Biotechnology and the Quest for Food Security: Panacea, Panoply or Palliative?

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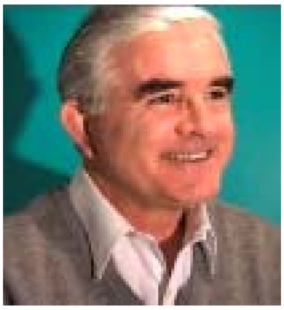

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Biotechnology can help confer traits in crops and livestock that enhance yields and quality and reduce costs, often with attendant benefits to the environment. In economic terms biotechnology offers the potential of substantially reducing the research time and costs of genetically enhancing crops and livestock. Biotechnology is viewed as a way of substantially lifting yield potentials in much the same way as conventional breeding did with the dwarfing genes leading to the Green Revolution in rice and wheat in the 1960s. To realise this potential for developing countries will require more explicit attention to their priorities and an array of complementary investments and policies. These include an increased focus on 'orphan crops' and traits of particular relevance to the poor and food insecure, and on more marginal environments. In addition these will require enabling policies and enhanced public agricultural R&D investments that will facilitate public-private partnerships in developing countries. Substantial increases in other multi-sectoral investments are also required if child malnutrition, the most insidious form of food and nutrition insecurity is to be meaningfully reduced. Increased food production alone, even aided and abetted by biotechnology, will not suffice. Biotechnology alone is not a panacea for achieving food security, or even a panoply. As argued in this paper, at best it is a palliative requiring many complements.

Introduction

It seems that a higher proportion of those living in developing countries favour the use of modern biotechnology in food and agriculture than those in high income countries, with the exception of the US (Pinstrup-Andersen and Cohen 2001). This augers well for the future of biotechnology in developing countries, although many challenges remain before the promise of biotechnology can be realised there. The paper will highlight some of the potentials and pitfalls in biotechnology for developing countries. The needs for complementary priorities, investments and policies to reap the rewards that biotechnology offers are then described.

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The potential of biotechnology

Biotechnology can help to confer traits in crops and livestock that enhance yields, improve quality and reduce costs, often with attendant benefits to the environment. Among these traits are improved water and nutrient use efficiencies, drought tolerance, pest and disease resistance, enhanced shelf life and improved nutritional contents. A range of techniques is being used to achieve these outcomes. These include the use of molecular markers for selection and breeding, introgression of new germplasm into breeding lines, genetic diversity analysis, introduction of new genes, gene discovery and DNA fingerprinting to identify improved cultivars, breeding lines and germplasm accessions. In economic terms, biotechnology offers the potential of substantially reducing the research time and costs of genetically enhancing crops and livestock. This can have a large economic value in comparison with conventional methods, although Morris et al. (2001) found that in spite of an estimated 3-year time saving for release of improved maize cultivars using marker-assisted compared to conventional breeding at

CIMMYT, the rate of return on the latter was higher.

There is evidence that the rate of growth of yields of the major food staples in developing countries has slowed markedly in the last decade. Of perhaps more concern is that yield potentials for some crops like rice on research stations may also have plateaued. In this environment biotechnology is viewed as a way of substantially lifting yield potentials in much the same way as conventional breeding did with the dwarfing genes leading to the Green Revolution in rice and wheat in the 1960s. To realise this potential for developing countries will require attention to their priorities and an array of complementary investments and policies. Biotechnology alone is not a panacea for achieving food security, or even a panoply. As will be argued in this paper, at best it is a palliative.

The area planted to genetically modified (GM) crops has grown from 1.7 M ha in 1996 to 52.6 M ha in 2001 (ISAAA 2001). Three-quarters of the area is in developed countries. Six developing countries grew the other 25%, with Argentina by far the largest among them, followed by China, South Africa and Brazil. GM soybean dominates GM plantings (63%) followed by GM corn (19%), transgenic cotton (13%) and GM canola (5%). Herbicide tolerance is the dominant trait, followed by insect resistance. GM soybean covers 46% of the total soybean area. The GM proportions for the other crops are far less than this. Early adopters of GM crops in developing countries have primarily been large farmers in Latin America, according to Lipton (1999). More recent data, however, seem to indicate that smallholders are increasingly involved and represent 75% of the 5.5 million adopters in 2001 (ISAAA 2001).

