Biotechnology for Agriculture Enhancement in Ghana: The Challenges and Opportunities

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Abstract: Ghana, a developing country in sub-Saharan Africa, has agriculture as a major contributor to the economy. The system of agriculture is, however, subsistence and needs to be developed as the nation strives to attain a middle income status. For agriculture to develop for enhanced economic growth, biotechnology has been identified as one of the technologies that must be utilized for rapid development. Biotechnology is in its developmental stages in Ghana and the research institutions as well as the universities are using the various tools for research and also to support the farmer. There are several challenges that the development of biotechnology is faced with; these however, present opportunities that can be exploited. This paper outlines agriculture based biotechnology research activities in Ghana using the Council for Scientific and Industrial Research Institutes as a case, and other challenges and opportunities that come along with the technology. Information on advances made in plant biotechnology, the constraints confronting researchers, and how the technology is being tailored to benefit the agriculture industry and the nation are discussed.

Keywords: Agriculture, crops, Ghana, research, technology

Introduction

Ghana, a developing country in Sub-Saharan Africa, is located in West Africa - the Gulf of Guinea to the south of the country, Cote d'Ivoire to the west, Republic of Togo to the East and Burkina Faso to the north.¹ The climate is tropical with bimodal rainfall distribution from April to July and from September to November in the south. In the north the
rainy season begins in April and lasts until September. Annual rainfall ranges from about 1,100 mm (about 43 in) in the north to about 2,100 mm (about 83 in) in the southeast. Ghana’s agricultural sector can be characterized as low-input, rain fed (a paltry 0.05 per cent is under irrigation), small holder dominated, heavily dependant on women’s labour and management, very poorly served by basic infrastructure and support services.²

According to the year 2000 population census, there were 18,800,000 people comprising 51 per cent females, and 49 per cent males. The population growth rate is 2.6 per cent with a population density of 78.9 persons per sq. km. The labour force is 4.1 million, with agriculture and fishing comprising 55 per cent, industry - 18.7 per cent, sales and clerical-15.2 per cent (2000 Census). Adult unemployment rate for Ghana is at 8.2 per cent (2000 Census) and the projected population is 36.9 million by the year 2015.³

Ghana has twice the per capita output of the poorer countries in West Africa. However, Ghana remains heavily dependent on international financial and technical assistance. Gold, timber, and cocoa production are major sources of foreign exchange. The domestic economy continues to revolve around subsistence agriculture, which accounts for 36 per cent of GDP and employs 55 per cent of the work force.

The economic data of Ghana is as follows: GDP: $5.9 billion (2002), GDP per capita: $1,980 (2002), GDP growth rate: 5.2 (2004 cited by government), GNP/capita: $1,900 (2000 estimate). This is a measure of per capita income that takes into account relative purchasing power across countries. GDP composition by sector is: agriculture: 36 per cent industry: 25 per cent services: 39 per cent (2000 estimates). Per capita income of Ghana in the year 2002 is US$ 290 while the income per capita growth is 1.3 in 1999-2000. Gross National Income (GNI) is 6.6 billion (ranking102); Budget revenue is $1.603 billion in 2001, Budget expenditure is $1.975 billion in 2001 (estimated). Budget deficit: 3.4 per cent of GDP (2004); total debt: US$5.5bn (2000); $6.9bn (2001); and $7.2bn (2002).

As mentioned above, agriculture accounted for almost 40 per cent of GDP⁴, and employs three-fifths of the workforce. However, despite its importance, sectoral growth has lagged behind other sectors of the economy and has been unpredictable, as most farming is reliant upon rainwater. The farming is also done mostly by small scale farmers with very little or no mechanization. The removal of subsidies on fertilizers and other agricultural inputs has adversely affected crop yields. Crop
production in Ghana varies for the various climatic zones; dry savanna to wet forest. Some of the major agricultural crops include cassava, yams, grains, cocoa, oil palms, kola nuts, and timber. Ghana is the second largest producer of cocoa in the world. Large tracts of forest have been cleared for cocoa crop, which thrive in the rich soil of the rain forest. The application and adaptation of modern and improved agriculture practices is slow and the use of biotechnology by the private sector is very minimal. However, the technology is still at the developmental and adaptation stages in schools. Due to the cost involved in equipping laboratories and the need for well trained experts, the knowledge in most educational institutions at the undergraduate level is theoretical. It is only at the postgraduate level that students have some practical exposure, where students have to use the technique for their research work. University agriculture science students are, therefore, encouraged to adopt biotechnology methods to expand the frontiers of agriculture. This is because biotechnology methods could speed the transformation of agriculture to facilitate food security as Ghana seeks to move from low income nation to a middle income level.

