Agricultural biotechnology for poverty alleviation: One more arrow in the quiver!

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Abstract

Agriculture is the largest contributor to the economies of many African countries, generating more than half of the annual Gross Domestic Product (GDP) for many of these countries. The livelihoods of most rural and low-income communities in these countries are to a large extent based on agriculture. While global availability of food has increased, 35% of the 800 million poor of the world live in Africa, and face food insecurity. And yet agriculture constitutes, for the majority of these poor, the primary means of survival and livelihood sustenance. Agricultural biotechnology, which comprises a wide range of biological disciplines, offers enormous potential to speed up the development of plant varieties with pro-poor traits such as drought tolerance, pest resistance or tolerance, higher yields, increased nutritional value, among others. Similarly in animal production there is substantial opportunity for development of vaccines and diagnostics targeting diseases which constrain livestock production in developing regions of the world. In addition, genetic markers can aid breeding of livestock for important traits such as disease resistance, improved product quality as well as improved productivity. However, to date, the innovation essential to achieve these improvements has largely remained a technology of the North. While biotechnology does not provide the 'silver bullet' for poverty alleviation, it does enhance the effectiveness of other disciplines such as plant breeding, integrated pest and nutrient management, and livestock breeding, feeding and disease management. Importantly, because use of these technologies, as any other, is associated with risks, African scientists need to have access to the knowledge and scientific infrastructure to assess these risks and to contribute to better informed public discussions of the opportunities and challenges of these technologies. Should biotechnology be a preserve for the rich? Can developing nations afford to ignore the potential of biotechnology? Rather than debate on whether biotechnology can meet the needs of the poor, this paper argues that being just one aspect of a complex set of inter-related interventions required to enhance the contribution of agricultural development to poverty alleviation, discussions should be had on how best to take advantage of the opportunities and manage the risks associated with these technologies, for the benefit of the poor. There is need to explore new ways to build the capacity of the public sector - notably national governments in developing countries and development partners, as well as to tap into the resources of the private sector - to enable the continent come up with African solutions to the problem of poverty alleviation. This will require closer collaboration and transfer, between the North and the South, of appropriate biotechnology and the management of bio-safety issues. Thus, risk assessment has to be an integral part of biotechnology research and development. Africa missed out on the 'Green revolution', and should not miss out on the 'Gene revolution' as well.

Introduction

Africa remains the world's poorest continent. Most African countries have economies characterized by slow and declining growth, low and declining per capita incomes, and declining participation in the global markets. The limited exports from Africa are predominantly low value commodities, while hunger, malnutrition and poverty remain widespread in the continent. An estimated 25 to 30 million children are malnourished and the World Health Organization estimates that 54% of child mortality in African countries is associated with malnutrition. About one-third of the children in sub-Saharan Africa are stunted because of poor diet, while thousands of people die each day from hunger. Another one-third of the continent's adult population, about 200 million, are food insecure and are forced to live below their full potential because they lack the energy and full health to function at their best. If current trends continue, by 2010 Africa would account for nearly two-thirds of the undernourished people in the world. This vicious cycle of hunger and poverty needs to be broken.

Agriculture is the most important economic activity in Africa and offers the means to reverse these trends and to stimulate wider economic growth. This is because 70% of the people in sub-Saharan Africa live in rural areas and are dependent on agriculture for their livelihoods. However, African agriculture is performing dismally: crop production is the lowest in the world. Yields of basic food grains, for example, are one-fifth those of China. Fertiliser use in Africa is 8 kg per hectare; in Latin America, it is over 60 kg per hectare, and in Asia, over 100 kg per hectare. Only 4% of Africa's farmland is irrigated; in the Middle East and Asia, the figures are 29% and 34% respectively. The Green Revolution has had very little effect on the continent's agriculture in the last decade or so. In Asia and Latin America, between 60% and 80% of crop area is planted with modern varieties; in Africa, the figure is between 20% and 30%. As a result, Africa imports more than 25% of the grain it consumes. Ironically, up to 40% of the continient's harvest is lost to post-harvest damage. Moreover, due to rapid increase in human population, there is need to produce more food on less land, with less water, while conserving the environment.

