Technology Exchange*

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Agriculture in developing countries faces a huge challenge. In the next 50 years the number of people living in the world's poorer countries will increase from 5 billion to 8 billion. To feed these people farmers in 2050 will need to produce at least 50% more food, which for the 2000-2001 World Resources Report, could have devastating implications for human development and the welfare of all species.

Paul Ehrlich, one of the most influential ecologists in the USA and author of the book *The Population Bomb*, developed an equation in the 1970s to describe the impact of human population on the environment. A version of this equation, called the population-resource equation, helps put the challenge facing agriculture into stark perspective. The equation says that:

(Natural resource use) x (technology) = (population) x (per capita consumption).[i]

Given that populations are growing, per capita consumption needs to increase to feed the 830 million underfed people in the world, and our natural resource base is already seriously damaged, the only option would appear to be very rapid technological change. Is this really the only option? And if so, where are these technology gains going to come from?

Vernon Ruttan, a professor emeritus in the Departments of Economics and Applied Economics at the University of Minnesota believes, as do many others, that biotechnology is the answer. Ruttan writes, "biotechnology is poised to become the most important new general-purpose technology in the first half of the twenty-first century"[ii]. The private sector agrees. Monsanto puts it this way: "agricultural biotechnology will play a major role in realising the hope we all share. Accepting this, science can make a dramatic difference to millions of lives."

There is a strong opposing view. The United Nations (UN) Development Programme's Human Development Report 2001, published in July, urges that there should be "greater public investment in GM [genetically modified] research and development to ensure it meets the needs of the poor". However, the report was immediately slated by nearly 300 organisations around the world, including Oxfam, Greenpeace International and Action Aid who chastised the UN for its uncritical support for biotechnology. The fact that so many organisations were so quick in their condemnation bears testament to how deeply and widely reservations about biotechnology are held. Indeed, this feeling has already led to a consumer boycott against GM food in Europe that has included GM food being barred from the menu at the UK headquarters of a transnational biotech company.

In our opinion the debate has become polarised and the result is 'two-value thinking'-the assumption, frequently unexamined, that every question has two sides, and only two sides, and that organisations and individuals are either on one side or the other. In this article we examine the issues on both sides of the debate and suggest a way through the middle that, while not seeing biotechnology as the new panacea, does not dismiss it as a false and dangerous dawn.

Technology change that biotechnology may or may not bring is at the heart of both people's hopes and people's fears. Some have found it useful to think of technology change as an evolutionary process. People, as a result of the pressures they face and the opportunities they see, learn and then generate new ideas, things, and ways of organising themselves. If these novelties work well then others adopt them and they spread. Agricultural change is built up of many replications of this novelty generation, selection and diffusion process, just as we have evolved through countless natural selection iterations. Unlike natural selection though, this 'learning selection' process is not blind. Who benefits depends on who generates the novelties, how selection decisions are made, and how innovations are promulgated.

The main role of science in agriculture has been to propel this evolutionary process by generating novelties that allow us to produce more with less land and less effort. Results have been spectacular. The Consultative Group on International Agricultural Research (CGIAR), a grouping of 16 international agricultural research institutes, is best known for starting the Green Revolution of rice and wheat in Asia. In the 30 years from 1971 to 2000 the improved crop varieties produced by the International Rice Research Institute (IRRI) and the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) have helped raise average rice and wheat yields by 2.3 and 1.65 times respectively, helping to feed an Asian population that grew by almost 70% in the same period. Data from the UN Food and Agriculture Organization (FAO) show that from 1961 to 1991 the Asian population doubled from 1.6 to 3.4 billion (Article published by IRRI). In the same period, rice production grew from 199 million tonnes in 1961 to 540 million tonnes in 2000 (170%), thanks largely to the yield associated to the new, improved rice varieties. Using these data, a team of researchers from IRRI found that the total annual gains from the adoption of these new modern rice varieties now stand at US $ 10.8 billion, *i.e.*, about 150 times the total investment made in rice research over the same 40-year period by IRRI and its national research-for-development partners in Asia.

