Improving the Livelihood of the poor in Africa Using Crop Biotechnology

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Africa's woes

More than three quarters of the worlds 1.2 billion people, corresponding to over 180 million people, living in extreme poverty, are found in the rural areas of Africa (World bank 2002). This number is expected to exceed 300 million by 2020 (Amoako, 1999). 80 % of all Africans live on a daily income of less than 2 US$ and nearly half struggle to survive on 1 US$ a day or less. Rural people strive to feed themselves, while the urban population spend more than 70% of its earnings on food, leaving only 30% for other minimum basic needs such as housing, education, health care, water and livelihood. Hunger, poverty and malnutrition are the main factors interacting to create an enormous set back to socio-economic development, especially in the rural areas of Africa.

Agriculture is the backbone of most African economies and people livelihoods because it employs 70% of the population and accounts for 35% of its total gross domestic product (GDP) and 40% of its total export earnings. Over the last two decades, however, Africa has witnessed a considerable decline in agricultural productivity, with the annual agricultural growth rate falling from 2.3 % in the 70s to 2.0 % between 1980 and 1992. In the few cases where high capita production was observed, growth was mostly a result of area expansion with yield increases accounting for less than 2%. The average yield for major crops such as maize, rice and sorghum, stands at 1.2 tons ha^{-1}, compared to 4.9 tons ha^{-1} for China and 6.6 tons ha^{-1} for the USA. As a result, 14 million Africans are presently threatened with starvation in about six countries. Even though Africa imports 25% of its grain requirements, more than half of African countries need food aid.

More than 200 million Africans suffer from malnutrition as a direct result of the decline in agricultural productivity. In effect, Africa records a per capita food output of 2100 kilocalories per day. This is about 9% less than the recommended minimum daily nutritional requirement of 2300 kilocalories and 40 to 41% less than Western Europe and North America, whose daily minimum nutritional intake stands at standing at 3500 and 3600 kilocalories respectively (Nderitu, 2002). A staggering one third of the population in sub-Saharan Africa is therefore malnourished, with young mothers, children and the elderly being the most vulnerable (UNDP, 1998)**.**

The decline in agricultural productivity, leading to hunger, poverty and malnutrition, could be attributed to several interrelated and complex factors. These include weak and inappropriate policies concerning price controls that restrict internal trade in farm produce, as well as heavy taxation of agricultural exports to generate the capital for industrialization, which contributes to the reduction of incentives for agricultural production in Africa. The inequitable international trade regimes also contribute to restricting the growth of agricultural exports. Agricultural subsidies in developed countries, which are six times more than total overseas development aid flows, also distort agricultural markets (Lennart and Bage, 2001).

African population growth rates remain among the highest in the world, despite the projected increases in mortality resulting from infectious diseases. Africa's population is presently estimated at 520 million and is projected to increase to 1.3 billion in the next 25 years. While population grows at a rate of 3.5 % per annum, food production increase is 2.5 % or less depending on the country. These conditions provoke an increase in human agricultural activity including expansion of cultivated area, commercial harvesting, increasing firewood utilization, on which at least 90% of Africans depend for their energy needs, and overgrazing. These in turn lead to increasing deforestation and land degradation. Africa has lost 66 million ha of forest due to deforestation between 1980 and 1995, with 65% of this deforestation occurring in the1990s. Deforestation and land degradation are in turn associated with severe droughts and desertification, escalating soil erosion, salinization, soil compaction and poor soil fertility. With respect to the latter, many farmers have limited access to financial and technological inputs necessary for sustained agricultural production. The resulting decrease in unit land per family also creates pressures on ecosystems resulting in the loss of biodiversity, conflicts, and facilitates the spread of HIV/AIDS and other infectious diseases.

These challenges are compounded by the major health problems faced by the continent. Sub-Saharan Africa accounts for 80% of the infectious diseases. Each year, malaria alone reduces the GDP by 1%. It accounts for about 10 and 25% of direct and indirect child mortality respectively and on the whole, the death of 2 million people. The spread of HIV/AIDS and other infectious diseases like tuberculosis, which has re-emerged and is causing havoc, and is a great problem, diarrhoea, pneumonia, whooping cough, poliomyelitis, measles, river blindness and sleeping sickness, has worsened the situation and added a heavy burden to the challenges of food security.