Although the continent's GDP has improved over the years, the proportion of people living in absolute poverty is higher than it was in the 1980s and 1990s (UNDP 2005). While the economies expanded by 3% per annum between 1990 and 2004, the proportion of Africa's population classified as 'absolute poor' increased by 2 percentage points every year. It is estimated that it will take sub-Saharan Africa until 2012 just to restore average incomes to their 1980s levels (UNDP 2005). There is very limited opportunity for poor people to participate meaningfully in the economy as either producers of goods and services or as suppliers of labour.

Potential role of biotechnology

Science and technology are recognized globally as drivers of increased wealth and continuously improving standards of living. The role of science and technological innovation in economic change and sustainable development is receiving attention at national, regional and international levels. There is ample evidence that economic advances in the developed and newly industrializing countries are results of technological and organizational innovations (Mokyr 2002). Scientifically and technologically advanced countries have become continuously wealthier, and their rates of growth have not slowed significantly over time (Pritchett 1995). These countries have succeeded by reinvesting a growing percentage of their gross domestic product (GDP) in further advancement of research. Translation of research into new, more efficient modes of production has brought dramatic benefits. Technological innovation is associated with turning scientific knowledge into products and processes: putting new technologies and their products on the market and incrementally modifying and adjusting them to respond to socio-economic conditions (Juma 2005). Some of the East Asian countries that capitalized on these opportunities have transformed themselves into middle- or high-income economies (Nankani 2005). The key to success has been to focus on improving skills in solving existing and new problems, putting a premium on continuous learning.

Application of knowledge through new technologies will provide opportunities for improving developing country economies and the well-being of the people, and offer a means for increasing agricultural production, improving human health, and addressing environmental degradation. In this way it creates economic competitiveness and enhances industrialization. However, these benefits can only be achieved if countries formulate appropriate policies to facilitate the development and utilization of requisite human and financial resources and appropriate infrastructure and functioning support institutions.

In agriculture, advances in biotechnology have resulted in improved research leading to: drought resistant crop varieties; increased pest and disease resistance in crops and livestock; new, refined diagnostics and vaccines for livestock diseases (e.g. Foot-and-Mouth disease and East Coast fever); rapid propagation of clean planting material (e.g. flowers, vegetables, bananas etc.).

Current constraints to the research and application of biotechnology in developing countries include: lack of policies; lack of human and financial resources; lack of public and private investments at levels that can make a difference; absence of systems for the delivery of technologies to potential users; lack of awareness, leading to misconceptions about the potential of, and risks posed by, biotechnology.

What is the evidence that biotechnology can benefit developing countries?

There is now ample evidence to demonstrate the opportunities offered by biotechnology in developing economies, and from which Africa should learn. Two examples are given here, from China and India.

China

In the early 1980s Chinese leaders decided that science and technology (S&T), especially biotechnology, would be one of the drivers to improve the agricultural sector, and committed substantial public investments in biotechnology, e.g. rice biotechnology (mapping rice genome) and rice breeding (to develop hybrid rice varieties), cotton biotechnology for insect resistance, production of value-added horticultural crops, and complimentary innovations such as use of nematodes for biological pest control leading to increased export markets. Currently, hybrid rice accounts for over 30% of rice in China and over 5 million small farmers are growing Bt-cotton on 1 million hectares of land. Use of biological control has reduced pesticide use on cotton by 30% nationally. Today, horticultural exports are expanding. Thus, through a deliberate effort to revolutionize agriculture, China is making quantum leaps in agricultural productivity and sustainability improvements. The country is now moving to the ‘post-Green Revolution era’ towards becoming an industrialised nation. As has been pointed out above, an efficient agricultural sector ensures food security and enables industrial development.

