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Review

The role of biotechnology in ensuring food security and sustainable agriculture

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Food security and sustainable agriculture have become a burning issues in the national discuss at all levels of government as plans are being made for a changing global climate and increasing global population. One of the most important environmental challenges facing the developing world is how to meet current food needs without undermining the ability of future generations to meet theirs. Agricultural production must be sufficient to feed us now and in the future. Evidently, the current state of agricultural technology will not suffice to meet the production challenges ahead. Innovative technologies have to be exploited in order to enable sufficient food availability in the future. In the current practice of modern agriculture which relies on high inputs such as fuel-powered tractors, chemical fertilizers and chemical pesticides, deploying a smart mix of farming techniques using genetic engineering of biotechnology and integrating same into the traditional smallholders farming system offer a bright prospect of meeting the growing demand for food by improving both yield and nutritional quality of crops and reducing the impact on the environment.

Key words: Biotechnology, food security, sustainable agriculture, developing countries, technology integration, population growth.

INTRODUCTION

The issues of food security and sustainable agriculture in the developing world and especially in sub-Saharan Africa continued to dominate public debate and have remained an issue of global concern. Exacerbating these issues is the complex subject of population growth. According to Population Reference Bureau (PRB), the world population reached 6.6 billion people in 2006, up from 6 billion in 1999. It is projected that world population will beat the 8 billion mark in the year 2025; most of the increase is expected in the developing world (PRB, 2006). In order to meet these needs, FAO (1999) estimated that global food production must increase by 60% in developing countries to accommodate the estimated population growth, close nutrition gaps and meet dietary needs. In a similar report, FAO observed that more than 800 million people in the world do not have enough food to eat, causing 2400 people to die daily of hunger, three quarters of whom are children and under five. Additionally, the United Nation's sub-committee on nutrition (2000) estimated that 33% of children under five in the developing countries have experienced stunted height-for-age growth. This suggests chronic undernourishment throughout childhood, which can hinder overall health as well as intellectual development.

Population growth has direct implications on available land (and this is in the light of decrease in arable land worldwide). For Africa, where the rural population is close to 70% in most countries and where consequently the main economic and social activity is farming, these facts are issues of grave concern. It is estimated that population growth and income will lead to a further doubling of food demand over the next generation (McCalla, 1999). Yet, growth in farmers' crop yields has been slowing down since the 1980s, and in some regions of the world, grain yields have tended to level off (Pinstrup-Andersen et al., 1999). The challenge for developing countries therefore, is to ensure that their citizenry enjoys food security. Evidently, the current state of agricultural technology will not suffice to meet the production challenge ahead. This problem is further compounded by

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the fact that most of the agricultural research in the developing countries focuses on a narrow range of crops and many of the crops used by local communities have not benefited from modern research. Thus, innovative technologies have to be exploited in order to enable sufficient food availability in the future. In this context, modern biotechnology offers the best available options for diversifying agricultural production by speeding up the development of new varieties, including those of under-utilized crops.

BIOTECHNOLOGY AND THE ISSUE OF FOOD SECURITY

Biotechnology is broadly defined as a “technique that uses living organisms or substances from those organisms to make or modify a product, improve plants or animals, or develop microorganisms for specific uses” (Persley, 2000). It also deals with the construction of microorganisms, cells, plants or animals with useful traits by recombinant DNA techniques, tissue culture, embryo transfer and other methods besides traditional genetic breeding techniques.

Although, biotechnology applies across a number of fields, agricultural biotechnology however, appears to be the most crucial for African countries and especially for resource-poor farmers whose sole livelihood depends on agriculture. The technique of biotechnology alone cannot solve all the problems associated with agricultural production but it has the potential to address specific problems such as increasing crop productivity, diversifying crops, enhancing nutritional value of food, reducing environmental impacts of agricultural production and promoting market competitiveness.

Crop yields have grown slowest in many parts of the developing world, especially in Africa. It is estimated that cereal yields in Africa have increased by nearly half of the rate in Latin America since 1970 (World Bank, 1993). Poor soils, low rainfall, high temperatures and the prevalence of pests continue to undermine food security in many parts of Africa. These challenges are compounded by the high costs of imported agricultural inputs. Improving the situation will require greater investment research and reliance on emerging technologies.