Other factors frustrating agriculture are low technology transfer and limited empowerment of farmers. The continent remains essentially a producer of primary goods for the rest of the world, while at the same time, it is steadily losing its

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world market shares for major export crops like coffee, tea and cocoa. The issue of the competitiveness of African agriculture is a challenge. There is, however, no single formula that will guarantee poverty reduction in all African countries (Amoako, 1999). It is clear that Africa urgently needs long-term solutions to end its cycle of despair. The continent is in search of new ways and means to battle its long-standing development problems. The most recent demonstration of this is the pledge by African leaders to face up to the pressing duty to eradicate poverty and to place their countries on a path of sustainable growth and development and to participate actively in the world economy and politics through The New Partnership for Africa's Development (NEPAD).

Agriculture for sustained food production

The direct translation of the underdevelopment of Agriculture is at the core of the long-standing disappointing growth of African economies with its negative implications for people's livelihoods. Agricultural development is therefore critical to present and future economic growth and improvements in the welfare of Africa and the livelihood of its people. In countries where governments have actively supported new investments in agriculture and rural development, people have witnessed a start in the turn around of the negative trends. For example, when political leaders embraced new agricultural programmes in the 1990s in Uganda, rural poverty was reduced from 50 to 35 % (IFPR 2002).

African countries currently spend, on average, only 0.85 % of their agricultural GDP on research. This figure is much lower than the average 2.6% of industrialized countries. Though returns to public agricultural research investment in Africa have averaged more than 40%, matching levels elsewhere in the world, farmers still have limited access to crops and livestock breeds that mature early and can tolerate severe climatic conditions, and also farm inputs such as fertilizers, pesticides and herbicides. Africa's technological base conducive to cultural practices is also very limited. All this accounts for the low agricultural yields and quantitative and qualitative food production in the continent compared with other countries with similar agro-climatic conditions, even in good years. (Wakhusama, 2002).

The redistribution of existing global food surpluses is often advanced as a way of solving the problem of hunger and malnutrition especially in Africa. However, this approach is synonymous with social and economic stagnation for Africa, where 70 % of the workforce is employed in agriculture, producing food and other commodities vital to rural incomes and livelihoods. Moreover, farmers need to move from subsistence to more market oriented production, which will enable them to meet their other basic needs.

Another suggested solution is that more investments should be made in conventional breeding, which has been successful in Africa in the past, and that the farmers know best. Though the gains achieved using this approach have been encouraging, they have not been enough to offset population growth. In addition, from the scientific point of view, scientists have solved the relatively easy problems that can be tackled through conventional crop breeding.

Whatever the situation, farmers still cry out for help in order to combat the continuous onslaught of drought, pests and diseases on their crops and livestock. Scientists are doing their best to provide them with the help they need. Ways are being found to accelerate progress, and it is evident that this acceleration will be hard to achieve unless new technologies are applied to tackle the more difficult existing problems. They have therefore been reaching out to embrace biotechnology wherever this seems likely to shed new light or to offer a way forward.

Crop biotechnology as a solution

Biotechnology could broadly be defined as the manipulation of living organisms to produce goods and services useful to human beings. One of its main applications is in agriculture, where it is used in the production and processing of crops, livestock and to make food and other useful commodities. It is agreed that biotechnology should not be conceived as a panacea; however, some of the most promising gains in turning around the decline in agricultural growth may come from new biotechnology research. This is because most of the world's poor are rural based, and agriculture is a catalyst for a broad-based economic growth and development in most low-income countries. This paper will focus on new crop biotechnology, which involves the application of biotechnology to develop and disseminate new crop varieties. Herein we opine that crop biotechnology could be an effective tool, which can be harnessed to contribute to improving food production and hence the livelihood of the poor.

The three basic groups of techniques that can be applied to crop improvement are tissue culture, genetic markers and genetic modification. Tissue culture is relatively the simplest and most inexpensive technique. Genetic marker technology is relatively sophisticated and requires fairly expensive facilities, equipment and highly trained scientists, whilst genetic modification is the most sophisticated of the three techniques. These techniques cannot replace conventional approaches to developing and disseminating crop varieties but could be utilized to complement them. Although they can be used separately, yet their effect on crop production is most significant when used together.