India

India’s National Dairy Development Board (NDDB) oversees improved dairy production by millions of smallholder livestock producers, including many women. Success in using increased milk production to generate increased income on a daily basis is the result of investments in S&T targeting: improved feeding and nutrition of dairy cattle; vaccines to control endemic diseases; and improved animal genotypes and their delivery to farmers. The NDDB organizes delivery of services (including biotechnologies) at the points of milk collection. Payments for technical services are affordable and deducted from milk payments to smallholders. In the 1960s and 1970s India regularly had famines and was a net food importing country. The Green-Revolution in crops and the White Revolution in dairy production are the result of investments in S&T and infrastructure, especially irrigation and communications and the formulation and implementation of supportive public policies (prices, trade etc.) to encourage farmers to go into production. India is now using its productive agricultural sector to guarantee food security and is moving towards industrialisation. Although there are still millions of people living in poverty in South Asia the trends in India and some of its neighbours are heading in the right direction, with millions moving out of poverty each year.

Livestock and poverty impacts: Role of science and technology

Livestock products have for generations been known to be a pathway for income generation by the poor. There is also evidence that small-scale livestock income plays a disproportionately high role in the income sources of poor rural women and other disadvantaged groups in most parts of the developing world (von Braun and Pandya-Lorch 1991). Demand for food products of animal origin is expected to increase dramatically in developing countries (Delgado et al. 1999). The consumption of meat and milk, for example, is projected to grow at 2.9% and 2.7% per annum respectively, between the late 1990s to 2020. This 'livestock revolution' is also expected to result in increases in demand for pork (60%), poultry meat (80%) and red meat (50%) by 2020, with developing countries accounting for two-thirds of global meat consumption and more than half of global milk consumption. The trends in consumer demand for livestock products are driven primarily by growth in human population, increases in income and urbanization and associated changes in consumption patterns. In East Asia, even lower income rural households have begun to shift increasingly to food consumed outside the home, as they have elsewhere in urban areas of the developing world, which typically involves consuming larger amounts of higher quality animal products (Gale et al. 2005).

In Africa, livestock production remains largely in the hands of small-scale farmers who collectively keep approximately 70% of total livestock units. Given this concentration of livestock production, the potential for a viable industry built around these producers provides a significant opportunity for them to escape poverty while supplying the consumer demand. Diseases sharply reduce the productivity of livestock. Conservative estimates of annual losses of US$ 4 billion in meat and milk production have been reported for sub-Saharan Africa—representing approximately one-fourth of the total value of livestock production. These losses have a significant impact both on food security and poverty. Apart from the zoonotic diseases (such as tuberculosis and Avian influenza) that also afflict poor people, who are in constant contact with different livestock species, there are also a number of other livestock diseases (such as Foot-and-Mouth disease, contagious bovine pleuropneumonia, Rift Valley fever and African Swine fever) which preclude livestock and livestock products of the poor from markets.

Concerns about animal disease transmission keep global livestock to less than 10% of the value of global production, whereas it is 40% for fish, a commodity with equally great food safety issues and where trade is overwhelmingly from the developing to the developed countries (Delgado et al. 2003). Implications of animal health issues on trade are, today, receiving increasingly high prominence at a time when developing country producers are recognizing expanded opportunities for international trade in livestock and livestock products. The stakes in effective disease control in developing countries and reliable 'point of transaction diagnostics for disease-free-status certification' have risen considerably as producers in many of these countries have become aware of the possibility of export as an addition to what had been relatively less attractive domestic markets. This is affecting not only those producers immediately capable of supplying export markets, but is also having an impact on all other producers in the these regions. The negative impact of border closures in the Middle East due to an outbreak of Rift Valley fever (RVF) on the price of livestock in the remotest areas of East Africa (Nin-Pratt et al. 2005) is a case in point.