To date it has been the private sector in developed countries that has invested most in biotechnology[2]. It has been directed primarily at commercial crops in those countries and in a few developing countries with large seed markets and effective intellectual property (IP) and biosafety regimes (Byerlee and Fischer 2002; Pray *et al.* 2002).

Universities and public research institutions in developed countries protect biotechnology intellectual property, often in partnership with the private sector, and this limits collaboration with developing countries. Byerlee and Fischer (2002) maintain that there are increasing incentives for the private sector to be involved in developing countries but because of market failures their role will remain limited.

Hence the public sector will have to step into the breach if resource-poor farmers, and the ‘orphan crops’ of poor people and marginal environments, are to benefit from the promise of biotechnology. Most public sector national agricultural research systems (NARS) have not formulated a strategy for this and it is doubtful if the required public resources will be forthcoming.

The annual growth in agricultural research expenditures in developing countries has been declining. In the late 1970s growth was 7% per year, falling to 3.9% in the late 1980s and to 3.6% in the early 1990s. In Sub- Saharan Africa where food insecurity is most acute, research expenditure actually fell in the latter period. The gap between the agricultural research intensities in developed and developing countries has also been widening. In 1995 the former invested \$2.64 on public research per \$100 of agricultural output, some 4.3 times more than the \$0.62 in developing countries. In 1975 the gap was 3.5 times (Pardey and Beintema 2001). Clearly the public sectors in developing countries will not be able to realise on the promise of biotechnology unless these trends are reversed.

Not only has agricultural research expenditure growth faltered in the 1990s, the share of agricultural lending to developing countries by the major international financial institutions has been falling for the past 40 years at a much faster pace than the decline in both the share that agriculture represents of GDP and the share of the total poor in rural areas. In the late 1970s lending for agriculture was around one-third of total World Bank lending. In 1990 it was 19%, falling to 13% in 1995 (World Bank 2002). In spite of the Bank’s new 1997 Rural Strategy: Vision to Action, which aimed to reinvigorate agriculture, these trends have not been reversed as the share in 2001 fell further to 9%. Overall in the six major international financial institutions, the share of

[2] Some 94% of private agricultural research is in developed countries, where it is 50% of the total. In developing countries it represents only 6% of the total agricultural research investment (Pardey and Beintema 2001). Only around 12% of private research is concerned with farm-level technologies for improving crops and livestock. The bulk is on embodied technologies like purchased inputs, post-harvest processing and product development where intellectual property is easily protected

lending to agriculture has fallen from 15% in 1990-92 to 12% in 1994-96 and 10% in 1997-99. Hence the overall agricultural R&D investment climate in developing countries does not appear conducive to a realisation of the full potential for biotechnology.

Public-private sector partnerships are seen as the way forward. However, There are many policy issues, to be addressed before such partnerships will become a reality in many countries. These will be discussed in a later section of the paper. Of course the resources of the private sector cannot substitute for those of the public sector. Partnerships require joint investments, responsibilities and agreement on priorities that meet the needs of the poor and food insecure. On its own, the private sector cannot be expected to focus on the poor. Lipton (1999) contends GM innovations and the associated intellectual property rights (IPR) is crowding out public sector research and only encourages traits for commercial farmers and crops. To the contrary, Pardey *et al.* (2001) maintain that researchers in developing countries are freer than one might think to make use of innovations protected in developed countries. This is because there is no such thing as an ‘international patent right’. They are awarded by national governments and the protection does not extend beyond the borders of the country. The difficulties emerge when a crop using GM processes protected elsewhere is exported there. This is an infringement of IPR. However most of the staple food crops of the poor in developing countries are not traded and hence researchers are effectively free to operate using protected technologies, at least in the medium term until TRIPS becomes a reality. The limiting factor is the resources to keep abreast of biotechnological developments and to forge partnerships with the private sector.