Tissue culture

Starting tissues are removed under sterile conditions in the laboratory from parts of the plant known to be capable of regenerating into whole plants and placed in a growth medium. They grow into plantlets, which are then transferred to another medium, which encourages them to develop roots. The resulting plantlets with roots are then taken from their sterile and controlled laboratory conditions to the glasshouse where they are allowed to acclimatize, and then to the field under the less predictable and generally less favoured conditions in which they must survive and grow.

The advantage of tissue culture is that the ensuing plants are generally stronger, reach maturity earlier than ordinary plants, free of pests and likely to be free of most diseases, except viral diseases that may be present in the mother plant, and produce higher and better quality yields. The yield advantage is increased further when the mother plants are of improved varieties developed by crop breeders and because they are genetically identical to one another, there is a greater, though not absolute certainty, that they will all perform in the same way when grown in the field. This method greatly increases the rate of multiplication of plant materials and is therefore a powerful means of disseminating improved crop varieties to farmers, especially those with low multiplication ratio, such as cassava, sweet potato or banana. Tissue culture is also used to bulk up genetically identical raw material for other biotechnology processes especially genetic modification.

Genetic markers

Genetic markers are DNA sequences that could be used to track down certain traits in a plant. They are identified through the use of restriction enzymes that cut a strand of DNA whenever they recognise a specific sequence of the base pairs or nucleotides that are repeated along its length. These markers include the random fragment length polymorphisms (RFLPs), random amplified fragment length polymorphic DNA (RAPDs), amplified fragment length polymorphism (AFLPs) and microsatellites. They help in determining the segments of chromosomes where genes could be located. A more accurate set of markers called DNA expression arrays, which reveal whether or not a gene is expressed or switched on at a given time in the development of the organism, has only recently been made available.

These markers assist in the development of new crop varieties, which could be resistant to biotic and abiotic stresses. They are used in detecting genes associated with important traits by simple laboratory tests on young plantlets. It is therefore no longer necessary to grow plants to maturity in the field to find out whether or not they posses a particular trait. As such, the time it takes to develop a new variety could be greatly reduced through the use of accurate markers for a gene or genes. These markers are more useful when a recessive gene, the expression that often skips a generation, making visual selection in the field prone to error, determines a trait. The markers are also used to analyse genetic variability or to assess the relationships between populations or gene pools. This helps in the search for potentially useful materials, which could be used in breeding, or to decide on conservation measures, for example, where to collect specimens, representative of the diversity of a threatened crop. The markers could also be used in mapping genomes for specific traits. This involves crossing a variety known to have the trait with one without it and studying the expression of the trait in the progeny.

Genetic modification (GM) transformation or engineering

This technique is used to transfer a gene(s) between organisms or species that are unrelated, or between a wild relative and a cultivated variety of a crop. In effect, these genetic distances are too great to allow a high success rate using conventional plant breeding. Genes linked to the trait(s) to be transferred are attached to a disabled form of the tumour-inducing or Ti-plasmid, which is a piece of DNA from the naturally occurring soil bacteria *Agrobacterium tumefaciens* that can insert part of itself into the genome of other plants. The Ti-plasmids are then introduced into the plant to be modified. Though the use of this technique has been successful in most dicotyledonous plants, they have been less successful on monocotyledonous plants. In the case of the latter, the particle or gene gun technique is used. In this technique, the gene(s) to be transferred are coated on small particles of gold or tungsten and shot into the plant tissue of the variety to be modified. Another less widely used technique is to treat plants cells with various chemicals or by electroporation, which employs the use of enzymes and electric shocks, to make them momentarily more porous and able to absorb the DNA.

GM technique ensures greater speed, accuracy or certainty in the transfer of traits. In conventional breeding, the genes of parents are mixed resulting in a more or less random recombination in the offspring, with some remaining linked together thus making it almost impossible to separate the traits for which they are responsible. On the contrary, GM allows a more accurate transfer of just one or a few genes. As such, desirable traits are delivered alone rather than in the company of other unwanted traits. This is a very important advantage because it enables plant breeders to retain the gains made through thousands of years of breeding when they develop new varieties. Thus on the whole, GM could lead to the development of a new plant type which might have been developed with great difficulty or not at all.