Technological change in animal disease control with associated policy reforms could bring about a major shift in the distribution of world livestock production in favour of developing countries with abundant labour and land resources (Rich 2005). Beyond the development and application of technologies (such as vaccines and diagnostics) to improve animal health and food safety for trade, there is also need for market and policy research to demonstrate the high costs of compliance with traditionally accepted norms and to evaluate the costs and benefits of alternative options for reducing risk of disease transmission, some of which may be more appropriate to particular developing country situations.

Livestock biotechnologies and poverty: Opportunities for Africa

Animal health

Building on a good understanding (based on cumulative knowledge from within and without the continent) of the biology of livestock (hosts), disease vectors and pathogens, research on animal health in Africa should focus on the development of technologies to address the constraints posed by major livestock diseases in the continent to reduce losses (so as to secure the livestock assets), improve productivity and facilitate access to markets (domestic, regional and global).

As pointed out above, diseases such as contagious bovine pleuropneumonia (CBPP), rinderpest, Newcastle disease (ND), RVF, trypanosomosis, gastrointestinal nematodes, tick-borne diseases (such as East Coast fever (ECF), Heartwater and African Swine fever (ASF)), *inter alia*, continue to present significant challenges for livestock keepers particularly the poor small-scale farmers. These diseases affect intensification, productivity and trade. In terms of interventions, while regulatory measures and cost-effective technologies for disease control have been effective in developed countries, this has not happened in Africa.

Rapid advances in classical and molecular epidemiology, molecular biology, immunology and such new sciences as genomics, bio-informatics and proteomics are providing new technological options that can be applied for the control or eradication of animal diseases in Africa. Some of these technologies are on the threshold of being developed into effective new tools such as diagnostics and vaccines, and investment is required in applied research to facilitate this process. For some diseases, for instance, ND (vaccines), ASF (diagnostics) and ECF (vaccines) progress towards developing effective products is at stages where probability of success is high with only modest investments. Conversely, CBPP (vaccines and diagnostics) requires a two-pronged approach: a quick-win option to improve current vaccines and diagnostics and medium- to longer-term research to generate improved and more sustainable ‘new generation’ products.

Most, if not all, of the investment in research and development (R&D) relating to the above diseases has been obtained from public sources in developed countries with a fair amount of up-stream activities undertaken in the North. However, many of these diseases, e.g. ASF, ECF, CBPP, RFV, trypanosomosis, among others, have little relevance to the developed world and are unlikely to be of continuing interest to development partners in the North, except for scientific curiosity. In the case of ECF vaccine research, a substantial international effort has contributed to the progress toward proof-of-concept for a vaccine. Nonetheless, funding for completion of current and subsequent steps of R&D is not guaranteed. Similarly, research on short-term options for CBPP has benefited from some ‘external’ funding but there has not been adequate and sustained funding to increase the likelihood of success.

It is increasingly becoming imperative for Africa not only to define the continent's R&D agenda for livestock health but also to mobilize the required resources, including allocation of national resources, to implement the agenda. Recent technological advances, many already being successfully applied to address human and animal health problems in the North and, indeed in some developing countries in Asia and Latin America, provide opportunities which Africa needs to capture. The level of commitment will be needed both to support quick win options that will translate into products and strategies (such as the Pan-African Rinderpest Campaign initiative, improving the ND vaccine, developing ASF diagnostics, improving current CBPP vaccines and diagnostics) in the shorter term, but also to support medium- to longer-term R&D initiatives.

For some of the disease constraints, there are existing technologies previously developed and working for similar diseases or those developed for the same diseases but under different settings (e.g. pathogen strains, delivery infrastructure etc.) elsewhere. In these cases focus should be on the adaptation of these existing technologies to optimize their use or to enhance their strategic relevance to a wider range of users and production systems. In marginal areas, animal health constraints will need to be addressed through a strategy that combines disease control (through development of appropriate vaccines and diagnostics) and use of appropriate livestock genotypes (which combine productivity and adaptability to local environmental stresses). Conversely, in the rapidly changing sub-sectors, such as smallholder dairying in higher potential areas where exotic breeds and crossbred livestock are predominant, technological interventions need to focus on reducing disease risks and improving animal productivity taking advantage of the more benign environmental conditions.

