizations that meet, knew their neighbors less, met less frequently with friends and socialized with their families less often. They bowl more than three decades ago, but they bowl alone more often.

A similar concern about disintegrating social connection has been voiced here in Canada during the current federal election campaign. Political observers are bemoaning the hollowing out of constituency organizations, once the backbone of political parties.

But opposition to agricultural biotechnology is bucking the erosion of social capital. It has managed to unite people across ideologies, social classes, education, income, and even in disparate neighborhoods. You are as likely to find opponents to agricultural biotech in Toronto's posh Rosedale as in the grim Jane-Finch corridor, or in Chevy Chase as in southeast DC.

Why? Well, of course, there's the media.

Media and Perceptions of Agricultural Biotechnology

As prime minister, Margaret Thatcher famously said, when chastising the British press for reporting IRA attacks, "Publicity is the oxygen of terrorism." But opposition to agricultural biotechnology is not simply a media construct, although extensive media coverage adds legitimacy to the opposition. It exists because of public distrust of this technology.

My conversations with people who aren't journalists, nor involved in public policy, lead me to believe that this distrust is visceral, almost primordial. That makes it very difficult to counter. People are not opposed to making agriculture more bountiful, to helping to feed more of the world's hungry mouths at affordable costs. And many would go further. At least in North America, I think (and public opinion polls suggest) that a majority approves of the idea of nutraceuticals.

Consider this contrast. Norman Borlaug, the "father" of the Green Revolution, had widespread name recognition among the public and was generally admired. By contrast, Swiss researcher Ingo Potrykus, the "father" of beta-carotene-enriched Golden Rice™, is largely unknown by name yet either vilified or demonized by his association with this development.

Why?

Correctly or otherwise, Borlaug was seen as working within nature's laws, of not trying to play God. By contrast, much of agricultural biotech (as with Potrykus) has become branded as unnatural, as attempting transformations that nature never intended, of playing God in fact—and without a proper safety net.

A widespread ignorance of even the most basic elements of science on the part of many journalists has contributed to this image of agricultural biotech.

Let me acknowledge right at the start that a widespread ignorance of even the most basic elements of science on the part of many journalists has contributed to this image of agricultural biotech. This lack of knowledge leads to too many journalists taking even the most exaggerated claims of extreme opponents at face value. Activists and axe-grinders can get a free ride on scientific topics that they would never enjoy in sports, business, entertainment and other areas. Even in politics, for instance, we run reality checks during a federal election campaign.

However I should note that two years ago my newspaper, *The Toronto Star*, gave prominent coverage to *Nature*'s disavowal of the research that journal had originally published claiming that genetically modified corn had made its way into native varieties in a remote area of southern Mexico. I wrote that retraction story, even though I had not covered the original research in November 2001.

The media's contribution is largely one of omission, of views and issues not reported, of risks not put into context. I will examine the reasons underlying the public distrust of anything that even smacks of agricultural biotechnology, no matter how it is gussied up and sold. Most of these reasons will be familiar to you.

There is skepticism, cynicism and widespread disbelief that governments are equipped to adequately regulate such fields, and the doubt that they would do it, even if capable.

Reasons for Public Distrust of Agricultural Biotechnology

The number one reason by far is the skepticism, cynicism and widespread disbelief that governments are equipped to adequately regulate such fields, and the doubt that they would do it, even if capable. There are ample grounds for such distrust. Nationally we had the shameful failure of public-health regulation in the tainted blood scandal. A commission headed by Judge Horace Krever found health officials had conspired to try to conceal their deliberate decisions to roll the dice with people's lives.

In Ontario we had the deaths at Walkerton caused by drinking-water treatment that was well below Third-World standards. Subsequent investigation revealed that a whole chain of public regulatory bodies had fallen down on the job.

In the field of agricultural biotechnology in particular, the reasons for public unease about regulatory rigor were laid out extensively in a report in February 2001 from an independent Expert Panel set up by the Royal Society of Canada at the request of the federal Health Department. In the United States, a similar review process is operated by the National Academy of Sciences.

The Royal Society panel concluded that the basic approach of federal regulation of agricultural biotechnology products was "scientifically unjustifiable." The review by federal experts was too often cursory, almost always secretive and overly dependent on unverified material supplied by the parties who stood to benefit directly. This flawed approach exposed Canadians to potentially severe health risks, including toxicity and allergic reactions.

The Royal Society singled out the overly cozy relations between federal regulators and the biotech industry, and the virtual co-opting of many university researchers by industry funds. Both arrangements led to excessive secrecy and contributed to "the general erosion of public trust in the objectivity and independence of the science *behind the regulation of food technology*." [emphasis added]

Maybe this report would have been a two-day wonder, and passed quickly from the public consciousness, except for the reaction of the top officials in the federal health department. They attacked the fifteen experts on the panel, saying they hadn't grasped how the regulatory system worked and how thorough and rigorous it was.

Consider that as a tactic in winning the public's confidence; you invite outside experts to examine your system, expecting some suggestions for a minor tune-up here-and-there, but overall anticipating the Good Housekeeping Seal of Approval. Instead you're told that the system may have worked so far but it's inadequate for the next generation of products entering the pipe-line.

Your response is to call the experts "dumb." Think of the message this sends to the public. If a Royal Society expert panel isn't competent to make a considered judgment, then who is? Only the Health Department itself, and maybe also their good friends in the agricultural biotech industry? The public distrust and suspicion only grew when it became clear that the federal health officials had not given the Royal Society experts access to some key material about their major misgiving—the application of the principle of substantial equivalence.

Barely mentioned in the Royal Society report was another reason for public suspicion of the government's commitment to rigorous regulation. The fox is guarding the hen-house. One of the biggest promoters of agricultural biotechnology is the federal government itself. Admittedly the promotion and regulation functions are in different departments. But the same perception issue with nuclear power was addressed by setting up an independent, arms-length regulator, the Canadian Nuclear Safety Commission.

That was all three years ago. No outside review of federal regulation of agricultural biotechnology has been done since, so there is no independent evidence that anything has changed.[1]

A second reason for public suspicion of this field is the presence of so many large multinationals, mostly American in origin.

A second reason for public suspicion of this field is the presence of so many large multinationals, mostly American in origin. As must be evident after the Enron scandal, Michael Moore's movies and the revelations of falsehoods at the *New York Times*, few in North America have reason to trust large corporations to tell the truth or to act ethically. And when corporations divide the Supreme Court of Canada 5–4 over the right to patent plant genes, they may have won a legal battle, but they are well on the way to losing the public relations war. Without even taking into account beating up on someone with an inoffensive name like Percy Schmeiser.

[1]However, on October 5, Prime Minister Paul Martin announced a 10-year, $35-million federal grant to establish the Canadian Academies of Science. One of the chief tasks of the Academies is to continue the Expert Panels begun by the Royal Society, one of the three constituent members of the new body.

There is cognitive dissonance between the avowed goals of agricultural biotechnology, of feeding more people at lower cost, and the reality of the existing applications.

Third, there is cognitive dissonance between the avowed goals of agricultural biotechnology, of feeding more people at lower cost, and the reality of the existing applications. As the FAO (2004) noted in an overview report in May, corn, soybean, cotton and canola aren't leading crops in much of the developing world. Yet those crops are where most of the agricultural biotechnology effort has been centered.

Modifications like genetically engineered herbicide resistance in crops have largely cut input costs for participants in a sector already heavily subsidized by the public purse, and boosted profits for all concerned. They have not substantially improved agricultural output in many areas. In countries like Argentina, genetically modified soybean has produced an environmental crisis through overuse of herbicides. This may be a mishandling of the technology rather than an inherent fault of the technology itself. But as the nuclear accidents at Three Mile Island demonstrated, that's a distinction that usually gets lost where public distrust is concerned.

Fourth, we get to the actual title of this talk, the topic of popular culture. When General William Booth, founder of the Salvation Army, was asked why he instituted the famous "hallelujah" bands he declared: "The Devil has no right to all the good tunes!"

That's one thing that sustains public doubts about agricultural biotechnology once they have been planted. Your field doesn't have many good songs. You don't even have any catchy titles. As a wordsmith, I appreciate that proponents might wince at genetically *engineered* foods, in the same way that *nuclear* magnetic resonance was a big turnoff in the health-imaging field. But the health folk replaced "NMR" with "MRI." I'm afraid "products/plants with novel traits" just does not cut it. Not against "frankenfoods," that's for sure.

Genetically modified (GM) foods are seen as the first step on a slippery slope that leads, inevitably, to the genetic manipulation of animals and humans.

Nor does such language stand a chance against the assault from *Oryx and Crake*, the most recent bestseller by Canada's Margaret Atwood. Some people abandon this book because they can't bear the thought of a world where everyone has been genetically modified. But Atwood is an example of the cross-pollution that affects agricultural biotechnology. Already we have the production of a mouse starting with genetic material from only two female mice. Few people who follow the field believe that cloned humans will be far behind, despite all the supposed regulations to control it. And if we are unable to fend off cloned humans, are frankenfoods really so hard to believe?

This cross-pollution works both ways too. Earlier this year, I carried out several interviews with researchers in British Columbia working on the genomes of the Atlantic salmon and the cabernet sauvignon grape. They repeatedly emphasized that they were not attempting any genetic manipulation. Just the initials GM were considered a kiss of death for the salmon and wine industries.

The last reason for public suspicion is the tardiness and miserliness in funding research into what I'm going to call "public good" applications of biotechnology in the food area, and into the ethical, societal and legal dimensions of agricultural biotech.

The last reason for public suspicion is the tardiness and miserliness in funding research into what I'm going to call "public good" applications of biotechnology in the food area, and into the ethical, societal and legal dimensions of agricultural biotech. Both these areas were essentially unfunded in Canada until a year ago when the Advanced Foods and Materials Network was established, one of the Network of Centres of Excellence established across the country. The food network has just $22 million funding over five years to support the work of more than eighty researchers from government, industry and academia. You can do the math and figure out just how much your project could count on.

One of the network's goals is to pool the best Canadian scientific capacity "to do the research that will lead to new discoveries and new, socially acceptable, value-added products and processes." As far as I can tell, this November 4, 2003, announcement from the University of Guelph marks the first time in Canada that any agricultural biotechnology initiative has conceded that social acceptability is something that has to be earned by the nature of the research, rather than by the size of the profit.

Those are six elements that help nurture and sustain public distrust of agricultural biotechnology. Now add to those some institutional peculiarities of the media.

- Among most reporters and editors in North America, there exists a deep-rooted ignorance of basic scientific and technical information.
- Journalists are even more suspicious than the general public of the government's competence to regulate agricultural biotechnology.

- Journalists assume that regulators are often captured by the industries they regulate.
- Struggling daily to express complexities in plain language, journalists react badly to "jargon" or specialized polysyllabic words. They see this as elitism, laziness or deliberate obfuscation. They're usually right.