Enhancing the nutritional value of crops is another important aspect of food security. A good example in this area is the modification of rice to enhance its vitamin A content. United Nations projections show that while chronic malnutrition will decline in Asia and Latin America in the coming decades, the numbers for Africa will increase significantly. Biotechnology will make it easier to maintain traditional diets while improving their nutritional value.

Modern biotechnology could help in enhancing the competitiveness of agricultural products from the developing countries and thereby promoting their integration into the global economy. Efforts to diversify agricultural production in the developing world will not only promote food security in those regions, but it will also add new crops to world food market.

BIOTECHNOLOGY AND SUSTAINABLE AGRICULTURE

As articulated in the 1990 "Farm Bill", sustainable agriculture means "an integrated system of plant and animal production practices having a site-specific application that will, over the long term: (i) Satisfy human food and fiber needs, (ii) enhance environmental quality and the natural resource base upon which the agricultural economy depends, (iii) make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls, (iv) sustain the economic viability of farm operations, and (v) enhance the quality of life for farmers and society as a whole" (FACTA, 1990).

The cluster of techniques that comprise biotechnology can, if effectively harnessed and applied, radically transform farming systems by reducing post-harvest loss and increasing crop resistance to drought. The main limiting factor to the ability of the developing countries to benefit from advances in modern biotechnology is the lack of scientific and technological capacity and the low level of enterprise development in most of these countries. The responsibility to formulate policies and strategies for the wider use of biotechnology lies with these countries. However, international cooperation and partnerships are essential in promoting sustainable agriculture in the developing world. Biotechnology and sustainable agriculture in Africa debate raise several key-issues:

(1) How do you transfer biotechnology to African countries and strengthen their technological competence to acquire, assimilate, further develop and effectively apply the technology for enhanced agricultural production?
(2) What policy and institutional arrangements should be put in place to make the technology and its products accessible to rural farmers in the region?

Biotechnology on its own may not be the panacea for the world’s problem of food crisis. However, genetic engineering presents outstanding potential to increase the efficiency of both crop improvement and animal production thereby enhancing global food production and availability in a sustainable way. This is achievable once the entire technology can be integrated into the traditional smallholder farming systems. Sustainable agriculture will require that developing countries makes prudent choices and that they are not restricted to using only the technologies available today. Making such choices requires access to a wider range of technologies, especially those resulting from advances in molecular biology.

The international public research system has a critical role in ensuring that access to potential benefits of new technologies is guaranteed for poor people and environmental conservation is maintained. There must be recognition of the need for increased public involvement in biotechnology and for complementing private sector research, to ensure transparency and accountability and to promote a broad range of public goods research just as markets expand for results of private goods research. There is a need for win-win-win scenarios for all concerned actors and for creative efforts to identify and put to work enabling mechanisms for the developing countries to benefit from the gene revolution. To win the battle for food security and sustainable agriculture, priority should be given to enhanced crop productivity which provides easy access to foodstuff for the bulk of the populace.

POTENTIAL OF BIOTECHNOLOGY IN CROP IMPROVEMENT

It must be emphasized that biotechnology should not be understood as a substitute for traditional tools of crop improvement but integrating recombinant techniques into conventional breeding programs could substantially enhance the efficiency of agricultural research and development. Whereas, traditional crossbreeding is confined to the exchange of genetic material within a certain crop species, recombinant techniques enable the transfer of valuable genes across species and even across kingdoms. Traditional plant breeding techniques are limited by sexual incompatibility barrier. In addition, many valuable traits such as tolerance to specific herbicides and insects do not exist in plants. The new DNA manipulation techniques provide practicable means to overcome the limitations of plants breeders. Genes can be isolated from bacteria, viruses, fungi or animal and made to express in plants. Thus, the following areas of innovations seem of particular importance to future agricultural needs:

(1) those that breed resistance against specific diseases and common pests and insects,
(2) those that reduce environmental burden of fertilizers,
(3) those that reduce the demand for irrigation water and
(4) those that continue to improve crop production per hectare.