The Green Revolution crop varieties were novelties that farmers rushed to adopt. In 1982, IR36 was planted on 11 million hectares, making it the most widely planted rice cultivar ever. However, problems emerged when millions of rice farmers all moved from growing a number of their traditional landraces to just one or two genetically homogenous cultivars. Some of the resistance that the breeders had given the improved varieties against pests and diseases broke down within 3 to 5 years leading to huge crop losses. In Indonesia, for example, a fifth of farmers lost their entire crop to brown plant hoppers in 1985 and 1986. Farmers in Thailand and the Philippines suffered a similar fate.

In evolutionary terms the cause of the problem was not with the novelties *per se*, but with the selection and diffusion mechanisms that led to the technologies being so widely adopted without considering the consequences. Farmers did not know the consequences because they were used to operating on the scale of their own fields, not to thinking about what might happen over millions of hectares. And the research and extension systems that were encouraging them to adopt did not know the consequences either. This has been a salutary lesson to the **CGIAR** system: reductionist science that isolates problems and ignores contexts and scale issues can become horribly unstuck even in relatively simple agroecosystems. It does not necessarily produce sustainable solutions.

The world now needs a second Green Revolution to feed growing populations in developing countries. We believe that biotechnology has a role to play, but only if the lessons of the first Green Revolution, and from decades of experience in agricultural development in general, are learnt. In addition to the lesson about reductionist science, these lessons are:

- farming in developing countries is profoundly different to farming in developed countries;
- farms are generally small, and farming systems often complex and 'fine grained' where each grain represents a different set of opportunities and constraints that often require different solutions;
- technologies, in general, do not transfer from developed to developing countries. Rather, they need to be built up *in situ* using local knowledge and innovative ability after which, if successful, they will spread from farmer to farmer;
- sustainability is about empowering local communities to be able to adapt successfully to change; and
- if a country produces enough food to feed itself this does not mean there is no hunger. Whether people have enough food is determined by infrastructure and government policy, as well as who has access to technology.

To help farming in developing countries, therefore, biotechnology needs to support local innovative capacity and to be assessable. Local people and institutions need to be in control of the novelty generation, selection and diffusion processes. Biotechnology will not help the poor if it is transferred in a top-down, reductionist way, from first world to third. However, there is real concern that this is what is going to happen because of some actions taken by large multinational biotech companies. An example is the use of so-called Genetic Use Restriction Technologies (GURTs) to develop 'Terminator seeds', *i.e.*, seeds modified to produce infertile seed thus forcing farmers to buy new seed every year. This makes good sense for a company whose primary loyalty is to making profits for its shareholders, but is not at all in the interest of the 1.4 billion people, nearly all living in developing countries who rely on saved seed as their primary seed source. Furthermore, such technology threatens to undermine the indigenous innovation system that over the last 10,000 years has 'invented' and then refined the world's crops.

A related threat to indigenous innovation is the current patent system that offers no protection for indigenous and community-based innovation to private sector claims. The US patent on the Mexican enola bean, for example, raises the spectre of poor farmers being prevented from growing seed they have been breeding for centuries.

Hopefully biotechnology will never be used to thwart indigenous plant breeding in developing countries. Some in the private seed sector (*i.e.* Monsanto and Syngenta) have already given commitments not to use GURTs. Both companies see it in their own interest to develop partnerships with the public sector that will help bring benefits to developing countries. In April 2000, for example, Monsanto announced that it was making its draft rice genome sequence data available to public researchers involved in the International Rice Genome Sequencing Project. Within this decade, research in crop improvement will also be targeting improvement of food quality, *i.e.* vitamin A content. Golden Rice and other crops with capacity to produce beta-carotene may contribute to a balanced diet in poor rural areas as well as new demands for varied diet from urban populations with enhanced income. The private sector announced that some of the patents associated with the development of GoldenRice will not be enforced to allow consumers in the developing world to benefit from this new crop variety. Research groups are already attempting to improve GoldenRice further by enhancing the quality of the rice protein to contain more essential amino acids.