Come up with some better songs.

Lobby for an arms-length regulatory body for agricultural biotech.

Accentuate the positive.

WHAT RECOURSE?

Is there anything you can do about all this—the widespread public distrust and the media's own peculiar take on agricultural biotechnology? Even if this is all misperception, rather than reality, you still have to tackle it. Here are some ideas:

Come up with some better songs.

Lobby for an arms-length regulatory body for agricultural biotech, perhaps modeled on the Canadian Nuclear Safety Commission.

Accentuate the positive. Energetically publicize the involvement of industry and academic partners in undertakings like the Advanced Foods and Materials Network.

Convince the gatekeepers in the media that their reporters and copyeditors could profit from workshops on some of the scientific concepts underpinning agricultural biotechnology, including risk analysis. Facilitate the workshops but don't control them. Buttress your case by noting that the Canadian Broadcasting Company is now running a Critical Skills course internally for its employees that includes segments on basic science and risk.

Of course, I could be dead wrong about all this. As you likely know, there's an active branch of research pursuing the concept of selecting various dormant gene-expression patterns in organisms. I think the public could see this as far more natural than inserting genes from a foreign organism. And all of the industry's problems would be solved. Just don't let anyone dub these new organisms with a disparaging name as catchy as frankenfoods.

REFERENCES

Putnam R (2000) Bowling Alone: The Collapse and Revival of American Community. New York: Simon & Schuster.

Royal Society of Canada (2001) Expert Panel on the Future of Food Biotechnology. Ottawa: Royal Society.

Food and Agricultural Organization (FAO) (2004) The State of World Food and Agriculture 2004. Rome: FAO.

Peter Calamai is the national science reporter with *The Toronto Star* based in Ottawa. He is a founder of the Canadian Science Writers Association and past member of advisory boards to Environment Canada and the Natural Sciences and Engineering Research Council.

Mr. Calamai graduated with a BSc in physics from McMaster University in 1965 and worked as correspondent and editor with the Southam company for 30 years. As a Southam Fellow at Massey College, 1982–83, he studied Canadian history and constitutional law. In 1985–86, he was Max Bell Visiting Professor in the journalism school at the University of Regina. From 1990 until 1996, he was editorial page editor of *The Ottawa Citizen*. Recently he co-authored *Subsidizing Unsustainable Development*, a report to the Rio +5 Summit for the Earth Council. He also served as a guest columnist for the Microsoft Network's online coverage of the 1997 Canadian general election. He is a three times winner of Canada's highest print journalistic honor, the National Newspaper Award, and an adjunct research professor in the School of Journalism and Communication at Carleton University.

His spare-time pursuits include conchology with specialization in the cowry (*Cyprae)*, ornithology, astronomy, and the genetic engineering of tomatoes.

Agriculture's Future: "Reading the Tea Leaves"

John P. Oliver
Maple Leaf Bioconcepts
Napanee, ON

The agricultural industry is capital intensive, technology driven, and absolutely critical to the health and welfare of every person on this planet. Unfortunately agriculture has become politicized and, to a degree, marginalized in our society. Although the results that we have been able to deliver via the application of technology to a natural resource-based industry have been absolutely phenomenal over the past 50 years, our profile—our political clout—has diminished.

I will discuss a new way forward that I believe will place our agricultural industry and the fruits from the application of the biosciences "on the table" (pun intended) in a dramatic way. Hopefully, I will leave no doubt that agriculture is a foundation—a pillar—necessary for societal progress.

One of the limitations in this industry is our inability to come to grips with long-range planning. When I talked with Alan Wildeman about this presentation, he suggested looking at the tea leaves to about 2050. In some societies, particularly parts of Asia, people do have a focus beyond 5 or 10 years, to 20 years or more. But, 2050 seems too far out beyond those time horizons. It leaves too large a gap in an industry fluctuating between reasonable profitability and uncertain survival, for people to cross. It is hard to think about draining the swamp when you are up to our thighs in alligators.

Recently I visited a processing company in the mid-west of the United States. In discussions about long-range planning, I focussed on 2015. Senior management said that they cannot plan effectively beyond 5 years, and 3 years is a better horizon. In agriculture, much of our planning has been done on a 3-year time period, but by drawing a straight line from last year to next year.

We must go out to the future then return to the present in order to long-range plan effectively. I will discuss three trends—drivers—that I think will shape the next 15 to 20 years. Hopefully we can weave these drivers together into a strategy, into a recipe for the future. Finally, I will make some comments on a new process that we have undertaken in Canada that will, hopefully, provide one option as a path forward to the future.

Trends and Drivers

Recently, a speaker at a conference in Florida talked about hard trends and soft trends and the difference between them. He classified a soft trend as something that may happen based on a set of circumstances at present and a hard trend as one that is solid and verifiable scientifically with physical evidence to back it up. As an example of a soft trend, within a year of the death of Elvis Presley in 1977 there were so many imitators that a trend indicated that by the year 2000 one in three people in the United States would be a Presley impersonator!

Global population growth is a hard trend. Eight billion people will be trying to find standing room on this planet by the year 2020. The population doubled, from three billion to six billion, from 1960 to 1999, just 39 years. Now add another 33% in the next two decades—where does that kind of trend end and what will be the effect on the enclosed biosphere that we call Earth?

I worked in the broiler-chicken feed business in my first years out of college. Those of you in poultry or animal production know what happens when you concentrate large numbers into a limited space. We are doing the same thing with *Homo sapiens*.

China and India and also, potentially, smaller Asian nations will emerge as the economic tigers of the twenty-first century.

First Trend

China and India and also, potentially, smaller Asian nations will emerge as the economic tigers of the twenty-first century. We talked about population growth from three billion in 1960 to eight billion in 2020, a 133% increase in six short decades. Peeling those gross numbers reveals that, in 2020 the population of India and China will equal that of the world in 1960. These two countries are industrializing rapidly and will devour limited natural resources like we have never seen before.

In North America, we are gluttons when it comes to energy use. In 2002, the United States consumed oil at a rate of 67 barrels/1,000 people/day, Canada 62. China consumed only 3.8 barrels and India 1.9. China's industrialization and push to prominence will significantly increase global consumption of energy even in the short term—between now and 2015. It is expected that, within 30 years, China and India's rate of oil consumption will be at least half that of North America. For this reason the issues of alternative energy and energy security are increasingly important, which is reflected in current pricing. However, $40 per barrel of oil will look really cheap in 15 years.

The same trend will apply in the agricultural industry; we will have to deal with increased growth in animal-protein consumption and changes in diet and absolute increases demanded by newly affluent consumers in Asia. We are most used to thinking about animal protein in the form of terrestrial animals and poultry. However, farming the oceans in various shapes and forms of aquaculture will eclipse our beef industry, for example, which is based on high intake of plant-based protein to produce a pound of animal protein for human consumption. As hard as it is for us to plan long term in agriculture, we have to make the attempt and we must deal with it, because change, like time, will not wait for us. The future is all about demands for enormous volumes of healthy food plus energy security.

Second Trend

The population of the developed world is aging. Japan is the oldest in terms of average, but North America is coming on strong. In the United States alone, almost 80 million baby-boomers—born after 1946 as a result of soldiers returning from the Second World War—are approaching retirement: one turns 50 every 7 seconds! The population born between 1946 and 1964 is the greatest demographic "bubble" that we have ever faced. Truly, an "age wave" is sweeping over society. This population is technology literate, mobile, wealthy, and inheriting from their parents (the generation that scrimped and saved through the depression) anywhere between $12 trillion and $40 trillion, depending on what source you use. This population is also very health conscious, quality-of-life conscious, and wants to live forever. As the boomers age, they will place a tremendous demand on the healthcare system, a demand larger than ever seen before. Remember: two thirds of all people throughout all of history who have lived to be 65 years of age are alive today.

Third Trend

As society demands environmental sustainability, more and more responsibility is being taken by the individual for the environment. People are looking to hybrid cars, to retrofitting their homes to be more energy-efficient (albeit that much of this is driven by economics as energy prices rise). Energy conservation is becoming more a part of daily life. Much media noise and debate exist around the Kyoto Agreement and greenhouse-gas emissions. New studies emerge almost daily about endangered species; a recent report from Oslo, predicting that the Arctic Ocean may be inhospitable to polar bears within 20 years, has helped raise public awareness. This new consciousness will drive a demand by society that everything we do in our daily lives—government, corporate, or individual—must be tempered by the desire to leave the smallest possible environmental footprint as we pass by.

Managing Dramatic Changes

In my opinion, these three trends will drive the future. They also must drive our actions, to develop and implement strategies to manage these dramatic changes. Let's look at these three drivers, as three points on an equilateral triangle. Our strategies must deal with what's inside the lines because there is a great deal of overlap, cause and effect between the three points.

China and India as industrial powers. . . . will drive consumption of animal protein, vegetable oils and energy from all sources at rates never seen before.

China and India

Let's start with population growth and dominance early in the twenty-first century by China and India as industrial powers. Each of these countries will have between three and four times the combined population of Canada and the United Station and their economies will have increasingly affluent consumers. That factor of three to four will drive consumption of animal protein, vegetable oils and energy from all sources at rates never seen before. The economies of India and China are in take-off phase much like an airplane roaring down the runway. They aren't airborne yet, but there is going to be a dramatically increased need for energy and power as they move up the steep slope of economic growth like a climbing plane. It will attack availability of energy, it will attack availability of certain foods and it will drive up pricing. We in North America must be able to produce abundant high-quality food and we must become as energy secure through alternative sources as we possibly can. We must unhook from our dependence on fossil fuels whether domestically produced or from overseas. Expensive and timely technology development, energy conservation, and even a sacrifice in style and quality of life are all options on the table. The message from last August's blackout should resound with all of us. That was a great wake up call. We cannot be complacent: we must plan for the possibility of blackouts, power interruptions and oil and gas shortages. This calls for a strategy on energy security, which I believe is recognized in the United States but not yet in Canada. To achieve that goal will require new technology, new management and conservation techniques, a longer-term view by our politicians and, most of all, a new acceptance of individual responsibility. North America is a like an island with three nations clustered on it. We must develop a North American strategy if we are to deal with this issue in the right time frame and with the right spirit.

Environmental Sustainability

Environmental sustainability is hooked to population growth, to energy use and to lifestyle, and it must become a way of life for all of us. We cannot pay lip service to it. We cannot say that it is too costly. Each and every one of us must consciously say that we are going to leave a smaller environmental footprint for other generations to follow. We cannot leave a huge debt for our children and grandchildren to pay, a debt that may not be repayable in some cases because the damage may not be repairable. The need to reduce greenhouse-gas emissions is real and must be dealt with. The need to conserve energy is real and must be dealt with.

Let's use the power of our marketing, our access to the press and our powers of persuasion to get every person in North America to realize that it is their responsibility individually and our responsibility collectively to leave this planet better than how we found it.