There are only a few studies documenting the on-farm economics of the adoption of GM crops, the most thorough being done in the US. These indicate that the average additional benefits in terms of yields and gross margins per hectare may be of the order of 10-15%. This excludes the environmental and health benefits and the value of time saved. The rapid adoption rates do indicate that farmers perceive the total benefits to be large. In some years and in some locations, however, real gains are minimal, as Marra *et al.* (2002 p.34) conclude with respect to the US:

- Growing transgenic cotton is likely to result in reduced pesticide use in most years in most states, and it is more likely than not to be a relatively profitable enterprise in most of the US Cotton Belt.
- *Bt* corn will provide a small but significant yield increase in most years across the Corn Belt, and in some years and in some places the increase will be substantial.
- Although there is some evidence of a small yield loss in the RR soybean varieties, in most years and most locations savings in pesticide costs and, possibly, tillage costs will more than offset the revenue lost from the yield discrepancy.

Unless the benefits to farmers in developing countries from GM crops can be more assured and sizeable than appears to be the case in the US, where rural infrastructure and support is second to none, it is doubtful if biotechnology will offer the type of gains that are required to ensure food and nutritional security. Of course there must also be attractive returns for the private sector. In South Africa where the IPR regime is relatively strong, it seems the economic benefits of GM crops are largely accruing to farmers and consumers rather than to multinational firms (Pray *et al.* 2002). According to Pinstrup-Andersen and Cohen (2001) the literature suggests that, even under monopoly or oligopoly ownership of the technology, farmers and consumers gain from these technologies, and consumers especially. It is not clear that landless labourers would benefit though from the dominant trait developed so far with biotechnology, herbicide tolerance in GM crops, as it would most likely save on weeding labour, thus reducing their income-earning potential. This serves to illustrate that the existing biotechnology priorities of developed countries with different resource endowments are not necessarily those which are appropriate for the poor and food insecure in developing countries. Hence the need to reorient the biotechnology agenda to ensure the needs of this vulnerable group are addressed explicitly, not simply as a spillover from developed countries.

Complementary agricultural R&D priorities

Biotechnology is only one, albeit exciting, element in the quest for food security. The development community should not lose sight of the demonstrated effectiveness of other pre-biotechnology investments in rural areas in improving human welfare. Recent research by Fan *et al.* (2000 and 2002) indicates that agricultural R&D, roads and education are the wisest rural investments in both India and China. Not only do they sustainably increase agricultural productivity, but they also significantly reduce poverty and far more than other investments like rural development, soil and water conservation, health, irrigation, electricity and poverty loans. Irz *et al.* (2001) use a cross-country empirical estimation of the links between changes in agricultural yields per hectare and the incidence of poverty. They find the elasticity to be around -0.9, which is similar to that found by Datt and Ravallion (1998) of -1.0 for India. These imply that yield increases of 20% could lead to a reduction of at least 18% in the numbers of poor. As agricultural research has led to these types of yield gains in the past and could no doubt continue to do this in future, perhaps at a greater pace with biotechnology than without it, the scope for poverty reduction and increased food security from enhanced investments are large. As Irz *et al.* conclude: 'It is unlikely that there are many other development interventions capable of reducing the numbers in poverty so effectively' (p. 449).