Main set backs in crop biotechnology

Whilst some believe that the development and application of these techniques will enhance global food production, others call for its demise. Of the three techniques, GM attracts more controversies and criticisms. Though many set backs in crop biotechnology have been suggested by critics, the main ones are related to the erosion of the environment, biopiracy and intellectual property rights and the lack of explicit domestic biotechnology policies and institutional arrangements.

Environmental concerns

'Gene escape' is the most important environmental concern. During the growth of the crop, genes introduced to GM crop varieties could be transferred to other organisms through pollination by insects, wind dispersal or other means. However, the chances are low and transgenes are no more likely to be dislodged from a plant than the numerous other genes it contains. Even if a transgene does escape, there is a likelihood that it will be eradicated through selection pressure within a few generations. It is also unlikely to significantly upset the ecological balance. Everybody is concerned about the gene for herbicide tolerance. This gene, which has been introduced into crops such as maize, cotton, and soybean, could lead to the development of new GM 'super weeds' if it should enter into the local weed population. Another concern associated with herbicide-tolerant GM crops is that reducing weed infestation will provoke the loss of some biodiversity particularly bees, birds and insects, which will be deprived of essential feed resources and breeding grounds. This is of real concern especially in countries where these forms of wildlife are still very much intact. These risks should therefore be kept in mind.

Biopiracy and intellectual property rights

This is the appropriation by the private sector and without payment of the raw material for improved seeds and technology. In developing countries, resource-poor farmers have for a long time been involved in the development of raw materials. Biopiracy is therefore a legitimate concern. However, if examined closely biotechnology *per se* could not be considered as the culprit since biopiracy also occurs in the case of conventional technology development. Concern is also being expressed over the increasing concentration of intellectual property rights to genes and improved seeds in the hands of a few private companies. This trend is indeed worrying. These concerns are however being discussed at the international level with the aim of defining efficient strategies that will lead to the recognition of farmers' rights.

Domestic biotechnology policies and institutional arrangements

Most African countries lack explicit biotechnology policies, which promotes the development and application of the technology and at the same time reduce any potential risks of biotechnology products. Only a few countries, including Nigeria and South Africa, have formulated such policies and strategies. Most African countries have not identified specific areas in which to invest to meet specific food security goals. In the absence of identified priorities, it is difficult to make policies that target food security considerations. Institutional arrangements for biotechnology research and development in many countries are either ill defined or do not exist at all.

Only a few countries like Egypt, Zimbabwe and South Africa, have national programmes and centres dedicated to agricultural biotechnology research and development. In many cases, it is just an add-on to the conventional research programmes. Private industry involvement in agricultural biotechnology is also limited. The limited human and financial resources in Africa have been thinly spread across biotechnology sectors and research agencies. Countries have not established and applied strategies for identifying institutions and ways of setting priorities. They continue to operate with isolated, competing and often scientifically weak research agencies. Current funding levels are comparatively too low to enable African countries to engage effectively in cutting-edge biotechnology activities.

Globally, 168 countries, including some African countries, adopted Agenda 21 and the Convention on Biological Diversity (CBD) at the 1992 Rio summit for the United Nations Conference on the Environment and Development (UNCED). Article 19 (3) of the CBD calls on parties to consider the need for, and the modalities of, a protocol setting out the appropriate procedures, including in particular, advance informed agreement for the safe transfer, handling and use of any living modified organism (LMO) resulting from biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity. The Cartagena Protocol on Biosafety of the CBD has special focus on the transboundary movement of any GM product from modern biotechnology. Parties to the Convention are urged to fashion their national biosafety laws in line with the Cartagena Protocol on Biosafety, which they are supposed to ratify. Though many African countries have signed the Protocol, they are yet to ratify it. In West and Central Africa, only Côte d'Ivoire, Cameroon and Nigeria are at the stage of passing such laws. In East Africa, both Kenya and Uganda have biosafety frameworks in place and Kenya has its draft law near legislation. In Southern Africa, both Zimbabwe and South Africa have the necessary legislation in place to control research, development and commercialisation of GM products. In North Africa, Egypt has its biosafety laws in place and routinely implements it. Most African countries are yet to develop, legislate and implement their biosafety guidelines. It must be stressed, however, that there are numerous biotechnology products crucial to socio-economic development that are not GM and do not require biosafety legislation.