Aging Population

The most immediate and most impactive concern is the effect of the aging population in Canada, the United States and in the developed world as a whole. In Canada, we are on the threshold of having to pay a huge bill; over the next 10 years, healthcare delivery is going to cost $1.4 to 1.5 trillion. We cannot avoid the bill, but we can do something about how we pay it. The population of seniors over 65 grew 130% between 1970 and 2000 and will grow another 125% between 2000 and 2020. Thus in North America, increasing numbers are predisposed to the degenerative diseases associated with aging. Furthermore, Statistics Canada has determined that 48% of Canadians between 20 and 64 are overweight, and 15% are obese. Excess weight leads to high cholesterol and heart disease, and to diabetes and numerous other diseases. Already, 41 million Americans either have diabetes or are pre-diabetic. The demand on Canada's healthcare system will chew up 75% of new budgetary expenditures—three out of every four new dollars in our provincial budgets. Keep in mind that provincial governments pay 75 to 80% of Canadian healthcare-delivery costs. Canada has only three provinces with a population base and budget that can sustain and pay for the healthcare system currently envisaged. "Healthcare is the policy gift adored ferociously by Canadians that keeps on taking," Jeffrey Simpson commented rather cynically in the *Toronto Globe & Mail* recently. This healthcare monster is on our doorstep chewing through the front wall. Canadians have two choices: figure out a new strategy to pay and hopefully reduce the bill or raise personal income taxes by 65% over the next 10 years.

This is lemonade time. We have a big lemon; let's make lemonade. The lemonade is the opportunity that agriculture and the bioscience industry offers to reduce the costs, increase the value of technology and fuel the new knowledge-intensive, bio-economy of the twenty-first century. Agriculture must move beyond a cheap food policy and being marginalized to becoming a health-utility industry that can be a pillar in the delivery of quality human healthcare. We need value strategies that provide options to the healthcare community in the forms of nutrition targeted initially at preventative medicine then moving to population medicine with products and diet regimes that prevent disease. Peel the three drivers apart and there are huge opportunities for technology-intensive agricultural industry to have a greater profile and a stronger position to play in the future, a future dominated by the demand of an aging population for access to better healthcare and the demand of society as a whole for environmental sustainability.

We must create a vision of what our industry could be in the future.

Role for Agri-Industry

What do we need to do? First, we must create a vision of what our industry could be in the future; we need a national vision that people can touch, feel and believe in. We need a compelling vision that everyone, from all parts of society, can see and will want to be a part of. We need a vision that proves that the destination is worth the price and the hardship of the trip. This is the essence of leadership. In Canada and United States there has been no compelling vision of what we as an industry could be. If our politicians cannot see beyond power for power's sake, we can make a start in this industry, because we are a pillar for a healthy future for Canadians, Americans and other peoples of the world.

Every one of us in all parts of this industry must align our actions on two deliverables: better healthcare and environmental sustainability.

Secondly, every one of us in all parts of this industry must align our actions on two deliverables: better healthcare and environmental sustainability. In every action contemplated, we must ask whether it helps to potentially improve the efficiency and effectiveness of healthcare delivery and/or whether it leaves a potentially smaller environmental footprint.

Thirdly we must build from a foundation of strength. We have a foundation of science, we have a foundation of good farms and farmers, and a foundation of solid industries, but our number-one competency to move our vision and strategy forward is trust. Ipsos-Reid did a study in the summer of 2002 on the fallout in society of the catastrophe of September 11, 2001, in New York. Ipsos-Reid found North American society to be very uncertain about its future—searching for certainty—a society in which the future would be based on competition for public trust.

In the Leger poll announced on February 27, 2004, in the *Toronto Star*, Canadians and Americans ranked firemen the most trustworthy with a trust level of 99%. The second highest level of trust, at 97%, was in nurses. The third level, at

91%, was in physicians, and the fourth level, 89%, was in farmers. (Used car dealers, at 19%, were deemed more trustworthy than politicians at 14%.)

Stop and think about marrying strengths: Nurses plus healthcare delivery, doctors plus healthcare delivery, farmers plus healthcare delivery—that's what it's about. We have that foundation of trust within a society searching for certainty where the dimension of competition is for public trust.

We now need alignment of the like-minded. We began to attack the alignment question in April, 2004, here in Canada by putting together a group of people in a think-tank hosted by the University of Guelph and the Royal Bank. We ended up with seventeen participants comprising roughly a third in provincial government, a third in industry and a third in academia. We did not want a group of people representing all sectors of society. We wanted knowledgeable committed people with the right personal chemistry to work effectively in a closely knit team. Our goal was to construct a vision of the agrifood industry in Canada in 2020.

Vision Statement

We developed a vision statement over a day and a half of facilitated creative thinking here at Guelph, having backed off to 2015 as the time horizon because we wanted to link all parts of society to a compelling reachable destination:

> *In the year 2015, Canada is a world leader in the enhancement of human, animal and environmental health through the application of research, technology and social innovations in agriculture and the bioscience industry.*
>
> *As a solution-provider to society, we reduce the burgeoning health deficit, improve quality of life, and embrace environmental sustainability.*
>
> *We are the trusted standard against which others measure themselves.*

Bumper-Sticker Version

- Agriculture: A fundamental pillar for a healthy Canada.
- The future is going to happen. We will have to pay the bill for healthcare. We will have to foot the bill also if we fail in terms of environmental sustainability.
- The future is going to happen. We can let it happen or we can shape it and lead it.

I believe that the only way to predict the future is to create it. The option is ours.

Raised on a mixed farm near Napanee, Ontario, **John Oliver** has more than 35 years experience in agricultural science and agribusiness. He began his career as an agricultural market specialist after receiving his BSc in agriculture from Ontario Agricultural College (University of Guelph) in 1961.

Mr. Oliver is president of Maple Leaf Bio-Concepts and Lojon Associates International, consulting firms in biotechnology and government affairs. He was a founding member and past chairman of the Canadian Animal Health Institute; a founding member of the Canadian Agri-Marketing Association (CAMA); chairman, Crop Protection Institute of Canada (now CropLife Canada); and president, DowElanco Canada, Inc. His achievements include being the recipient of the first CAMA lifetime achievement award; currently, he is a member of the Agricultural Institute of Canada.

Disaggregating Biotechnology and Poverty: Finding Common International Goals

Ronald J. Herring
Cornell University
Ithaca, NY

I was asked to provide concluding commentary for this conference. Fortunately, everyone attending realized that this task is unmanageable: the papers have been far too rich and wide-ranging for any tidy summary or conclusion. I will instead try to provide some sense of the thoughts stimulated by the sessions, in the hope that others may find them useful.

The wealth of empirical materials engaged in the plenary and breakout sessions should send a strong signal to analysts of the public-policy issues in biotechnology: disaggregate, disaggregate, then disaggregate.

The wealth of empirical materials engaged in the plenary and breakout sessions should send a strong signal to analysts of the public-policy issues in biotechnology: disaggregate, disaggregate, then disaggregate. There is significant variation in the relationship between technical change in agriculture and societal welfare implications along numerous dimensions. This variation is by crop, by agro-ecological system, by social structure, by property relations, by policy regime — both domestic and global. I will illustrate this lesson below with discussion on the relationships between biotechnology and poverty.

To begin disaggregating at the top, I suggest that we abandon use of the term "developing countries." Though common shorthand, the construct increasingly strikes me as empirically imprecise, deceptively linear, philosophically glib, and vaguely patronizing. Equally, we need to keep before us the distortions that excessive aggregation creates for analytics of poverty. Mahatma Gandhi once said something to the effect that India was not a poor nation, but rather a rich nation inhabited by many poor people. What benefits a powerful landlord in rural India may have no effect whatsoever, or a negative effect, on a landless worker with nothing to sell but her labor power in a crowded market. There are far more of the latter than the former. Because of inappropriate aggregation, we hear discussion of "India's interest" in biotechnology, or other technologies, when in fact there are multiple interests, often conflicting. Disaggregation gives us a better reading of the effects of new technologies of various sections of the population, and thus grounds for thinking about complementary policy.

Moreover, "development" is a process of—etymologically—"unfolding." The meaning of development for a tadpole is beyond dispute, genetically given; one can tell whether or not the frog is coming into being. There is a defined end-state: a frog lacking lungs, or possessed of three legs, has not developed properly; something in the development process has gone terribly wrong.

Nations are quite different; much of politics is a struggle to define what vision, what potential should be unfolding, what criteria should mark progress as opposed to retrogression. In 2002, the United States, for the first time since 1958, experienced an increase in the infant mortality rate, already the highest rate of any OECD country. This outcome would consensually be a step backwards on any developmental trajectory, however large the GDP may become. There is no consensual end-state: all societies are at all times potentially "developing"—or slipping. Human societal development presents continuous challenges, moving targets, redefinitions of what is possible, conflicts over what is best, what is unacceptable. There is no consensual analog of a tadpole-to-frog template. Finally, the use of the construct "developing countries" suggests that currently low-income nations are on some defined path moving upwards. The reality is progress and retrogression, radically uneven over time and space, across epochs. To talk of "developing countries" when referring to most of Africa in the 1990s, for example, would not only imply a gloss that is imprecise and naïve, but analytically distorting. Just as imperial powers rise and fall over time, development miracles come and go: Pakistan of the go-go 1960s to the crisis-ridden 1970s to contemporary volatility is archetypal.

Finding Common International Goals is an ambitious conference theme in this context. As elaborated by Alan Wildeman (2004), all three constituent elements of this theme are of special importance to the poor: ensuring safe and healthy food, reducing ecological damage, and improving quality of life. We find in the optimistically evoked "international community" repeated declarations of a global commitment to reduction of poverty; in some formulations, poverty reduction through application of biotechnology tools rises above the level of opportunity to the level of moral obligation (Nuffield Council, 1999). The absolute numbers of the absolute poor continue to increase globally, despite striking growth of GDPs and other measures of economic activity in many parts of the world. Of the many definitions of poverty available, one used by Robert McNamara as president of the World Bank in 1974 has always struck me as most apt, and I paraphrase here: absolute poverty is a condition of life so limiting as to deny the potential of the genes with which humans are born.

The very existence of absolute poverty in this sense constitutes a global imperative to apply new knowledge to alleviate limits on achievement of human potential. What might biotechnology have to do with alleviating such conditions as part of common international goals? For many in the NGO community, this very question is part of an instrumental ideological cover for corporate globalization. This flatly oppositional view of biotech lacks nuance, and certainly comes to premature conclusions about the poor, but is rooted in serious concerns about property and costs of cultivation of greatest importance to the marginal producer. The empirics thus far do not seem to bear out the most pessimistic scenarios of opponents to transgenics, yet their premises warrant our collective attention if we are serious about the condition of the poor.