Fan *et al.* (1999) have shown irrigation investments in India have diminishing marginal returns and that it is now rainfed areas where the marginal returns in terms of productivity gains and poverty reduction from additional government investments in technology and infrastructure are the largest. These regions have been relatively neglected in the past. The potential in rainfed areas is further reflected in the fact that, in CIMMYT research since 1980, yield potentials in marginal wheat environments have been rising at about double the rate of those in irrigated or high rainfall environments (Pingali 2001; Rajaram 2002). The growing gap between such yield potentials and farmers' current yields implies that there are high poverty and food security payoffs from closing the gaps. This does not require rocket science or biotechnology, but added investment in the tried and true methods of conventional multidisciplinary applied/adaptive/participatory research, which can be somewhat location specific. Here the participatory involvement of farmers and their husbands will help ensure the desired outcomes. Complements to crop improvement such as agronomy, soil and water management, tillage and IPM will need more prominence on the agenda. Pretty (2001) has documented 89 examples of sustainable agricultural initiatives such as water harvesting, zero tillage, IPM, green manuring etc. that on average led to a 93% increase in per hectare food production. These were local-level improvements with social learning and participatory involvement. They were management and knowledge intensive, which require building the capacity of farmers, their husbands and communities to learn about the biological and ecological complexities of their fields. Added investments to facilitate this are required.

Perhaps the most insidious manifestation of food insecurity is the prevalence of child malnutrition. The major determinants of this are per capita food availability and the status of women, as reflected in their life expectancy and their education compared to those of men. Sanitation and hygiene are also important. Biotechnology can contribute to enhancing food availability but has little role to play in the others. Currently there are 166 million malnourished children (underweight for age) in developing countries, some 70% of them in South Asia and Sub-Saharan Africa (Smith and Haddad 2000). Rosegrant *et al.* (2001) using their IMPACT model have estimated the additional rural investments required to reduce these numbers (Table 1). To do so requires a multisectoral approach. Agricultural R&D is only one part of the equation.

The above investments have benefits to many others besides children. but only those to malnourished children are shown here. The analysis showed that for an added expenditure of $US 225 billion over 23 years to 2020 from the baseline to the optimistic scenario, the number of malnourished children could decline by some 41 million.[3]

This amounts to an added expenditure of $US 239 per benefited child per year, or 65 cents per day. If the pessimistic scenario eventuates there would be almost twice as many malnourished children compared to the optimistic one and 12 million

[3] According to a report on the World Food Summit plus five in The Economist (2002), FAO estimates that halving hunger by 2015 would yield $120 billion in gains per year from longer, more productive lives; illustrating hunger is both a symptom and cause of poverty. The economic benefit-cost ratio would be about 5:1 from the $24 billion per year it is estimated it would cost to reduce hunger to these levels.

Table 1. R&D investments and projected child malnutrition outcomes in developing countries [a]

Additional investments ($US bill.)	1997	2020 projections		
		Baseline	Optimistic	Pessi-mistic
Irrigation	na [b]	175	343	0
Rural roads	na	120	129	100
Education	na	76	103	55
Clean water	na	87	98	73
National agricultural research	na	122	131	95
International agricultural research	na	14	15	11
Total	na	594	819	334
Number of malnourished children (mill.)	166	135	94	178

[a] Derived by the author from Rosegrant *et al.* (2001)

[b] Current investment levels are not available

more than there are today. Clearly progress can be made but it requires large multi-sectoral R&D investments. In this projection analysis one-third of the reductions in child malnutrition comes from reduced population growth rates, one-third from broad-based agricultural and economic growth leading to increased incomes, effective food demand and availability and one-third from improved access to education, female life expectancy and health (i.e. clean water). Increased food production alone, even aided and abetted by biotechnology, will not lead to major improvements in childhood food and nutrition security in the absence of such complementary investments.

The need for a multi-sectoral approach to rural poverty and food security is now being recognised by the World Bank (2002) in the new rural development strategy *Reaching the Rural Poor*. The focus goes beyond agriculture to embrace all sectors in 'rural space' such as infrastructure, health, education and social services. It recognises the dynamic and interactive link between rural and urban development and the need to increase the productivity and growth of both agricultural endeavours and the non-farm economy. While this is to be welcomed, if it is accompanied by a continuation of the decline in the share of agricultural R&D in the Bank's portfolio as documented earlier in this paper, there will be large foregone opportunities to reduce rural poverty and food insecurity. Currently 25% of total Bank lending is in 'rural space' (including agriculture). This appears inadequate to address the 75% of the poor who occupy that space. If the Bank is serious about reaching the poor this imbalance will also have to be made more congruent.