Ghana is a member of the United Nations and in 2000 the member states of the United Nations adopted the Millennium Declaration as a renewed commitment to human development. The Declaration includes eight Millennium Development Goals (MDGs) as follows: eradicate extreme poverty and hunger, achieve universal primary education, promote gender equality and empower women, reduce child mortality, improve maternal health, combat human immunodeficiency virus/acquired immune deficiency syndrome (HIV/AIDS), malaria, and other diseases, ensure environmental sustainability and develop a global partnership for development.

Approximately 70 per cent of the MDGs’ target group lives in rural areas, for most of whom agriculture is a critical component in the successful attainment of the MDGs. Agriculture is, therefore, a key sector to be developed and enhanced for the attainment of the millennium goals.

This paper outlines agriculture based biotechnology research activities in Ghana using the Council for Scientific and Industrial Research Institutes as a case, and other challenges and opportunities that come along with the technology. Information on advances made in plant biotechnology, constraints and how the technology is being tailored to benefit the agriculture industry are also outlined here.
Biotechnology Applications in Ghana

The application of biotechnology in Ghana has been for medical research and diagnostics as well as agriculture research. Biotechnology application started a little over two decades ago using mainly tissue culture tools for teaching and research purposes. Other technologies that came along were ELISA for disease diagnostics and isozymes for characterization. Below (Table 1) is list of major bodies employing biotechnology for agricultural research.

Table 1: Institutions carrying out Biotechnology activities in Ghana

<table>
<thead>
<tr>
<th>Institution</th>
<th>Biotechnology Application</th>
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<tr>
<td>Universities</td>
<td>Teaching and research</td>
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<tr>
<td>Biotechnology and Nuclear Agriculture Research Institute</td>
<td>Teaching and research</td>
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<tr>
<td>Cocoa Research Institute of Ghana (CRIG)</td>
<td>Research, teaching and training</td>
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<tr>
<td>Council for Scientific and Industrial (CSIR)</td>
<td>Research, training and research teaching</td>
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The Council for Scientific and Industrial Research (CSIR), which is the governing body overseeing scientific research in Ghana, is leading in the application of biotechnology in agriculture. The council is made up of 13 institutions.

The list of institutions within the CSIR that are using biotechnology in research include: Crops Research Institute, Animal Research Institute, Forestry Research Institute, Food Research Institute, Oil Palm Research Institute, Savanna Agriculture Research Institute, Plant Genetic Resources Research Institute and Science and Technology Policy Research Institute (STEPRI).

Application of Biotechnology Activities in Some of the Institutions

The Oil Palm Research Institute has the mandate to carry out research on oil palm and coconut. The mission of the institute is to conduct sustainable and demand driven research aimed at providing scientific and technological support for the development of the entire oil palm and coconut which are vital for the cosmetics industries. Presently, molecular diagnostic tools are being used in the institute for the development and production of coconut ecotypes tolerant to the Cape St. Paul Wilt Disease.

The Forestry Research Institute of Ghana is mandated to undertake
forest and forest products research to ensure sustainable management and utilization of Ghana’s forest resources and to engage in the commercialization of the research results and services. To enhance their research activities, they are using biotechnology tools for clonal micropropagation and molecular characterization of forestry germplasm.