Development Context: Dr. Swaminathan's Challenge

In my breakout-session group, there was considerable puzzlement and surprise at the comment of Dr. M.S. Swaminathan in the keynote session to the effect that glyphosate-resistant transgenic crops are not appropriate for India. The reason for surprise is a persuasive Malthusian approach to world hunger and world poverty in the standard narrative of transgenics and the poor. If India is a poor country, should any productivity-increasing technology in agriculture not be of benefit to the poor? The ghost of the good Reverend Malthus remains quite influential. For example, Per Pinstrup-Andersen and Ebbe Schioler, in a book that won the World Food Prize for 2001, concluded, "Once again Malthus's clash between population growth and food production looms threateningly on the horizon" (Pinstrup-Andersen and Schioler, 2000). Though sophisticated analysts such as Pinstrup-Andersen and Schioler understand the many caveats embedded in the Malthusian narrative, there remains a widespread misconception—echoing corporate public-relations—that biotechnology means more food and more food means less poverty. Dr. Swaminathan's comment puts us on another, and more fruitful, analytical track, but one that is conceptually and empirically challenging.

Broad statements about whether advances in biotechnology will benefit or disadvantage the poor are unlikely to be useful.

Broad statements about whether advances in biotechnology will benefit or disadvantage the poor are unlikely to be useful. Both "biotechnology" and "the poor" are heterogeneous categories. Yet the public and political discourse around biotechnology has largely taken a dichotomous and generalizing form[1], though more so in agriculture and food systems than in pharmaceuticals.

Biotechnology covers a wide range of practices and products. The most contentious—and potentially powerful—sphere is genetic engineering, though it is already clear that advances in biotechnology outside the transgenic realm make significant contributions to plant breeding. It is recombinant DNA work that has energized the debate, because of its unique potential and consequent susceptibility to suspicion. Transgenic organisms are regarded by proponents as offering unprecedented benefits to humanity and by their critics as introducing unacceptable uncertainty, perhaps serious risk. This disagreement becomes more pointed when proponents claim that genetic engineering offers means of improvement in the lives of the poor that can be approached in no other way, for example in creating nutrient-dense varieties of rice (Bouis, 2003). The ethical assumption is clear: poverty produces unnecessary suffering; human knowledge is a collective product and good; knowledge must be utilized to alleviate suffering if at all possible. Critics claim that it will be precisely the most vulnerable sections of the population that will be put most at risk by novel technologies, whether from ecological degradation, unsafe foods introduced via foreign aid or public distribution systems, allergenicity from new proteins, or monopoly control of genetic materials and thus of pricing and access to technology by multinational firms (Shiva, 2000; Altieri, 2001).

To take Dr. Swaminathan's comment in this context, it is clear that disaggregation across nation states and agrarian structures is necessary to talk sensibly about transgenics and the poor. Herbicide-resistant crops save farmers money and labor under certain agronomic conditions. Dr. Swaminathan was implicitly disaggregating a largish, indeed continental, entity we call "India" into constituent interests and suggesting that the vector sum effect of reducing labor via herbicide-resistant crops was not good policy. This is a plausible claim. The largest class of absolute poor is the rural landless who must find daily employment to maintain themselves. Reducing aggregate demand for labor under those agrarian conditions either destroys livelihoods directly or puts downward pressure on wage rates or both, in either event deepening poverty if no other systemic parameters change simultaneously. Worse, the rural poor who engage in weeding labor for a livelihood are frequently those cumulatively disadvantaged along other dimensions of social stratification: women, depressed castes, ethnic minorities. In those circumstances, even if herbicide-resistant crops would be desirable on other grounds—to encourage soil conservation, for example—a pro-poor approach would necessarily

[1]A very useful overview is Winston (2003); see also Dawkins (l997), McHughen (2000), Shiva (2000), Shiva *et al.* (2000), Altieri (2001), Charles (2001) and Paarlberg (2001).

begin discussion of land reforms, rural public works, food subsidies, and other mechanisms to avoid making the poor pay for others' profits (*e.g.* Herring, 2003a).

But the story is surely more complicated than Dr. Swaminathan suggested. Where farm labor is either scarce or mostly supplied by farmers who own their own land, ability to control weeds may enhance yields, returns for labor, and opportunities to take on more land for cultivation when available. All these outcomes could be pro-poor, depending on the net effect on costs and returns to direct producers. This view has been long advocated as correct for African conditions, and was advocated from the plenary floor by Florence Wambugu. There are rural poor in both India and Africa, but their objective interests in herbicide-resistant technology may well diverge. Moreover, even in India, demand for rural labor is highly uneven temporally: an aggregate surplus of labor, indicated by insecurity and poverty among landless workers, does not mean that acute labor shortages do not occur in times of peak demand. Farmers will frequently tell investigators that labor is in short supply. This observation may occasionally be literally true, but often means only that they cannot hire labor in discrete bundles at times separated by enforced idleness at a wage that gives them a decent profit. This farmer-profit wage may well leave the laborer below a pitiful poverty line over the course of a year, as labor demand is seasonal (Herring and Edwards, 1983). Agrarian structure matters fundamentally.

Because disaggregation produces complex analytics that require significant empirical research, the serious literature on transgenic crops and poverty is in its infancy. There is little doubt that development of affordable, scale-neutral technologies for reducing biotic and abiotic stresses on crops of special importance to marginal farmers would be important to global poverty reduction, assuming reasonable seed prices. Indeed, the great promise of recombinant DNA technology is that the specific problems of poor farmers can in principle be addressed in new and efficient ways (Lipton, 2000). The poor often face special agronomic difficulties because they are driven to the margins of agrarian systems; the best land, water, drainage, locations, credit connections, knowledge are not in their hands. Their crops do not attract the attention of the best-funded research institutions. Drought- or salinity-resistant crops are of special importance to the poorest farmers, but the technical problems in these traits exceed those of single-gene solutions such as insect resistance through *Bacillus thuringiensis*. There is thus both need and promise for transgenics developed specifically to alleviate the obstacles faced by poor farmers; but the distance between promise and delivery is long, and made longer by the political controversy surrounding biosafety and regulation, as discussed below.

The implication of this promise is that directed research and development become necessary. Critiques of biotechnology as a force for poverty alleviation thus target the incentives for and record of current research and development. Most of the currently available technology was developed for crops and agrarian conditions of wealthier farmers and countries as opposed to crops widely grown by poor farmers in poor countries [for representative data on global distribution of crops, see James (2003)]. This critique would be more powerful were the technology not so young and were there not so many new potential players at the national and global levels. Moreover, the *Bt* approach to insect control seems to be widely applicable to a common agricultural problem, regardless of size of holding. Nevertheless, the point about research and development concentration has some validity as a generalization. The political economy of this outcome, even if overstated, is very clear: unlike the international research and distribution regime of the "green revolution," most of the research in genetic engineering is in the hands of for-profit firms, rather than international public-sector and national research institutions. There is little private incentive to produce for small markets of poor people, especially when the political climate for acceptability of transgenic crops in poor countries is so uncertain or even hostile (Potrykus, 2004). Orphan crops join orphan drugs as instances of market failure. At its best, development policy is ideally suited to address such market failures. Getting the institutions right—public, private, national, global—for biotechnology is a necessary condition for purposive pursuit of poverty-reducing outcomes (Cohen *et al.*, 2003).

The spirit of pro-poor transgenic policy must begin reasoning from the needs of the poor, rather than from potentials of the technology.

Reasoning From the Bottom Up

The spirit of pro-poor transgenic policy must begin reasoning from the needs of the poor, rather than from potentials of the technology. This is explicitly a comparative enterprise: the question is always, implicitly, under what conditions do particular dynamics obtain? Though the poor are obviously a heterogeneous category, some primary desiderata can be posited universally:

- The poor need opportunities to improve incomes, which by definition would reduce poverty. Net employment and wage effects (shadowing productivity gains) relative to food prices are most important for the most vulnerable poor, whose main—often only—saleable asset is labor power.
- The poor need more affordable and more nutritious food to improve their health and to live longer and more productive lives. Affordable food is obviously important for the poor; yet the poor consumer's gain can be the poor farmer's loss when over-production causes prices to fall. Poor producers will be harmed by surpluses unless total factor productivity on farm rises and no new extractions of intermediaries—seed merchants, moneylenders—siphon off additional farmer income.

- The poor need environmental protection. This is true both because more often than for the rich, their livelihoods depend on ecological integrity, and because environmental degradation affects most quickly and seriously those with the least flexibility in life choices.

This simple accounting does not exhaust the needs of the poor; one thinks of land, shelter, political access, cultural acceptance, and personal security among other conditions. Nor should consideration of transgenics obscure the major levers through which poverty might be alleviated. The international regime of subsidies and protectionism in rich countries, for example, has a much larger impact on incomes of the rural poor than any transgenic yet developed. These macro and structural determinants of poverty and its effects must be bracketed for a discussion of biotechnology *per se*, but must not be forgotten.

Income

The easiest question concerns farmers who own their own land: what is the evidence that genetic engineering allows scale-neutral deployment with substantial benefits for very small and marginal farmers? In the narrative of proponents of transgenic crops, scale-neutral technical change can lower the size threshold of a viable farm, rescuing smallholders from the problem of having too small a farm to be viable—an increasingly troubling phenomenon. In the narrative of opponents, poor farmers in particular lack the power, autonomy or knowledge to avoid victimization by powerful purveyors of an alien and dangerous technology.

This is no place for a literature review, but the evidence seems to be squarely in favor of the scale-neutral interpretation. That is, new technology embodied in seeds does not face the lumpy investment hurdle of such innovations as tractors or tube wells that favor wealthy farmers over poorer farmers. The clearest evidence is probably from *Bt* cotton, where small farmers have increased their net income through two mechanisms: less cash expenditure on insecticides and better protection from pests, increasing production per acre (*e.g.* James, 2002; Lipton, 2003; Pray and Naseem, 2003; Zilberman *et al.*, 2003; Herring, 2005). The evidence that small farmers can take advantage of *Bt* technology to avoid debts for inputs such as pesticides and provide some insurance against crop failure and raise production has led to endorsements by global organizations such as the United Nations Development Program (UNDP, 2001)—certainly no corporate shill—and the Food and Agriculture Organization (FAO, 2004).