The IFPRI 2020 Vision agenda for an accelerated public investment strategy to enhance agricultural and rural growth with consequent reductions in poverty and food security includes:

- Yield-increasing varieties and hybrids of both food and commercial crops, which are more water efficient, drought tolerant and pest resistant, and improved livestock breeds, health and nutrition to encourage diversification;
- Yield-increasing, water-saving, labour-using soil and water management technologies and systems such as IPM and small scale irrigation in labour surplus/land scarce regions;
- Reliable, timely and reasonably priced access of farmers and their husbands to appropriate inputs such as tools, seeds, fertilisers and chemicals where needed and the credit to buy them;
- Strong extension systems and technical assistance to communicate timely information and developments in technology and sustainable resource management to farmers and to encourage development of farmer organisations to relay farmer-felt needs, perceptions and concerns to researchers;
- Improved rural infrastructure and effectively functioning markets;
- Primary education, health care, clean water and good nutrition; and
- Good governance and public administration.

Complementary policies[4]

Macroeconomic policies are crucial to the poor because of their effects on the sectoral patterns of growth, terms of trade and inflation. Countries in

[4] The first half of this section relies heavily on Ryan *et al.* (1998 pp. 7-11).

Africa undergoing structural adjustment for some years had agricultural production growth rates more than two percentage points higher than those not under such programs. The real exchange rate is most influential on supply response in agriculture, especially for agricultural exports. To the extent that the poor engage in production of export commodities they stand to benefit significantly from rationalisation of exchange rates. Development assistance is more about supporting good institutions and policies than in the provision of money (Dollar and Pritchett 1998). Institutional quality involves things like the rule of law, a quality public service and the absence of corruption. Sound policies include low inflation, budget surplus and trade openness. Developing countries with sound policies and high-quality public institutions have grown at 2.7% per year, whereas those without have contracted at -0.5% per year. With the now well-documented empirical relationship between economic growth and poverty reduction, clearly sound policies and quality institutions are significant determinants of the extent and incidence of poverty.

Policies are also needed that relate more specifically to biotechnology. These include:

- An effective intellectual property regime: balancing the rights of germplasm donor countries under the biodiversity convention with those of the public and private sectors, including farmers' rights;
- Biosafety: ecological risks; possible GM contamination in centres of diversity;
- Food safety: for consumers and livestock;
- Trade risks: export constraints on GM foods due to the 'precautionary principle'; restrictions on GM food aid;
- Concentration of input supplies to oligopolies and duopolies;
- Increased inequality if smallholders cannot access GM innovations;
- Incentives for the private sector to engage in research and/or make available IP which is relevant to the needs of the poor in developing countries;
- Incentives for NARS scientists: to collaborate with the private sector and ensure there is sufficient breeder and foundation seed supplies of GM cultivars of 'orphan crops' to encourage participatory research with poor farmers and their ultimate adoption;
- Competitive markets: for seeds, fertilisers and chemicals with adequate 'truth in labelling' and quality certification; explore role of community-based seed systems in marginal areas;
- Phytosanitary certification for exported seed; and
- More secure land tenure to encourage long-term sustainable investments in natural resources.

Conclusion

Biotechnology is a welcome complement to conventional agricultural R&D tools. It has the potential to significantly reduce research lags and lift yield potentials of agricultural commodities to new heights in environments of relevance to the poor and food-insecure. To realise these, however, will require new priorities, policies, institutional arrangements and enhanced multi-sectoral investments by both the public and private sectors, not only in biotechnology, but in a wide variety of other R&D themes. It is arguable whether these added investments will be forthcoming. Certainly neither the public nor the private sectors can do it alone. There are, however, synergies that can and should be exploited.

Biotechnology is definitely not a panacea for achieving food security for all. Nor is it even a panoply. However, with the appropriate commitment and co-operation of all members of the international community, it certainly is a welcome palliative.

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