Genetic improvement of livestock

There is little known about the genetic diversity in indigenous livestock breeds and potential for genetic improvement in developing countries. To improve utilization of these resources, information is needed on: how much diversity exists in specific populations; uniqueness of populations; what breeds/populations to conserve; what conservation methods to apply; and how the genetic diversity in indigenous breeds can be utilised to generate greater benefits for the poor livestock keepers, without compromising the diversity. There are no working models for livestock genetic improvement in low input systems in developing countries, nor true equivalents of the seed systems that have been critical for the success in crop production. Furthermore, given the time required to effect genetic change in livestock, it is even more critical that development of breeding objectives take into account ongoing evolution in the production systems, hence there is need to understand the system changes and the key drivers. Indeed, it is now well accepted that, while *ex situ* approaches can support conservation of livestock diversity, a sustainable strategy has to be one in which the diversity is dynamically maintained as a functioning part of the production system. This underscores the need for strategies and breeding technologies that take the issues of systems changes and links to 'genotype-evolution' into account. Progress in livestock species genome sequencing is opening new ways for the identification and improved understanding of economically important traits and genes. These developments are catalysing the emergence of new tools (e.g. bioinformatics and gene expression units, such as micro-arrays) the applications of which represent new opportunities with significant potential for gene discovery research. These are common technologies for both vaccine research (e.g. antigen identification) and genetic improvement. These new technologies are providing newer, faster and possibly more efficient ways to achieving the same objectives (e.g. a specific breeding goal) and exemplify 'value addition' to, rather than replacement of, 'traditional technologies', by new technologies. There are many international efforts focusing on gene discovery for productivity traits in livestock. Efforts in Africa should focus on adaptive traits needed for the unique circumstances in the continent (e.g. disease resistance), adapting and applying methodologies developed in the North to speed the realization of desired outcomes and achievement of impact at local levels. For diseases such as helminthosis, which affect livestock (especially small ruminants) across the world, there are good prospects for global partnerships.

Feeds and nutrition

Most African livestock production is under traditional systems in which feeding and nutrition is dictated by climatic factors. Thus, there are large cyclical swings in feed availability and quality closely following the rainfall patterns. During a large part of the year, there is inadequate feed and the nutritive quality of whatever is available is generally too poor to support animal maintenance, much less production; a common problem is low protein and high fibre content. There are a number of biotechnologies which use micro-organisms to 'bio-process' feeds/foods with a view to improving nutritional quality, including digestibility. Important feed ingredients such as maize and soya which are commonly used in monogastric feeds can also be nutritionally enhanced through genetic manipulation. Specifically, marker-based technologies are increasingly used to understand the genetic diversity in forages and in food-feed crops; the technology also has potential use in food-feed crops in ways that ensure that food yields and qualities are preserved or enhanced while at the same time improving the feed attributes.

Institutional arrangements to develop and deliver technologies

For both vaccine development and genetic improvement, lack of a working institutional arrangement to facilitate technology development and delivery can be a major impediment. The nature of these technologies requires the engagement of a large number of stakeholders, usually necessitating complex partnership arrangements, not made any easier by need for biosafety and intellectual property management. Consortia or networks of strategic international collaborators (including public research institutions in the North and the private sector) and national partners are almost invariably essential for success. Given the cost involved in putting together such consortia, it is advisable that, while the initial goal may be quite specific, their designs allow the flexibility to address other similar technological constraints. This is the basis of the concept of 'generic research platform' whose aim is to ensure that the best practices (at both technical and institutional levels) can be applied more broadly, for example, in the case of livestock, to multiple diseases, animal genetic resources and in other regions of the world under different settings. The nature of these platforms may vary considerably and will depend on the scope, focus on addressing a national or an international problem. An example of an innovative institutional arrangement of this type is a new initiative known as the Biosciences eastern and southern Africa (BecA).