The most obdurate problem of poverty is, however, in many settings that of the landless poor who must seek wage employment on whatever crops need labor. More an Asian than an African problem, as suggested above, the rural landless are everywhere especially disadvantaged in economies that generate too few jobs and experience urban bias in social support services. Labor-displacing ("saving" in the discourse of maximizing managers) transgenics then come under special scrutiny. Insect- or herbicide-resistant crops, by reducing the labor needed for applying insecticides or weeding, may reduce hired farm labor, thereby affecting the demand for labor from the most vulnerable class. At the same time, increased income for farmers could generate more rural employment: the familiar trickle-down dynamic (typically assumed by those who do not have to wait for trickles for their well-being, but live rather farther upstream). The dynamic of lower labor applications on transgenic crops would be attenuated under conditions of smallholder self-cultivation: so, for example, less prevalent in *Bt* cotton in China, in theory, than in India, where cotton holdings, though small, are larger than those in China [data from James (2002)]. On yet another hand, work opportunities lost in chemical applications may be compensated by more harvest labor, less polluted ground water and less exposure to toxins. This scenario could present a difficult trade-off for the very poor, but may not be inevitable. For example, in *Bt* cotton in India, if wages are based on weight harvested—rather than a daily basis—income would increase with yield and with density of viable bolls of cotton. The inverse is that there is no income for the landless at all in harvesting crops destroyed by bollworms. To the extent transgenics reduce risk of crop failure, they serve as a macro-insurance policy for the landless poor, as they do for farmers.[2]

Poverty implications for farmers and states seeking hard currency through agricultural export earnings are complicated by segmentation of global markets; segmentation in turn is a function not of poverty concerns but of differential interpretation of the science on issues of risk and uncertainty. Here European consumers have proved disproportionately powerful. Though there seems to be some softening of official European hostility to transgenics, it is still not clear how *identification and labeling of transgenic products* in *the global market will affect opportunities for poor farmers. The example of Japan's banning of transgenic papayas underscores the vulnerability of small farmers to discrimination against transgenic crops—ironically in this case to the benefit of a multinational firm dominating the market (Lee et al., 2003).*

Finally, income effects are difficult to specify with limited data and unanswered questions about the regime of property rights and mix of public/private investment in new technologies. It is becoming clear that the burden of patents, property claims and consequent fees has been exaggerated by opponents of transgenics. Activists in India said that Monsanto would crush the peasants, for example, but a) seed costs are typically only 7–10% of the cost of cultivation, b) most farmers who use the very expensive Bollgard® seeds seem to find that net income goes up, and c) farmers who wish to avoid the high costs of officially sanctioned seeds have many gray-market unapproved *Bt* cultivars as options, some of which are

[2]*Bt* cotton in India has been in the field for too short a time, and with too few independent and credible studies, for there to be firm conclusions on this point. See Herring (2005) for some sources and evidence. It is clear that the storm-generating claims on positive yield effects of the Qaim and Zilberman (2003) piece in *Science* were based on an unusually devastating bollworm infestation and represent not a typical outcome but a limiting case, as the authors recognized. Nevertheless, such catastrophes do occur from time to time, and *Bt* crops survived when others failed.

quite inexpensive and some of which are held superior to the Monsanto version by some farmers (Herring, 2005). The monopoly powers of political rhetoric and TRIPS negotiations prove difficult if not impossible to enforce on the ground, whether in Southern Brazil (soy) or Western India (cotton). It is certainly true that Monsanto has been quite vigorous and somewhat successful in demanding enforcement of its property claims in North America, and comes down very hard on farmers to set examples, but it is equally clear that such strong interpretations of intellectual property are anomalous on a global scale. Moreover, it is the public sector that seems to be supplying more and more of the transgenic research and products in the low-income countries (Cohen, 2005).

The potential of bio-fortification of food crops figures heavily in claims for the life-saving potential of transgenics.

Health

Most of the world's poor are not farmers at all. The overwhelming fact of poverty is insecurity and restricted options: food comes first, and consumes a larger share of expenditures the poorer one is. Moreover, food expenditures of the poor tend to be weighted towards staples rather than fruits, vegetables and animal protein. For the poor family, there is not enough food and it is not adequate nutritionally. As deadly as protein-calorie malnutrition is, it is increasingly recognized that micronutrient deficiencies generated by excessive reliance on staples in an unvaried diet may be equally or more debilitating. The potential of bio-fortification of food crops—of which pro-vitamin A rich "golden" rice is the poster plant—figures heavily in claims for the life-saving potential of transgenics. The model is clear: having plants make nutrients that will be bioavailable in staples for those who cannot afford the varied diets recommended by nutritionists seems superior both in terms of cost and sustainability to alternatives such as supplementation or fortification of processed foods (Bouis, 2003).

This topic was treated well in plenary by Suzanne Harris and mentioned in passing by others. It is hard to imagine that this contribution of biotechnology is not the most significant for the poor; cash can be lost, crops can be destroyed by natural catastrophe, recessions can dry up wage labor opportunities, but as long as adequate entitlements to food staples can be maintained for the poor, nutritional enhancement of those staples contributes to health in the most direct way. What is not known is how practical nutritional enhancements are in different agronomic regions and crops, how consumers will accept transgenic foods, whether farmers will grow bio-fortified varieties, and whether or not there are dangers in over-dosage of specific micronutrients for specific people.

Environmental Integrity

The poor are the first victims of environmental degradation. They depend on the environment more and have fewer options in comparison to the rich. There are dichotomous positions on the environmental consequences of transgenics. Proponents argue for substitution of destructive agro-chemical inputs in ways that improve environments. Synthetic chemicals in agriculture are among the most toxic substances in circulation; the poor are especially vulnerable. If someone is going to put on a backpack sprayer and walk unprotected and often half-naked through fields spewing toxins, the probability that it will be a rich male is close to zero. If anyone is going to drink contaminated surface water, or water from shallow wells, that person is most likely to be found at the bottom of the social hierarchy. Here the claim of *Bt* technology, especially in cotton, is very powerful. The evidence from China on farmer health in *Bt*-protected fields as opposed to sprayed fields is clear (Huang *et al.*, 2002; James, 2002; Pray *et al.*, 2002). Reduction of pesticide spraying can be expected to conserve water as well, and reduce the destruction of beneficial insects in the fields and wildlife that depends on agro-ecological niches.

Against this clear benefit is the prospect of uncertainty—not risk, yet, for no probability distributions are known—but an uncertainty about possible ecological dangers. The magnitude of the uncertainty is not known. Pitting certain benefits against uncertain dangers presents a difficult public-choice situation. It is not helpful to say, as techno-optimists sometimes do, that science should decide; there is no scientific means of placing values on uncertain outcomes. Rather, there are widely varying distributions of risk aversion and risk acceptance (Douglas and Wildavsky, 1982). This is true for societies as for individuals. Most North Americans consume transgenic foods with little thought of allergenicity; Europeans—and some African and Asian societies—take a much more risk-averse position. Risk aversions are not subject to refutation; some people fear airplanes, others fear statistically uncommon crimes, others fear rare diseases; no data will settle the issue of their preferences or relative risk aversion. The only solution to this public choice problem is some interaction between democratic processes and biosafety institutions. The poor are the least likely to be heard in these forums under existing institutional arrangements.[3]

INSTITUTIONS: BIOSAFETY, REGULATION AND PROPERTY

There is always one institutional caveat in the standard narrative of transgenics and the poor: the assumption that an effective regulatory regime can be put in place. On this point both proponents and opponents agree. There are three huge

[3]For results from a major project testing the conceptual and empirical dimensions of this issue, see *Democratizing Biotechnology: Genetically Modified Crops in Developing Countries*, Institute for Development Studies, University of Sussex, Brighton, UK (www.ids.ac.uk/biotech).

issues: how much regulation? will regulation work? is the result worth the cost? Joel Cohen confidently said in plenary, "Risk assessment will happen," but later added somewhat more ominously, "Farmers will find a way."

Seeds are not only divisible as working capital—contributing the scale-neutral characteristic of at least some transgenic crops, and hence their contribution to raising poor-farmer income—but largely invisible to regulators (Herring, 2003b). Seeds are also highly portable; the very idea of borders becomes as problematic in the genomics revolution as it has proved to be for drugs, arms, people and information. The contemporary conflict over genetically modified (GM) soy in Brazil underscores the point: the federal state is less a means of enforcing Brazilian law than a forum in which struggles take place over regularization of a transgenic crop that farmers clearly want. "GM-free" zones declared by governmental institutions are a fantasy.[4] Likewise, underground, unauthorized *Bt* cotton seeds spread without the knowledge of either Monsanto's Indian partner Mahyco or the nodal federal authority for enforcement of Cartegena provisions, the Genetic Engineering Approval Committee in Delhi. As a result of farmer stealth and underground seeds, a kind of genetic anarchy evolved in India's cotton regions. Farmer-generated *Bt* crosses, F2 seeds of earlier crosses, unauthorized transgenic varieties produced by small companies, and the three officially approved Monsanto Bollgard® varieties approved by the biosafety regime, were all competing for space in the fields at different price points. In the face of farmer political power, regulators basically retreated (Herring, 2003b, 2005). Gene police will be hard to come by in the villages.

Ironically, the same forces that preclude effective biosafety surveillance also preclude enforcement of property rights that both firms and opposing NGOs assume. The concern for the poor is quite straightforward. For poor producers, the shift from public-sector dominance of intellectual property in the "green revolution" to private-sector dominance in the transgenic revolution could deepen market-determined disadvantages. The worst-case scenario for poor farmers would be one in which technology fees were prohibitively expensive, yields were dramatically improved on the farms of early adopters of new transgenic crops, and the poor were caught in a backwash of lower output prices because of increased yields on adopter-farms, but with no reduction in input costs or increases in yields on their own farms. Technical change in this scenario would accelerate agglomeration of ownership and the ruin of small farmers.

---

[4]See for example, *Seed Quest*, Brazil Introduces Bill to Regulate GM Crops, Rio de Janeiro, Brazil, October 30, 2003. The national state sought first to limit underground transgenic soy to one state, Rio Grande do Sul, where farmers have been growing seeds smuggled in from neighboring countries for some time. The neighboring state of Parana then banned the crop and seized shipments from the port of Paranagua, but part of this shipment was grown in Paraguay, not Brazil, raising an international dimension to the conflict. The establishment of a biosafety regime at the national level led to significant political conflict, within and outside the government (Poddar, 2004).

Market-driven distribution with strong property rights is inappropriate for serving the needs of the poor.

As the transgenic cropping revolution unfolds, though, it seems that, to date, property rights have been much more fluid, contingent and variable than opponents of the technology had feared. China's public-sector *Bt* cotton seems to be quite successful and is likely to travel to India via a partnership with Nath Seeds. In India itself, public-sector research is picking up, though still is far behind that of China (Pray and Anwar, 2003). Private-property claims also turn out to be quite negotiable. The "golden rice" property claims have been sorted out to segment the market in a way friendly to poor producers; this outcome may serve as a model for future humanitarian transfers of technology. The analogy to pharmaceuticals seems clear: market-driven distribution with strong property rights is inappropriate for serving the needs of the poor. When the Indian firm Cipla entered the African market, multinationals with prohibitively priced AIDS drugs had either to write off the market or adapt with competitive pricing. Of course the possibility remains that just as "orphan drugs" are abandoned for lack of markets because only poor people get the disease in question, there may well continue to be orphan crops, as the poor lack both economic and political power.