Transgenic breeding should therefore, be targeted at achieving the following major objectives:

Agronomic traits

The agronomic traits are input traits which embraces all genetic modifications of plants that could stabilize or increase the yields in farmer's fields. Prominent input traits are mechanisms of pest and disease resistance, which are often encoded by only a single gene (monogenic traits). Different transgenic pest and disease resistances have already been commercialized. In assessing the potential value of such traits, it has to be considered that global crop losses induced by biotic stress factors reach a level of 25 - 30% (Oerke et al., 1994). Biotechnology could substantially reduce these losses without the need for pesticide applications. Other desirable agronomic crop traits include enhanced genetic yield potentials and tolerance mechanisms to abiotic stresses, such as drought, coldness and nutrient deficiencies in soils. These traits are often determined by multiple genes (polygenic traits). Recent advances in molecular mapping and functional genomics demonstrated that related biotechnology products are quite realistic in the near to medium–term future (Abelson and Hines, 1999). Thus, improved crop varieties could be tailored to marginal agro-ecological regions, which have been largely neglected by the green revolution.

Quality traits

The concept of quality traits here refers to the output traits such as appearance and chemical composition of the crop product. It also includes enhanced densities of macro- and micro-nutrients essential for healthy human diets. If such traits are incorporated into staple food crops they could be beneficial especially for the low income populace that often lack the purchasing power to afford the higher-value and more nutritious foods. For instance, researchers have been able to develop transgenic rice varieties with significantly enhanced vitamin A contents, now being used in rice breeding programmes. Promising advances in biotechnological research to improve the micronutrient density in plants have also been reported for a number of other important vitamins and minerals (Potrykus et al., 1999).

The main constraints to the capacity of biotechnology to engender food security in Africa are limited capacity– human, financial and infrastructural; ill-defined or non-defined institutional arrangements for biotechnology research and development and indecision/poor policy on biotechnology.

RISKS OF BIOTECHNOLOGY

Besides the great potentials of biotechnology for increased food production and agricultural productivity, the risks must not be neglected. Often, fears have been articulated that new risk dimension for the environment and for human health could occur due to the direct manipulation in the genetic makeup of organisms. As human knowledge is limited, the existence of unknown risks cannot be ruled out with absolute certainty, neither for transgenic crops nor for any other technology. According to current scientific knowledge, there are no indications that genetically modified crops are more dangerous than traditionally-bred varieties (Cooks, 2000). This does not mean that there are no risks at all. However, the predictable risks are not related to the biotechnological process but to the end-product to be released. Thus, risk assessment studies have been carried out on a case-by-case basis for each individual technology product.

Environmental risks that need to be considered include the possible loss of biodiversity, detrimental effects on natural food chains and the emergence of aggressive pathogen populations. Health risks include the possible occurrence of undesirable toxic by-products in the crops, the transmission of antibiotic resistances (used as marker genes) to microorganisms of human digestion and unknown allergic reactions by food consumers. Generally, the individual risk aspects apply to developed and developing countries alike. Yet, it is important to note that the likelihood of transgenes escaping into the wild through cross-pollination is higher in the developing world. The major centre of agricultural bio-diversity are found in the tropic and subtropics (Virchow, 1999), so that more wild relative of domesticated species are grown in the vicinity of farmland. If the transgenes encode traits of substantial competitive advantage, there is risk that some of the natural vegetation is suppressed.

A responsible management of biotechnology is a pre-requisite for sustainable agricultural development and it requires that effective regulation for bio-safety and food-safety are established wherever transgenic crops are to be developed and released. Responsible technology management, however, must not be confined to the risk side only. Risks should always be juxtaposed to the potential benefit and certain residual risks appear tolerable if they are offset by much higher benefit prospect. On the benefit side, it must not be forgotten that biotechnology could also bring about substantial positive environmental effects, such as lower conventional pesticides applications or reduce agricultural area expansion into ecological fragile environment.

Apart from the mentioned environmental and health risk of transgenic crops, there are also concerns which are rather socioeconomic. Biotechnological techniques, for instance, could alter international trade flows to the detriment of many developing countries; trade with agricultural raw products could be substituted, if tropical plants are adapted to the temperate zone or their products are produced in the laboratory, as is expected for vanilla and other valuable substances. Likewise, if biotechnology research and development would only benefit the rich while neglecting the needs of the poor, the innovation could engender an aggravation of existing income disparities. These kinds of risks should not be underrated, but it has to be clear that they are not inherent to biotechnology. Any far-reaching new technology can cause undesired equity effects under unfavorable economic and social framework conditions.