BecA, an ILRI-NEPAD (New Partnership for Africa's Development) initiative, is a joint venture involving NEPAD, ILRI and stakeholders of countries in the sub-region. It is providing a platform of shared state-of-the-art research facilities and capacity for application of biosciences in agriculture. The generic nature of the technologies and the partnerships and institutional arrangements are allowing ILRI to expand the impact of its expertise—in such areas as immunology, molecular epidemiology and animal genetics—and research outputs focusing on what gets done rather than just what ILRI does, including availing research capacity beyond what is needed just for livestock research. The vision is to enable African scientists and institutions to become biotechnology innovators as well as technology users. This is to be accomplished through the conduct of biosciences research and innovation targeted at issues affecting Africa's development, while accessing and using the best of science available worldwide. The shared research platform hosted by ILRI is open to African scientists—including those from universities and national research institutes—and researchers from the broader international community willing to collaborate with African partners to address African agricultural constraints.

Another example is a recent initiative known as the Global Alliance for Livestock Vaccines and Diagnostics (GALV), the purpose of which is to establish and support public private partnerships that will speed the development and delivery of vaccines and diagnostic products for use by poor livestock keepers in low income developing countries. It will do this by focusing on promising leads and aiming to develop these into useful pro-poor animal health products. The initiative is borne out of the recognition that academia and the donor community alone lack the expertise, experience and key technology required to turn promising leads, such as vaccine candidates, into new products for less developed countries through the complex and highly regulated development process. However, the private sector, whether big pharmaceutical companies or small biotechnology companies, usually do not have incentive to take on the expensive research and development programmes themselves for markets that are unlikely to provide a return on investment.

Conclusion

Economic development in Africa will, of necessity, have to be initially linked to agriculture (broadly defined to include crop, livestock, forestry and fish). Staple crops and livestock are the most likely to promote economic growth in the continent. To date, public sector investment in biotechnology in Africa has led to few products. This has, in part, been due to lack of viable private sector partners who are able and willing to take new products to markets. There is also a critical need for innovative public/private sector partnerships which will help link public investments in R&D with private 'know-how' and technology for product development. However, similar to what is happening in Asia and Latin America, there is great opportunity for Africa to mobilize science to create wealth for its people and achieve higher economic growth. This requires: strategic investments in science and technology, with time scales in the range of 20 years (from discovery to delivery); investment in physical, human and financial resources to build indigenous science and technology capacity (human and infrastructure); political will to commit the required resources to develop the requisite capacity and to provide a supportive policy environment; vibrant private sector, including facilitating emergence of a critical mass of innovative and enterprising smallholder farmers. In the short-term, some benefits are possible in Africa from previous discoveries, when adapted and adopted in the African context (e.g. Bt cotton). In the longer-term, there will have to be local innovations that focus on critical constraints in Africa (e.g. endemic diseases of livestock).

For biotechnology to create wealth, at least the following must happen: there has to be a clear definition of priorities/targets (participatory research can assist in target identification); the best of *relevant* science regardless of where it comes from around the world must be mobilized and adapted to address the identified targets (a mechanism for proactive identification of new, relevant science must be put in place); and a critical mass of resources (human and financial) must be available for the targets to be met. In addition, the local private sector and communities need to be involved in product development and commercialization so that new technologies can be both affordable and accessible. Further, more delivery mechanisms have to be developed so that new (bio) technologies are accessible to those who need them. Lessons from the rapid uptake of mobile phone technology in developing countries are pertinent: if a new technology is useful and the price is right, the spread is almost unstoppable. Clearly, biotechnology is not a substitute for other technologies, but is an additional arsenal which should be used as and when appropriate to increase the pace of agricultural development. It is simply another arrow in the quiver!

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