If some of the most pessimistic projections of the effects of strong intellectual property rights in transgenics seem exaggerated, there remains much that is uncertain. It is still true that high upfront technology fees will disadvantage poor farmers. To the extent that transgenics require more upfront cash than alternatives, they will reinforce the advantages of deep-pocket farmers over poor farmers. The poor are excluded from or disadvantaged by credit institutions and, by definition, are less likely to be able to afford cash payments from savings. They often pay more for credit. Black farmers in the United States won a massive settlement from the Department of Agriculture in 1999 to compensate for credit discrimination and loss of farms historically. Precisely the same probabilities of lower ranking in the social hierarchy that make poor farm laborers especially vulnerable to ravages of income insecurity and nutritional crisis afflict small farmers in stratified agrarian systems (Herring, 1977). More creative credit institutions are in general of special importance to the poor, and especially under conditions of technical change. By the same token, to the extent that transgenics substitute for upfront cash costs of inputs, they are of special benefit to the poorest farmers; in the case of *Bt* cotton in India, debts at usurious rates to pesticide firms have been a significant source of farmer financial crisis and the widely publicized farmer suicides of 1998 (Centre for Environmental Studies Warangal, 1998; Department of Agriculture and Cooperation, 1998). It is now clear that the Cry1Ac protein in practice substitutes for sprayed pesticides in a very cost-effective way, more so when technology fees are avoided than when they are paid (Roy, 2003; Herring, 2005).

These observations on underground seeds raise a serious concern about the feasibility of biosafety regimes. The discourse of Cartagena could well be more symbolic politics than real barrier to gene flow. If the benefits of introduction of transgenics are captured by a subset of farmers and seed companies, but the costs are spread to society generally, the case for transgenics is proportionately weaker on developmental grounds.

The first ethical dictum of development policy is to do no harm. The history of development is one of innovation, accepting risks to achieve gains. As always, the question of social justice is: who bears the risk, who is likely to gain, at whose expense? There is no dispute, for example, that the regulatory regime for genetically engineered organisms mandated by the Cartagena Protocol on Biosafety of the Convention on Biological Diversity will be costly and difficult to implement—particularly in the poorest countries—and perhaps ineffective. The opportunity costs of implementing this regime are high in terms of brain-power, skills and funds. Confronting these costs in the calculation of potential benefits of transgenics is a challenging but necessary task, one typically dodged in the standard discourse on biotechnology.

Among the common international goals for biotechnology, poverty alleviation must rank highly.

The Goldilocks Paradox

Poverty has been important, at least rhetorically, in the globally contentious politics surrounding transgenics. Supporters and opponents of transgenics have a poverty story to tell. This essay has argued that among the common international goals for biotechnology, poverty alleviation must rank highly. Conceptually, and to some extent experientially, this goal seems realistic, but is no easy mark.

The standard narrative of transgenics and the poor produces a Goldilocks outcome: societal well-being requires not too much regulation, nor too little regulation, but rather, an amount that is just right. Though reassuring for mass publics and policy analysts, the "just-right" parameters in real agro-ecologies in real social systems are extremely difficult to specify with anything approaching scientific rigor. We quickly enter the realm of Donald Rumsfeld's "unknown unknowns." In the social choice matrix into which transgenic policy must be inserted, the most complex question is then about the marginal dollar of development expenditure: where does genetic engineering lie in relation to alternatives? Every policy choice curtails or preempts others. There are, for example, a number of innovations in the area broadly known as "agroecology" that might be considered, possibly as complements, possibly as alternatives, to transgenics (Uphoff, 2003). Where should the marginal dollar of scarce development funding go? More difficult still is the question of regulation and biosafety regimes. These expenditures entail an enormous burden for low-income countries: the opportunity costs are high. The worst-case scenario is one in which biosafety costs are high, born by poor countries at the expense of pro-poor alternatives, and prove to be ineffective in practice. The evidence from *Bt* cotton in India confirms Joel Cohen's observation: "Farmers will find a way."

Though often posed as a matter of societal choice, in fact technical change typically produces differentiated costs and benefits and is driven by particular interests. Conflicts over new technologies have a long history in development studies. Ned Ludd contributed his name to one hostile characterization of opponents of technical change, yet his program was what economists tell us is the natural human condition: pursuit of individual interest. The critical developmental question for technical change is always: at whose cost, to whose benefit? To make a gross but fairly accurate generalization, capital prefers freedom to operate, labor prefers social protection – a reflection of their relative power in market society (Polanyi, 1944/1957). Because the poor are unlikely to win when dollars are criteria for power, the political system and resultant policies become critical for pro-poor outcomes.

Adoption of pro-poor strategies then presupposes political feasibility. "Finding common international goals" works better as conference theme than as political program. NGOs speaking on behalf of the poor have intermittently blocked even field trials of transgenic crops designed to find out whether or not there is environmental threat (Shiva *et al.*, 1999). This disagreement indicates the absence of even the most basic epistemological and methodological grounds for resolution of the politics. Those social forces that could form the base of a pro-poor coalition—public intellectuals, public-spirited NGOs, progressive political parties, social movements mobilizing the poor—are to date those most likely to be hostile to transgenics in poor countries. The discussion of developmental trade-offs above indicates a reasonable basis for opposition: not that transgenics make frankenfoods, but that the opportunity costs in terms of research, development, testing, monitoring, and regulation are too high. If these are the grounds of objections, there are grounds for negotiation. If the grounds of disagreement are more fundamentally epistemological, or have to do with irreducible conflicts over approaches to uncertainty and risk, there is less prospect for settlement. Democratic mediation has a Goldilocks character as well; dissent needs to fall within an elastic band: not too much, not too little, but sufficient distance for societal resolution through democratic means. There is much at stake in these politics: wrong conclusions on either side of the argument could have adverse consequences for the poor. If the critics are correct but proponents persist, the lives of the poor could be made even worse than they are now. If proponents of biotechnology are correct but critics prevail, the poor would be denied significant opportunities for improving their lives.

REFERENCES

Altieri MA (2001) Genetic Engineering in Agriculture: The Myths, Environmental Risks and Alternatives, Special Report No. 1. Oakland: Food First.

Bouis H (2003) The Potential of Genetically Modified Food Crops to Improve Human Nutrition and Health in Developing Countries, Presented at the Conference on Transgenics and the Poor, Cornell University, Ithaca.

Centre for Environmental Studies Warangal (1998) Citizens' Report: Gathering Agrarian Crisis—Farmers' Suicides in Warangal District (A.P.). Kishanpura: Centre for Environmental Studies Warangal

Charles D (2001) Lords of the Harvest: Biotech, Big Money, and the Future of Food. Cambridge: Perseus Publishing.

Cohen J (2005) Poorer nations turn to publicly developed GM crops. Nature Biotechnology 23 27–33.

Cohen J *et al*. (2003) Innovation, Regulation and Capacity for Bioengineered Crops—Sustaining a Pro Poor Agenda? Presented at the Conference on Transgenics and the Poor, Cornell University, Ithaca.

Dawkins K (1997) Gene Wars: The Politics Of Biotechnology. New York: Seven Stories Press.

Department of Agriculture and Cooperation (1998) Report of the Study Group on Distress Caused by Indebtedness of Farmers in Andhra Pradesh. New Delhi: Government of India.

Douglas N Wildavsky A (1982) Risk and Culture. Berkeley: University of California Press.

Food and Agriculture Organization (FAO) (2004) The State of Food and Agriculture 2003-2004: Agricultural Biotechnology: Meeting the Needs of the Poor. Rome: FAO.

Herring RJ (1977) Land tenure and credit-capital tenure in contemporary India. In: Land Tenure and Peasant in South Asia (Frykenberg RE Ed.). Hyderabad: Orient Longman.

Herring RJ (2003a) The political impossibility theorem of agrarian reform: path dependence and terms of inclusion. In: Changing Paths: The New Politics of Inclusion (Moore M Houtzager P Eds). Ann Arbor: University of Michigan Press.

Herring RJ (2003b) Underground seeds: the lessons of india's bt cotton episode for representations of the poor, property claims and biosafety regimes. Presented at the Conference, Transgenics and the Poor, Cornell University, Ithaca. http://www.einaudi.cornell.edu/conf/2003/gmopoverty/

Herring RJ (2004) Transgenics and the Poor: Bioproperty, Biosafety, Biopolitics. Presented at the Conference 75 Years of Development Research, Cornell University, Ithaca. http://www.arts.cornell.edu/econ/75devconf/home.html

Herring RJ (2005) Miracle seeds, suicide seeds and the poor: gmos, ngos, farmers and the state. In: From State to Market: Poverty and Changing Social Movement Strategies in India (Katzenstein MF Ray R Eds). Lanham: Rowman and Littlefield.

Herring RJ Edwards RM (1983) Guaranteeing employment to the rural poor: social functions and class interests in the employment guarantee scheme in Western India. World Development 11 7.

Huang *et al*. (2002) Plant biotechnology in China. Science 295 674–677.

James C (2002) Global Review of Transgenic Crops: 2001, Feature: Bt Cotton, Brief No. 26. Ithaca: ISAAA.

James C (2003) Preview: Global Status of Commercialised Transgenic Crops: 2003, Brief No. 30. Ithaca: ISAAA.

Lee DR (2003) Identity Preservation, Market Effects and Developing Countries: Implications of Hawaii's Experience with Genetically Modified Papaya. Presented at the Conference Transgenics and the Poor, Cornell University, Ithaca.

Lipton M (2000) Reviving Global Poverty Reduction: What Role for GM Plants? 19th Sir John Crawford Memorial Lecture. Washington, DC: CGIAR.

Lipton M (2003) From GR to GM: Can Genetically Modified Seeds Replicate the Green Revolution's Benefits to Small Farmers and Poor People? Presented at the Conference Transgenics and the Poor, Cornell University, Ithaca.

McHughen A (2000) Pandora's Picnic Basket: The Potential and Hazards of Genetically Modified Foods. Oxford: Oxford University Press.

Nuffield Council on Bioethics (1999) Genetically Modified Crops: The Ethical and Social Issues. London: Nuffield Council on Bioethics.

Paarlberg RL (2001) The Politics of Precaution: Genetically Modified Crops in Developing Countries. Baltimore: Johns Hopkins University Press.

Pinstrup-Anderson P Schioler E (2000) Seeds of Contention: World Hunger and the Global Controversy over GM Crops. Baltimore: Johns Hopkins University Press.

Poddar U (2004) Controversy Over Genetically Modified Organisms: A Comparative Study of Brazil and India, CIPA Thesis, Cornell University, Ithaca.

Polanyi K (1944/1957) The Great Transformation. Boston: Beacon Press.

Potrykus I (2004) Experience from the humanitarian golden rice project: extreme precautionary regulation prevents use of green biotechnology in public projects. Presented at BioVision Alexandria.

Pray CE *et al*. (2002) Five years of Bt cotton in China—the benefits continue. Plant Journal 31 423–430.