Some promising gains from crop biotechnology

Due to a rapid and continuing succession of exciting scientific breakthroughs over the past several years, biotechnology is now being used to modify plants for a much wider array of purposes. The recognition of the role of biotechnology in contributing to food security is now being translated into research programmes in a number of African countries. Some research institutions are investing in crop biotechnology, including the development and field-testing of GM crops (Table 1). The technique is being used to increase yield as well as boost the nutritional value of crops. GM varieties that are resistant to diseases and a wider range of pests are being created. Those tolerant to environmental stresses such as drought, salinity or heat and that are less susceptible to post harvest losses are also being created. During the last years crop biotechnology has come out of the laboratory into main stream agriculture with the expansion of the area of GM crops under cultivation exploding, although 75% of farmers using GM crops are in the developing countries, with most of them being in China and South Africa (James, 2001).

Table 1. Plant biotechnology in Africa: some selected cases (modified version of table in Juma, 1999)

Country	Area of research
Egypt	GM of potato, tomato, squash, maize and cotton Genome mapping of tomato and rape seed Transfer of *Bacillus thuringensis* (Bt) toxin genes into cotton and Egyptian clover Field testing of GM maize, cotton, potato resistant to potato tuber moth virus, tomato resistant to tomato yellow leaf curl virus, squash resistant to Zucchini Yellow Mosaic virus (ZYMV) Commercialisation of cotton with Bollard Bt gene
Morocco	Micro propagation of forest trees and date palms Development of disease free and tolerant plants Molecular biology of date palms and cereals Molecular marking techniques Field tests for transgenic tomato
Cameroon	Tissue culture of cocoa, rubber, coffee, yam, pineapple, cotton and tea In vitro culture for the propagation of banana, oil palm, pineapple cotton and tea
Côte d'Ivoire	*In vitro* production of coconut and yam Virus-free micro propagation of egg plant Production of rhizobia based biofertilizers
Ghana	Micro propagation of cassava, banana/plantain, yam, pineapple and cocoa Polymerase chain reaction (PCR) facility for virus diagnostics
Nigeria	Micro propagation of cassava, yam, banana and ginger Embryo rescue for yam Genetic modification of cowpea for virus and insect resistance Marker assisted selection of maize and cassava DNA fingerprinting of yams, cassava, banana, pests and microbial pathogens Genome linkage maps for cowpea, cassava, yams and banana
Senegal	Production of rhizobial and mycorrhizal-based biofertilizers for rural markets Micro propagation of tree species Marker and quantitative trait locus development for improving drought tolerance in cowpea Genome linkage map for cowpea
Kenya	Production of disease free plants and micro propagation of pyrethrum, banana, potato, straw berry, sweet potato, citrus and sugar cane Microprogation of ornamentals (carnation, alstromeria, gerera, anthurium, leopard orchids) and forest trees. *In vitro* selection for salt tolerance in finger millet Transformation of sweet potatoes with feathery mottle virus coat protein gene Tissue culture regeneration of papaya *In vitro* long term storage of potato and sweet potato Marker assisted selection in maize for drought tolerance and insect resistance Production of microbial biofertilizers Field trials for GM sweet potato
Uganda	Micro propagation of banana, coffee, cassava, citrus, granadilla, pineapple, sweet potato *In vitro* screening for disease resistance in banana Production of disease free plants of potato, sweet potato and banana
Zimbabwe	Genetic engineering of maize, sorghum and tobacco Micro propagation of tobacco, sweet potato, ornamental plants, coffee Marker assisted selection
Zambia	Micro propagation of cassava, potato, tress (*Uapaca*), banana Hosts SADC Nordic-funded gene bank of plant genetic resources

South Africa	Genetic Modification of maize, wheat, barley, sorghum, millet, soybean, lupines, sunflowers, sugar cane, vegetables and ornamentals Molecular marker applications in the diagnosis of pathogens and cultivar identification of potato, sweet potato, ornamentals, cereals, cassava Seed lot purity testing of cereals Marker assisted selection in maize, tomato and cereals for disease resistance Field trials for GM crops Commercialisation of insect resistance maize and cotton