The UN Human Development Report believes, however, that relying on the spotlight of public opinion to encourage multinationals to do the right thing is not sufficient. A main conclusion from the report is that policy, not charity, will determine whether new technologies become a tool for human development everywhere. One solution the authors suggest is that rich countries support a global effort to create incentives and new partnerships for research and development. The biotech products developed by the private sector must be deployed in a way that considers both environmental and human health issues. While this discussion remains sensitive, particularly for the inhabitants of the industrialised world, it is a debate in which the developing world should have a voice, and must set its own biosafety standards within the context of economy, ecology and climate. Of course, scientists and policy makers in the developing world must ensure that the New Science serves the needs and aspirations of their people. Some of these biosafety issues need to be addressed while deploying transgenic technology:

- transgenic plants should not lead to new pests or new pest strains;
- transgenic technology for pest control should not affect non-target organisms;
- transgenic food should not pose a health risk;
- agrobiodiversity should not be suppressed by adoption of new transgenic crops; and
- transgenic plants should not affect agroecosystems if new lands are to be incorporated into agriculture.

An interesting example of research-for-development in biotechnology is provided by CAMBIA,Center for the Application of Molecular Biology, to International Agriculture. This is a not-for-profit research institute in Canberra, Australia, which was set up in 1991 to develop and package the novelty generation and selection tools that biotechnology is making possible so that farmers and local researchers can use them. One of the technologies is 'transactivation', which is based on the fact that much of the genetic variability in plants comes not from the presence or absence of genes, but from gene regulation, *i.e.*, the extent to which genes are 'turned on' and in which tissues. Manipulating gene activity in this way can create a composite crop population with a tremendous degree of variety. The plan is to provide breeders and farmers with populations of these 'turned on' plants to allow them to select the novelties they want. The power of this approach is that it allows farmers and breeders to scan the evolutionary history of a crop and recreate a vast range of novelty that might have existed at some point but died out almost immediately through natural selection. Such novelty might be of huge benefit because what a farmer requires from a crop can be the opposite to what a plant needs to survive in nature.

Functional genomics and transactivation are just some technologies that fall under the heading of 'biotechnology' which can provide both opportunities and risks to developing countries, depending on how they are used. Others include:

- Tissue culture-together with improved selection techniques tissue culture allows plant breeders to generate a new plant variety in a few generations rather than the many required using conventional techniques.
- DNA probes that allow genes conveying desired traits to be identified much more reliably and faster than conventional 'phenotyping', *i.e.*, identifying the desired gene from the

traits it produces in plants growing in the field or greenhouse. DNA probes also make it possible to screen for several genes simultaneously which is very important because features such as high yields and stable resistance to pests and diseases come from the interaction of a number of genes, rather than the presence of just one.

- Genetic engineering, *i.e.*, the manipulation of an organism's genetic information by introducing or eliminating a specific gene. Whereas in conventional plant breeding, breeders are tied to using genes from the same species, genetic engineering allows them to look almost anywhere for genes providing the traits they desire.

Genetic engineering is the technology that provides the greatest perceived threat and has caused the most controversy. One area of concern is whether GM plants and food are safe for humans and animals to eat. So far the most potent 'smoking gun' has been the finding that pollen from GM maize kills Monarch butterflies in lab experiments (but not yet confirmed by field research). There are also concerns that proteins in GM food might also cause allergic reactions.

A more important area of concern for developing countries is whether GM organisms will 'flow' to other organisms. For example, a rice plant genetically modified to have drought tolerance would sooner or later out-cross with weedy rice. This could produce 'super-weedy' rice that might exasperate the already serious problem that South American farmers have with weedy rice. The more general fear is that plants or animals that gain genes that confer some advantage would then outcompete and reduce biodiversity. This is a greater threat for developing countries, which contain the centres of biodiversity for the world's most important crops, than for developed countries. However, there are no records of a plant becoming a weed as a result of plant breeding. Interspecific hybridisation appears to be rare in nature, and resulting hybrids are mostly sterile.

Conclusions

Whether biotech helps balance Ehrlich's equation depends on how it is used, and by whom. Nearly everything points to policy. Clear, strong and equitable policy is needed in both developed (innovative incentive and funding structures) and developing countries (biosafety regulations, intellectual property right arrangements). There is no global framework for supporting biotech research and development that addresses the common needs of poor people in many countries and regions. The **CGIAR** system could be it!

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[i] Ehrlich. P.R. (1986). The Population Bomb. Ballantine Publishing Group. 201 pp.
[ii] Ruttan, V.W. (1999). The Transition to Agricultural Sustainability. The Proceedings of the National Academy of Science (USA) 96:5960-5967.