The Animal Research Institute is also one of the CSIR institutions with mandate to undertake research aimed at providing solutions to problems relevant to the livestock industry in Ghana. The institute is also to advise government through the CSIR on livestock production policy matters, and to help the country to become self-sufficient and achieve food security in animal protein supply. Livestock production in Ghana contributes 7 per cent to the agricultural gross domestic product (GDP) and domestic production of meat supplies only 30 per cent of the national protein requirement. Factors affecting livestock production in Ghana include lack of improved breeding stock, poor nutrition, diseases, and poor marketing systems, non-availability of capital and high interest rates and transaction costs on credit. Biotechnology holds promise for improving the productivity of livestock in the area of animal breeding, nutrition and health. Presently sampling for serological /molecular monitoring of PPR in small ruminants in 3 agro ecological zones in Ghana has commenced. This would allow the epidemiology of the disease in the country to be studied using molecular based (RT-PCR) diagnosis tools. The molecular based diagnosis of PPR will form the basis for early diagnosis and control of the disease in the country.

The Crops Research Institute (CRI) is mandated to carry out research on all the food crops in Ghana. The mandate crops range from legumes (cowpea, soybean, groundnut, bambara groundnut), through cereals (maize and rice), roots and tubers (yam, cocoyam, taro, cassava, frafra potato and sweet potato), to vegetables (pepper, garden eggs, tomato, onion, leafy vegetables), plantain and banana, tropical fruits (citrus, mango, avocado, pineapple, cashew, pawpaw), and industrial crops (rubber and sugar cane). The institute has well established and functional biotechnology laboratories for the enhancement of research activities of breeders, agronomists and related disciplines. The biotechnology laboratories have objectives to provide the basic molecular tools vital for the enhancement of breeding programmes towards crop improvement and release. The laboratory has established collaboration with advanced laboratories and other sister institutes for the application of current state-of-the-art molecular techniques for crop development.
The following biotechnology applications can be carried in the facility: *in vitro* rapid multiplication and plantlet production and cleaning planting materials to eliminate pathogens. There is a reliable system for exchange of clean planting materials, cryopreservation, somatic embryogenesis, proteomics (tools for genetic engineering), another cultures (applied in rice improvement), and long term conservation of vegetatively propagated crops.

Presently the tissue culture activities in the CSIR-CRI laboratory include: receiving *in-vitro* materials, rapid multiplication of induced mutation cassava plantlets, rapid multiplication of clonally propagated crops, *in-vitro* conservation of germplasm using slow growth techniques, production of clean planting material, embryo rescue during crosses, somatic embryogenesis toward crop improvement, cryopreservation techniques for the conservation of vegetatively propagated crops, and efficient post-flask management of *in-vitro* plantlets. The tissue culture outfit of the facility has successfully used the technique in cassava, plantains, bananas, sweetpotato, pineapple, cocoyam, yam, mango, frafra potato, jatropha and citrus.

The molecular biology laboratory has the human capacity to apply the following techniques: genotyping/fingerprinting of germplasm, genetic diversity studies, marker-assisted selection as applied in breeding programmes, disease diagnostic studies, gene mapping, gene mining for trait capture, primer design and gene silencing in crop improvement.

The use of these techniques will help reduce breeding time, increase essential nutrients, improve yields, enhance stress tolerance, improve resistance to disease and pests, and lead to development of new products and growing techniques. These are aimed at producing varieties to serve industrial processing and address issues including global warming and its effects on drought in crop production.