These techniques can bring immense benefits to farmers, consumers as well as the environment in the following ways:

Helping to increase food production, lowering consumer prices and raising income of poor farmers

Against the background of the declining food production in Africa, the potential of biotechnology to increase production of basic staple foods assume tremendous significance. This could be perceived in two ways. Developing new varieties through conventional breeding in field crops may take 10 to 15 years. However biotechnology could reduce the period of developing crops products, sometimes by less than ¼ of the period taken by conventional application, and can tackle difficult traits like resistance to drought and low soil fertility, thereby making food available within a shorter period of time.

On the other hand the techniques could improve the quantity and quality of crop production. In Kenya for example, at present, only 7% of farmers have access to improved crops such as cassava and sweet potato (Wambugu, 2001). The use of tissue culture, combined with an effective distribution system, could raise the numbers to well over 50% (Wambugu, 2001). In this same country, farmers currently lose an estimated 40% of their maize crop to the maize stem borer. Transferring genes into maize to protect it against this pest could prevent losses. Small holders growing banana frequently suffer the loss of their entire harvest to a disease known as black sigatoka. A genetically modified variety resistant to the disease would save the harvest. In Uganda, GM cotton cultivation could raise production from the current 13 000 bales to 1 million bales annually, thereby raising income generated from cotton exports from 8 million to 9.7 US$ annually.

There is an active debate on transgenic crops. However, globally, scientists have experimentally modified nearly 100 plant species. In most countries the results have been slow to reach farmers' fields because of environmental and food concerns, which have led governments to introduce stringent regulatory procedures. However a handful of countries such as Argentina, Canada, China and the USA, have made much faster progress. Government and the private sector have actively promoted the use of GM crops in these countries; farmers have welcomed the technology and there has been little or no protest from consumers. As such the area under transgenic cultivation has been increasing steadily since 1995 to more than 44 000 hectares in 2000 (James, 2001). Africa urgently needs this technology to improve food production.

These are just a few examples of the immense power of biotechnology to transform a food deficit into a food surplus. These changes will be good for producers who will have increased options and flexibility in crops and cropping systems as well as millions of urban consumers, who would benefit from the drop in the price of food as supply increases and the costs of production fall.

Creating jobs, new market opportunities and stimulating overall economic development

Creating a food surplus would also have positive spill over effects on the rest of the economy. Jobs in marketing and processing will be created as well as increased demand for other goods and services. In addition to staple foods, the potential of biotechnology to increase production can be applied to a wide range of other food and non-food commodities, which are also vital to incomes, job opportunities and living standards. These include essentials such as firewood for cooking or timber for building, cash crops for the domestic or export markets, such as cut flowers, tea, coffee and sugar cane. New market opportunities for quality products will also be created.

Environmental protection and biodiversity conservation.

Africa's natural resource base is under threat. If Africa engages in intensified agriculture, the danger exists of poisoning birds, insects, soils, water and even the air by the over application of pesticides and herbicides. Three benefits of biotechnology to the environment are as follows.

<u>Reduction in the use of pesticides</u>

Genetic markers and/or modification enable scientists to create seeds tolerant to biotic stresses. As such, farmers can no longer be dependent on chemical forms of control. This technology not only lowers the risk of disturbing the natural ecological balance environment but also creates an increase in purchasing power of the population. Evidence from various countries such as USA, China and South Africa have shown that reducing spraying and associating it with the adoption of GM varieties is beneficial to the health of both the farmers and consumers, avoids pollution of the environment and helps conserve wildlife and biodiversity. Farmers cultivating insect resistant cotton were able to reduce their application of pesticides by up to 70%, and it was also estimated that the use of GM soya bean, oilseed rape, cotton and maize varieties modified for herbicide tolerance as well as the use of insect protected GM varieties reduced pesticide use by a total of about 22 million kg of formulated product (Phillips and Park, 2002). Farmers adopting the use of GM crop varieties have reported the return of insects and bird species not seen in their fields for a generation. These benefits can even be seen when herbicide-tolerant GM crops are grown, although the evidence on this point is mitigated. Reducing the use of spaying also lowers the costs of production, with savings in both material and labour, which in turn raises farmer's incomes and lowers the price of food to consumers. In Kenya for example, farmers spent around 4.5 million US$ on insecticides and 10.5 million US$ on fungicides in 1995 (Wambugu, 2001). If these expenditures are reduced by only 20%, national food production costs will be lowered by 3 million US$ a year. This is a sum large enough to unleash a considerable increase in purchasing power throughout the economy.