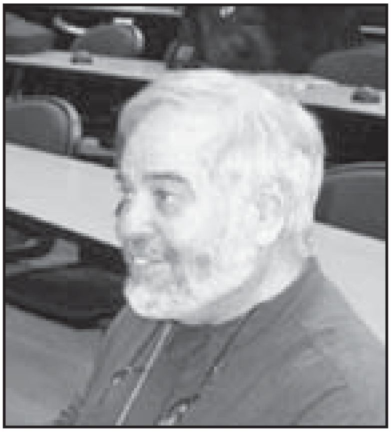
Pray C Anwar N (2003) Supplying crop biotechnology to the poor: opportunities and constraints. Presented at the Conference Transgenics and the Poor, Cornell University: Ithaca.

Qaim M Zilberman S (2003) Yield effects of genetically modified crops in developing countries. Science 299 900–902.

Roy D (2003) GMOs and Poverty in Gujarat: Is There a Connection? Presented at the Conference Transgenics and the Poor: Science, Regulation and Development Strategy, Cornell University, Ithaca.

Shiva V (2000) Stolen Harvest: The Hijacking of the Global Food Supply. Cambridge: South End Press.

Shiva V *et al*. (1999) Globalization and threat to seed security: Case of transgenic cotton trials in India. Economic and Political Weekly, March 6–12, 13–19.
Shiva V *et al*. (2000) Seeds of Suicide: The Ecological and Human Costs of Globalization of Agriculture. Delhi: Research Foundation for Science, Technology and Ecology.
United Nations Development Programme (UNDP) (2001) Human Development Report: Making Technologies Work for Human Development. New York: Oxford University Press.
Uphoff N (2003) Capitalizing on existing genetic potentials by changing crop management practices: another approach to benefiting the poor. Presented at the Conference on Transgenics and the Poor, Cornell University, Ithaca.
Wildeman A (2004) Agricultural biotechnology: finding common international goals. NABC News 28 2.
Zilberman D *et al*. (2003) The impact of agricultural biotechnology on yields, risks, and biodiversity in developing countries. Presented at the Conference on Transgenic and the Poor, Cornell University, Ithaca.



RONALD HERRING, John S. Knight Professor of International Relations at Cornell University, teaches political economy and political ecology. He was director of Cornell's Mario Einaudi Center for International Studies from 1996 to 2002. Before Cornell, he was professor of political science at Northwestern University, Evanston, IL, and taught for brief periods at the Universities of Chicago, Texas, Washington, and Wisconsin.

Dr. Herring has served as editor of *Comparative Political Studies* and worked with academic committees of the Fulbright Scholar Program, the Social Science Research Council (SSRC), the American Council of Learned Societies (ACLS), the American Institute of Indian Studies, and the MacArthur Foundation. His earliest academic interests were in land relations; *Land to the Tiller: The Political Economy of Agrarian Reform in South Asia* (Yale University Press/Oxford University Press) won the Edgar Graham Prize (London 1986). Current interests include state property rights in nature, politics of genetic engineering, and connections between foreign aid and ethnicity on which his edited volume, *Carrots, Sticks and Ethnic Conflict: Rethinking Development Assistance* (with Milton Esman), was published by the University of Michigan Press in 2001. He is professor of government and director/convener of the Governance and Nature: Rural Livelihoods and Biological Resources Program.

PART VI

List of Participants

Catherine Foluso Adejuyigbe
Agriculture Farmer's Friend Nigeria
9b Old Dugbe
Ibadan
Oyo 234 02
Nigeria

Clarissa Allen
5 Graham Street
Guelph, ON N1G 2B6

Niklaus Ammann
Botanic Garden
University of Bern
Altenbergrain 21
Bern, BE3013
Switzerland

Onyewuchi Anyanwu
Business Development
Net Solutions Limited
1st Floor Lansar House Plot 219
Rumuogba Layout Artillery
Port Harcourt
Rivers 234
Nigeria

Hardy Aviles
El Diario Autral
Los Establos 1513
Temuco
Chile

Susan Barefoot
Experiment Station
Clemson University
Clemson, SC 29634

Sarah Bates
Entomology
Cornell University
Geneva, NY 14456

Yong Mei Bi*
Molecular Biology and Genetics
University of Guelph
Guelph, ON N1G 4N3

Martin Bohl
Ministry of Agriculture and Food
1 Stone Road West
Guelph, ON N1G 4Y2

Charles Boyer
College of Agricultural Sciences
Oregon State University
Corvallis, OR 97351

Flavio Breseghello
Plant Breeding
Cornell University
Ithaca, NY 14853

Adam Bridell
US Grains Council
1400 K Street, NW
Washington, DC 20005

Delia Bucknell
University of Guelph
Guelph, ON N1G 2W1

Peter Calamai
Toronto Star
One Yonge Street
Toronto, ON M5E 1E6

David Castle
Philosophy
University of Guelph
Guelph, ON N1G 2W1

Ruth Chadwick
ESRC Centre For Economic & Social Aspects of Genomics
Furness College
Lancaster LA1 4GC
UK

Bruce Chassy
ACES/Office of Research
40 NSRC
University of Illinois
Urbana, IL 61801

Dharmendra Chaudhari*
Chemical Engineering
Block-556/6, J-Type, Category-2, Sector-16
Gandhinagar
Gujarat 382016
India

Michael Chippendale
Life Sciences Center
University of Missouri-Columbia
Columbia, MO 65211

Jens Christiansen
The Ohio State University
1680 Madison Ave.
Wooster, OH 44691

Lauren Classen*
International Development/ Anthropology
CIAT/University of Guelph
Box 278
Elm Creek, MB R0G 0N0

RonnieCoffman
Plant Breeding
Cornell Universisty
Ithaca, NY 14853

Joel Cohen
International Food Policy Research Institute
2033 K Street, NW
Washington, DC 20006-1002

Susan Coverdale
Economic Development Department
City of Hamilton
1 James Street South, 8th Floor
Hamilton, ON L8P 4R5

Nancy Cox
College of Agriculture Research Office
University of Kentucky
Lexington, KY 40546

Paul Cox

Ron Cox
21896 Grove Road
Merlin, ON N0P1W0

Jean Dalgleish
University of Guelph
43 Richardson
Guelph, ON N1G 2W1

Terry Daynard
Ontario Agricultural College
University of Guelph
Guelph, ON N1G 2W1

Janice Demoor
Ontario Agricultural College
University of Guelph
Guelph, ON N1G 2W1

Bradley Dent
Agricultural Economics and Business
University of Guelph
Guelph, ON N1G 4V9

Denise Dewar
Croplife Canada
21 Four Seasons Place, Suite 627
Etobicoke, ON M9B 6J8

Alex Dykstra
39 Lyle Avenue
Hamilton, ON L9C 4Z3

Allan Eaglesham
NABC
106 Pinewood Drive
Ithaca, NY 14850-1910
607-257-1212
FAX-257-2929
aeaglesh@twcny.rr.com

Robert Elshire
Plant Breeding
Cornell University
Ithaca, NY 14853

Carine Ferreira
Canal Rural
Rua 584 Street Cubatão, ap. 13
Vila Mariana
São Paulo-SP
Brazil 04013-002

Alessandro Farrugia
La Nazione
Via Fonteiana 126
00152 Rome
Italy

Walter Fehr
Office of Biotechnology
Iowa State University
Ames, IA 50011-3260

John Fitzsimons
School of Env. Design and Rural Devel.
University of Guelph
Guelph, ON N1G 2W1

Cecil Forsberg
Department of Microbiology
University of Guelph
Guelph, ON N1G 2W1

Jackie Fraser
Agcare
192 Nicklin Road
Guelph, ON N1H 7L5

Bernard Glick
Biology
University of Waterloo
Waterloo, ON N2L 3G1

Serguei Goloran
University of Guelph
Guelph, ON N1G 2W1

Nadilia Gomez
Agriculture, Food and Env. Sciences
University of Minnesota
St. Paul, MN 55108

Jillian Goode
International Food Information Council
1100 Connecticut Avenue NW, Suite 430
Washington, DC 20036

Winston Hagler
Agricultural Research Service
North Carolina State University
Campus Box 7643
Raleigh, NC 27695-7643

William Hannah
Philosophy
University of Guelph
Guelph, ON N1E 7A3

Carol Hannam*
Molecular Biology and Genetics
University of Guelph
Guelph, ON N1G 2W1

Margretta Hanson
Agriculture, Food and Env. Sciences
University of Minnesota
1146 Raleigh Street #1
St. Paul, MN 55108

Ralph Hardy
NABC
Boyce Thompson Institute
Tower Road
Ithaca, NY 14853
607-254-4856
FAX-254-1242
NABC@cornell.edu

Susanne Harris
International Life Sciences
One Thomas Circle NW
Washington, DC 20005

Majid Hassas Roudsari
Food Science
University of Guelph
Guelph, ON N1C 1B5

Tee Havananda
Plant Breeding
Cornell University
Ithaca, NY 14853

Spencer Henson
Agricultural Economics and Business
University of Guelph
Guelph, ON N1G 2W1

Ron Herring
Government
Cornell University
Ithaca, NY 14853

Stew Hilts
University of Guelph
Guelph, ON N1G 2W1

David Hume
Plant Agriculture
University of Guelph
Guelph, ON N1G 2W1

Sally Humphries
Sociology and Anthropology
University of Guelph
Guelph, ON N1G 2W1

Sanja Ilic*
Food Science
University of Guelph
Guelph, ON N1L 1L8

Garth James
Radio Tambrin
Tobago

Arani Kajenthira
University of Guelph
Guelph, ON N1G 2W1

Ji Hyoun Kang
Animal and Poultry Science
University of Guelph
Guelph, ON N1G 2W1

Kevin Kephart
Agricultural Experiment Station
South Dakota State University
Brookings, SD 57007

David Koetje
Biology
Calvin College
Grand Rapids, MI 49546-4403

Kira Kumagai
Philosophy
University of Guelph
Guelph, ON N1G 2W1

Roberto Labato-Ortiz
Plant Breeding
Cornell University
Ithaca, NY 14853

Cindy Lajoie
Syngenta

Valerie Laurie
International Development
Research Centre/
Street Mary's University
181 Bank Street—PO Box 71064
Ottawa, ON K2P 1W0

David Lavigne
International Fund For Animal Welfare
1474 Gordon Street
Guelph, ON N1L 1C8

Peggy Lesueur

Susanne Lipari
NABC
Boyce Thompson Institute
Ithaca, NY 14853
607-254-4856
FAX-254-1242
NABC@cornell.edu

Kathryn Lipic
Canadian Food Inspection Agency
59 Camelot
Gatineau, ON K1A 0Y9

Abigail Liu
South China Office
China Daily
16th floor, China Travel Business
Complex
(Zhonglu Shangwu Dasha)
Qiaolin Xi, Linhe Dong, Tianhe Bei Lu
Guangzhou
China 510610