POLICY CHALLENGES FOR DEVELOPING COUNTRIES

(1) There is an urgent need for clear priorities to invest in biotechnology. This requires that concerned countries should identify specific areas or technology trajectories in which to invest to meet specified goals and to utilize the available skills and resources optimally.

(2) Another crucial area of need is to ensure availability of finances for biotechnology research and development. Current investment in this area is not sufficient. This could be done by forging strategic alliances with the private sector, ensuring that the public good of availing food to all is not compromised by profit motivation.

(3) A responsible management of biotechnology should be established as a pre-requisite for sustainable agricultural development and it requires that effective regulation for bio-safety and food-safety are established wherever transgenic crops are to be developed and released.

(4) Developing countries should also consider the role of intellectual property rights and their impact on the acquisition, development and diffusion of biotechnology.

CONCLUSION

Modern agricultural biotechnology is one of the most promising developments in modern science. Used in collaboration with traditional or conventional breeding methods, it can raise crop productivity, increase resistance to pests and diseases, develop tolerance to adverse weather conditions, improve the nutritional value of some foods and enhance the durability of products during harvesting or shipping. With reasonable biosafety regulations and appropriate policies, this can be made accessible to small-scale farmers with little or no risk to human health and the environment. Therefore, in a world where the consequence of inaction is death of thousands of children, we must not ignore any part of a possible solution, including agricultural biotechnology.

REFERENCES

Abelson PH, Hines PJ (1999). The plant revolution. Sci., 285; 367-368.

Cook RJ (2000). Science-based risk assessment for approval and use of plants in agricultural and other environments In: Persley GJ, Lantin MM (eds): Agricultural Biotechnology and the Poor. Consultative Group on International Agriculture Research, Washington, D.C. pp. 123-130.

FAO (1999). The state of food insecurity in the world. Food and Agriculture Organisation of the United Nations, Rome.

FACTA (1990). "Food, Agriculture, Conservation and Trade Act of 1990. Public Law 101-624, Title XVI, Subtitle A, Section 1603. The National Agricultural Law Center. http://www.nationalaglawcenter.org/assets/farmbills/1990-6.pdf

McCalla AF (1999). Prospects for food security in the 21st century with special emphasis on Africa. In: Agric. Econ., 20(2): 95-103.

Oerke EC, Dehne HW, Schonbeck F, Weber A (1994). Crop production and crop protection: Estimated losses in major food and cash crops. Elsevier, Amsterdam.
Persley GJ (2000). Agricultural Biotechnology and the Poor. Promethean Science. In: Perseley GJ, Lantin MM (eds): Agricultural Biotechnology and the Poor. Consultative Group on International Agricultural Research, Washington D.C. pp. 3-21.
Pinstrup-Andersen P, Pandya-Lorch R, Rosegrant M (1999). World food prospect: critical issues for the early twenty-first century. 2020 Vision, Food Policy Report, International Food Policy Research Institute.
PRB (2006). “Population Reference Bureau”. 2006 World Population Data Sheet. Economic Information Bulletin Number 18. Washington, DC: USDA Economic Research Service;August2006. http://www.ers.usda.gov/publications/eib18/eib18.pdf.
Potrykus I, Lucca P, Xudong E, Al-Babilli S, Hurrel RH, Beyer P (1999). Contribution to food security by genetic engineering with rice. paper presented in the general meeting of the international programme on rice biotechnology, Rockefeller Foundation, Phuket Thailand.
United Nations Administrative Committee on Coordination Sub-Committee on Nutrition (2000). Fourth report on the world nutrition situation Geneva, Switzerland: ACC/SCN in collaboration with the International Food Policy Research Institute.
Virchow D (1999). Conservation of genetic resources; Costs and implications for a sustainable utilization of plant genetic resources for food and agriculture. Springer, Berlin.
World Bank (1993). World development report: investing in health. Washington DC, Oxford University Press, as Cited in United Nations Children's Fund. The State of the World's Children. New York, NY: Oxford University Press