<u>Biodiversity conservation</u>

Tissue culture and genetic markers are already being employed in several projects for conservation purposes. For example in Kenya, scientists are using tissue culture in banana to provide 'clean' planting materials of traditional varieties retrieved from orchards that are in near-terminal decline owing to pests and diseases. Similarly, in a number of threatened native tree species, including the famous prostrate-remedy tree *Prunus africanus*, international and national scientists are using genetic markers to guide the collection and conservation of the species' remaining biodiversity, with the more productive provenances being introduced to farmers through participatory research. In this, crop biotechnology presents itself as a user environmentally friendly technology.

<u>Curbing the expansion agriculture and conserving species, forests and fragile semi-arid rangelands</u>

If crop yield is increased, a smaller area will be needed to produce the same amount. As such, intensification in one area can help to take the pressures off others. The continuous and rapid increase in population will lead to uncontrolled migration into new areas despite yield increases elsewhere. If biotechnology is also used to develop crop varieties that can withstand drought and other stresses, it could encourage expansion into marginal lands. In such circumstances, biotechnology can contribute to more sustainable crop production, but not to the conservation of wildlife and biodiversity. On the other hand, whether expansion continues or not depends on such factors as the laws governing land use, the economic incentives to clear new land and the availability of jobs in the cities.

Priority areas where support is needed

All the benefits outlined above should serve as an incentive for Africa to embrace this technology. Whatever the case, Africa now urgently needs the power of biotechnology to boost food production and economic development. It therefore has to find its place in the biotechnology revolution. To benefit from biotechnology and its products, African countries need to engage in biotechnology research and development. They should develop and implement their own programmes that focus on solving local food production and insecurity problems. This, however, could only be effective if emphasis is place on the following important but not exclusive issues.

Research opportunities

Crop biotechnology research in Africa should address the needs of the continent and should aim at rendering Africa increasingly self sufficient in the production of food crops. The following areas currently need attention.

- Enhanced breeding for disease and pest resistance,
- Breeding for tolerance to abiotic stress especially drought,
- Rapid multiplication of disease-free planting materials,
- Development of high quality food products.

Adequate capacity building

Africa has to build an adequate research capacity in order to adapt and develop crop biotechnologies suited to the region's needs. It is sometimes maintained that these biotechnologies are too sophisticated for Africa. This view is patronizing. Certainly, some forms of biotechnology require expensive equipment and specialised training. Africa, nevertheless, has as much right to these techniques as the developed world. Africa has millions of resourceful people who represent our best asset for a more prosperous future. Among them are trained scientists, committed individuals already acting decisively and responsibly to further their countries development. Many more could be trained to take possession of biotechnology and make it work for Africa. Also the ability of African countries to search, access and acquire agricultural biotechnology is dependent on whether or not they monitor global trends in biotechnology. The ability to do this will result in the enlargement of the knowledge base of the countries. Several lines of action could be envisaged, which include the following:

- strengthening of existing centres of excellence through up-grading their staff and equipment and also for the monitoring and assessment of biotechnology,
- organisation of short-courses/workshops, and eventually degree programmes, in biotechnology with options in crop biotechnology,
- incorporation of biotechnological procedures into crop production processes.

These would enable African biotechnologists to produce some of their required goods and not just be passive users of biotechnology products. The involvement of the private sector in Africa will also enhance the development of goods using crop biotechnology. Networking and collaboration within and between countries is essential for creating the critical mass of scientists necessary to make the break through. Accompanying crop biotechnology research with participatory approach involving end-users will contribute greatly in creating impact.