Luis Maas
Plant Breeding
Cornell University
Ithaca, NY 14853

Mary Alton Mackey
Council For Biotechnology Information
1100-60 Bloor Street W
Toronto, ON M4W 3B8

Ahmad Mahdavi*
Environmental Biology
University of Guelph
Guelph, ON N1E 4L7

Victor Mahlangu
Farmer's Weekly
368 Jan Smuts Avenue
Craighall 2196
South Africa

Gerry Mandell
Adculture Group
6860 Century Avenue Suite 3000
Mississauga, ON L5N 2W5

Paul Mangat
University of Guelph
Guelph, ON N1G 2W1

Katy Martin
Plant Breeding
Cornell University
Geneva, NY 14456

Raymond Martyn
Botany and Plant Pathology
Purdue University
W. Lafayette, IN 47907-2054

Geraldine Maurer
Av. Guardia Civil 333 Consultorio 701
Lima 41
Peru

Stephanie May*
16 Riverview Ave
Markham, ON L3P 1E7

John Joseph McDermott
ILRI
Old Naivasha Road
Nairobi 100
Kenya

Murray McLaughlin
Foragen Technologies Management, Inc.
5–130 Research Lane
Guelph, ON N1G 5G3

Bruce McPheron
Research and Graduate Education
Penn State University
University Park, PA 16802

Sue Meek
Australian Department of Health and Ageing
MDP 54, PO Box 100
Woden, ACT 2606
Australia

Katie Meyer
Office of Research
University of Guelph
Guelph, ON N1H 4X2

Hussein Migdadi
National Centre For Agricultural Research and Technology
Amman
Jordan

Valentin Mitroi
Curierul National
Str. Cristian
Popisteanu
Nr. 2-4, Sector 1
Bucharest
Romania

AinsleyMoos
Beeld Newspaper
PO Box 333
Auckland Park 2006
South Africa

Shane Morris
Canadian Food Inspection Agency
59 Camelot Drive
Ottawa, ON K1A 0Y9

Ray Mowling
Council For Biotechnology
Information
1100-60 Bloor Street W.
Toronto, ON M4W 3B8

Valeria Netto*
Food Science
University of Guelph
Guelph, ON N1H 2G3

Kabi Neupane
Leeward Community College
96-045 Ala Ike
Pearl City, HI 96782

Kanayo Felix Nwanze
The Africa Rice Centre
01 BP 14029 Abidjan
Cote D'Ivoire

Ann Oaks
685 Woolwich Street
Guelph, ON N1H 8M6

Helen Hambly Odame
SEDRD
University of Guelph
Guelph, ON N1G 2W1

John Oliver
Maple Leaf Bioconcepts
Napanee, ON

Edmund Osuagwu
Imo State Agricultural
Development Programme
Box 457, Nkwogwu
Nigeria

Aboh Mbaise
Imo 234
Nigeria

Lynn Pardoe
Ontario Ministry of Agriculture
and Food
1 Stone Rd.
Guelph, ON N1G 4Y2

Theophile Pare
Environment Canada
351 St. Joseph Boulevard
Place Vincent Massey
Gatineau, ON K1A 0H3

Kirit Patel
Sociology and Anthropology
University of Guelph
Guelph, ON N1G 2V7

Katherine Perrott
197 Gordon Street
Guelph, ON N1G 1X2

Craig Person
Ontario Agriculture College
University of Guelph
Guelph, ON N1G 2W1

Steven Pueppke
Office of Research
University of Illinois
Urbana, Il 61801

John Radin
US Department of Agriculture
5601 Sunnyside Avenue, Rm 4-2232
Beltsville, MD 20705-5139

KatyRainey
Plant Breeding
Cornell University
Geneva, NY 14456

Manish Raizada
Plant Agriculture
University of Guelph
Guelph, ON N1G 2W1

Karabo Rangwetsi
Channel Africa
Radio Park, Henley Road
Auckland Park
Johannesburg 2092
South Africa

Edilberto Redoña
Philippine Rice Research Institute
Muñoz, Nueva Ecija 3119
Philippines

William Rees
Community and Regional Planning
University of British Columbia
Vancouver, BC V6T 1Z2

Muhammad Rehman*
Molecular Biology & Genetics
University of Guelph
Guelph, ON N1G 2W1

Thomas Remington
Catholic Relief Services
209 W Fayette Street
Baltimore, MD 21201

Silvia Richter
Holsteinische Strasse #21
12161 Berlin
Germany

Sandra Ristow
Agricultural Research Center
Washington State University
Pullman, WA 99164-6240

Owen Roberts
Office of Research
University of Guelph
Guelph, ON N1G 2W1

Carina Rodriguez
Canal Rural
Marcelo T. De Alvear
1465 – 1∫ Piso
Buenos Aires 1060
Argentina

Jim Romahn
Ontario Farmer Publications
Keats Way, ON N2C 6E6
Canada

Steven Rothstein
Microbiology
University of Guelph
Guelph, ON N1G 2W1

Majid-Hassas Roudsari*
University of Guelph
Guelph, ON N1G 1L3

Mehrnaz Roudsari*
Food Science
University of Guelph
Guelph, ON N1G 1L3

Lourdes Edith Rudino
El Financiero
Quinto Retorno de Mariquita Sánchez
190-B
Colonia CTM Culhuacán
CP 04480
Delegación Coyoacán
México D.F.
Mexico

Ezequiel Villanueva Ruiz*
Plant Agriculture
University of Guelph
Guelph, ON N1G 2V7

Natalia Russell
US Grains Council
1400 K Street, NW
Washington, DC 20005

Maria Salas
Plant Breeding
Cornell University
Ithaca, NY 14853

Eugene Sander
College of Agriculture and
Life Sciences
University of Arizona
Tucson, AZ 85721-0036

Marc Saner
Institute on Governance
Ottawa, ON

Andrew Schofield
University of Guelph
Guelph, ON N1G 2W1

Graham Scoles
2030 College of Agriculture
University of Saskatchewan
Saskatoon, SK S7N 5A8

Dayna Nadine Scott
Osgoode Hall Law School
35 Massey Street, #1
Toronto, ON M6J 3W4

Parvinder Sekhon
Plant Breeding Genetics and
Biotechnology
10/77 Punjab Agricultural
University Campus
Ludhiana
Punjab 141004
India

John Semple
Biology
University of Waterloo
Waterloo, ON N2L 3G1

G. Chandra Shekhar
Business Line
Kasturi Buildings
J.Tata Road
Church Gate
Mumbai 400 020
India

Anthony Shelton
Entomology
Cornell University
Geneva, NY 14456

Edgar Silveira
Anchorman-Canal Rural
Rua 584 Street Cubatão, ap. 13
Vila Mariana
São Paulo-SP
Brazil 04013-002

Steven Slack
Ohio Agricultural Research and
Development Center
Ohio State University
Wooster, OH 44691

Leo Smits
University of Guelph–Humber
92 Sparkhall Ave.
Toronto, ON M4K 1G8

Stuart Solomon*
College of Arts Student Union
University of Guelph
Guelph, ON N1H 2W9

Candace Stewart
Animal and Poultry Science
University of Guelph
Guelph, ON N1G 2W1
Canada

Art Stirling
Pioneer Hi-Bred Limited
7398 Queen's Line
Chatham, ON N7M 5L1

Gord Surgeoner
Ontario Agri-Food Technologies
1 Stone Road West, 4th Floor
Guelph, ON N1G 4Y2

M.S. Swaminathan
M.S. Swaminathan Research Foundation
3rd Cross Street, Taramani Institutional Area
Chennai, Madras 600–113
India

Johan Sweigers
Nufarmer
1st Floor PAETA Building
529 Belvedere Street
Arcadia 0083 Pretoria
Gauteng
South Africa

Amelio The*
10 Bassett Blvd. Unit#181
Whitby, ON L1N 9C7

Aislinn Thomas*
306 Pine Avenue
Oakville, ON L6J 2J9

Vernon Thomas
Wildlife Ecology and Management Zoology
University of Guelph
Guelph, ON N1E 4J8

Nancy Tout
Syngenta

Lomas Tulsieram
Pioneer Hi-Bred Production Ltd.
12111 Mississauga Road
Georgetown, ON L7G 4S7

Neal Van Alfen
College of Ag & Env Sciences
University of California
Davis, Ca 95616

Daniel Vautour
Ontario Agr-Food Technologists
1 Stone Road West, 4th Floor
Guelph, ON N1G 4Y2

Chris Verschoor
University of Guelph
Guelph, ON N1G 2W1

Tom Vestal
Institute of Food Science and Engineering
Texas A&M University
College Station, TX 77845

Robert Wager
Biology
Malaspina University College
Nanaimo, BC V9R 5S5

Florence Wambugu
Africa Harvest Biotech Foundation
International
190 Robert Speck Parkway, Suite 109
Mississauga, ON L4Z 3K3

Donald Weeks
Biochemistry
University of Nebraska
Lincoln, NE 68516

Wilfried Wesselink
Independent Journalist
Huyerenseweg 35 E
7678 SC Geesteren Ov.
Holland

James White
Adculture Group Inc.
6860 Century Ave
Mississauga, ON L5N 2W5

David Wickland
93 Airdrie Road
Toronto, ON M4G 1M4

Alan Wildeman
University of Guelph
Guelph, ON N1G 2W1

Jennifer Wilker
Plant Agriculture
University of Guelph
Guelph, ON N1G 4S7

Jean Woo
International Development
Research Centre
250 Albert
Ottawa, ON K1G 3H9

Alan Wood
Life Sciences & Biotechnology Institute
Mississippi State University
Mississippi State, MS 39762

Randy Woodson
Purdue University
W. Lafayette, IN 7907-2054

Rickey Yada
Food Science
University of Guelph
Guelph, ON N1G 2W1

Jae Ju Yu*
Crop Science & Biotechnology
Jinju National University
Jinju-City
Kyungnam 660-812
South Korea

Milton Zaitlin
Plant Pathology
Cornell University
Ithaca, NY 14850

Alejandro Zamora-Melendez
Plant Breeding
157 Biotechnology Building
Cornell University
Ithaca, NY 14853

Jun Zhou
Southern Weekend
Nanfang Weekend
289 Guangzhou Dadao Zhong
Room 1202
Guangzhou
China 510601

Asif Zuberi
Daily Business Recorder
Recorder House
531-Business Recorder Road
Karachi-74550
Pakistan

Uko Zylstra
Biology
Calvin College
Grand Rapids, MI 49546-4403

*Student Scholarship Recipient.

Index

NOTES

NOTES

NOTES

NATIONAL AGRICULTURAL BIOTECHNOLOGY COUNCIL
Boyce Thompson Institute, Rm. 419
Tower Road
Ithaca, NY 14853
607-254-4856 fax-254-1242
NABC@cornell.edu
http://www.cals.cornell.edu/extension/nabc

Printed on recycled paper