Effective policy framework development

An enabling policy environment for biotechnology development and application should be created. Nigeria's biotechnology policies focus on building indigenous scientific and technological capabilities through partnerships with international research bodies and private companies, increasing funding to national programmes, launching biotechnology training in local universities and building science infrastructure in selected centres of excellence. South Africa has a strategy that puts emphasis on the development of national centres of excellence in biotechnology in general and genetic modification in particular. More African countries should now identify the specific areas in which to invest in so as to meet the specific food security objectives. Institutional arrangements should also be well defined integrating effective partnerships with the private sector and other forms of financing.

The development of an effective policy framework that includes biosafety oversight mechanisms is also of equal importance. The overall objectives of biosafety regulatory systems are to review and offer guidance to new developments and to monitor and evaluate applications. Many more African countries should be encouraged to ratify the Cartagena Protocol on Biosafety and proceed to access funding set aside by the UN Agencies and bilateral donors to assist them to develop and implement their biosafety laws. This is necessary if Africa is to benefit from genetic engineering and be a global competitor in biotechnology derived products. Moreover, this will assist in the planning and prioritisation of research efforts, thus enhancing research competence, especially through linkage with institutions which have advanced technologies to solve local problems requiring the use of modern crop biotechnology.

Biotechnology policies are strongly associated with the access to genetic resources. One of the main policy issues is intellectual property right. This is locked up in the private sector. Policies should be developed to protect and patent innovations from public institutions like the NARS[2] and Centres of the CGIAR[3]. The possibility of intellectual property goodwill donations from private sector for the public should be examined.

Socio-economic inputs such as efficient resources utilisation, employment, equity, income distribution and sustainability as well as continuous communication among scientists, policy makers and stakeholders are also important in developing an effective and sound biotechnology policy framework. All this will ensure that research and development are geared towards solving local problems and addressing local needs.

Awareness creation

Public perception of modern biotechnology is now one of the factors that influence the direction of innovation in the commercialisation of biotechnology in Africa. It is widely influenced by values and physiological factors as well as public confidence in scientific institutions responsible for risk assessment and management. It is also influenced by information coming from the industry, governments, scientists, public interest groups and the media. African stakeholders do not participate enough in the current debates on the impacts of GM products, which are strongly dominated by Western perceptions. African social, political, economic and cultural considerations are rarely considered in these debates. The participation of African countries in the on-going debates on biotechnology should be influenced and informed by their own aspirations, needs and perceptions of this technology. In order that many people adopt these new technologies therefore, there is an urgent need to increase the efforts in creating awareness. People would initially reject new technologies because they fear the unknown. However, with continued reassurance,

[2] National Agricultural Research Systems

[3] Consultative group on International Agricultural Research

their attitudes evolve as they gain better understanding of the technology. Those introducing new technologies should explain how it works, its uses and, most importantly, how they can benefit from them. The disadvantages and risks involved must also be highlighted. The information conveyed to the masses should be balanced, accurate and especially put in a language that can be understood.

Conclusion

Over 180 million people, living in extreme poverty, are found in the rural areas of Africa. Most of the countries in these areas are low-income ones, and hunger and malnutrition are the greatest problems creating a major set back to development. Agriculture is a catalyst for a broad-based economic growth and development in most low-income countries. Farmers are crying out for help in order to combat the continuous onslaught of drought, pests and diseases on their crops and livestock, which are contributing factors to low income. Scientists are doing their best to provide them with the help they need. One of the reactions has been the use of biotechnology wherever this seems likely to shed new light or to offer a way forward.

Though biotechnology is not a panacea, it is a vital asset that cannot be ignored and which can provide valuable solutions in the area of crop improvement. It is, in effect, a social construct whose development and application largely depend on human beings. It is therefore critical to establish systemic and long-term measures that will enable the society to benefit from the technology and address any negative impact it may cause.

Africa was by-passed by the Green revolution of 25 years ago, mainly because the technology developed at that time was suitable for large scale, irrigated farms on which chemicals could be used with reliable results, and could not fulfil the needs of the rain-fed farming systems of Africa, whose small holders face riskier conditions. The biotechnology revolution, in contrast, brings to Africa a highly refined set of tools, which allow the development of crop varieties that are far better adapted to these difficult environments. It is, therefore, vital that Africa invests in identified crop biotechnology research opportunities, capacity building, establish effective policy frameworks and create awareness so that it does not, for a second time, miss the opportunity of benefiting from this infinitely more powerful revolution in agriculture.

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