Presently at the CSIR-Crops Research Institute, the biotechnology tools have been applied to several crops, including cocoyam (*Xanthosoma* sp.), groundnut, cassava, yam plantains and bananas, sweetpotato, maize and soyabean. Considering cassava as an important staple and industrial crop in Ghana, the Crops Research Institute over the years has released improved cassava varieties to farmers. These varieties are high yielding and tolerant to most diseases and pests. However, these varieties are mainly used for industrial products like starch, gari, and few staples. In that effect the local landraces which are preferred by farmers and consumers because they have good cooking qualities for all the food preparations have been
left unattended to. These landraces are susceptible to cassava green mites and Africa cassava mosaic virus (ACMV) with its attendant low yields. Several research interventions have been put in place to improve the farmer-preferred cassava landraces. These include introgression of ACMV resistance genes into local landraces; induce mutation breeding to improve shelf life of tubers and starch content; and introgression of useful genes into the local landraces to improve the shelf life. The local cassava varieties that are popular with the farmers have short shelf life leading to rotting of fresh tubers when not used immediately after harvest. The research activities, therefore, include the use of biotechnology (Marker Assisted Selection) for pyramiding useful genes from wild relatives of cassava into elite progenitors to develop landraces with prolonged shelf life and pest and disease resistance. Genes for resistance to pest, diseases and delayed post harvest physiological deterioration are, therefore, being mined for in the wild gene pool. Current tissue culture activities include rapid multiplication of induced mutation cassava plantlets and clonally propagated crops, *in-vitro* conservation of germplasm using slow growth techniques, production of clean planting material, embryo rescue during crosses, somatic embryogenesis for crop improvement, cryopreservation techniques for conservation of root and tuber germplasm, and efficient post-flask management of *in vitro* plantlets. Crops that are being worked on currently using tissue culture techniques include cassava, plantain, banana, sweetpotato, pineapple, cocoyam, yam, mango, frafra potato, Jatropha, citrus, bambara groundnut. At CRI, biotechnology applications are aimed at reducing maturation time, enhanced nutrients, yield and stress tolerance, improving resistance to disease, pests and herbicides, meeting processing needs for industry, and reducing time for crop development.

**Status of Biosafety Law**

As the biotechnology tools are developed and adapted, there are sectors that need critical attention, and these include biosafety issues, and regulatory mechanisms on biotechnology. Biosafety is the safe use, transfer and handling of living organisms modified through modern biotechnology and it reviews the scientific evaluation of the potential of a genetically modified organism (GMO) to effect human and animal health and the environment. Issues concerning biosafety are very sensitive. Human health, environmental and socio-economic issues are the three major concerns of biosafety. The decision-making components of biosafety are: national
policy, stakeholder input, safety issues which comprise environmental and food safety and non-safety issues which comprise socio-economic considerations, international agreements, ethical issues, impact on trade and public opinion. To serve as a guide for issues relating to biosafety and legal, technical, administrative and information management systems, are the Cartagena Protocol on Biosafety (CPB) and National Biosafety Framework (NBF). Some key elements of an NBF are a government policy on biosafety, a regulatory system, an administrative system, a decision-making system and mechanisms for public participation and information sharing. Ghana has put in place a comprehensive programme for Biosafety Systems Project (PBS) and an advisory group. The necessary foundation was built through the training of scientists, trial managers and regulators on confined field trials. Policy/legal framework was reviewed and the Ghana biosafety draft law for resubmission to cabinet has been done. Biotechnology communication workshops have been held among scientists, the media, farmer groups, policy makers, NGOs and members of parliament. PBS has offered training on biosafety, food safety and biosafety curriculum development through internships. To circumvent the delay in the passage of the Bill and allow for the practice of good science, a biosafety Legislative Instrument (LI) has been drafted. The LI uses the existing CSIR Act 521 of 1996 as a template since it has provisions for the conduct of research in general and seeks to simply extend this to the conduct of research on GMOs. Arrangements have been made at institutional levels to see to procedures, liability and redress, miscellaneous and schedules. The LI recognizes and empowers the National Biosafety Committee (NBC) as the National Focal Point on Biosafety, authorizes the conduct of confined field trials, provides the regulations for the conduct of confined field trials and does not allow the commercialization or release of products to farmers and consumers. Approval by the NBC for researchers to conduct confined field trials and contained laboratory experiments, will be on a case-by-case basis. Some confined field trials that would be conducted include ACMV resistant cassava, Bt maize, Bt cotton and Bt cowpea. If guidelines are followed, these GM foods are safe, however, legitimate concerns will not be ignored. The vigorous training of scientists, technicians and the provision of functional laboratories is critical.

Biotechnology Opportunities and Challenges

Considering the above biotechnological developments in Ghana, there exist several challenges and opportunities that can be utilized to change
the phase of agriculture in the country and this will affect the sub-region. There is tremendous opportunity to promote effective collaboration between Ghana and countries well advanced in the use of biotechnology. There is plenty of manpower. There is advantage of the labour force which is not expensive and can be fully utilized in collaborative research for manpower training and technology transfer.

One underexploited area in biotechnology in Ghana is the use of in\textit{v}itro methods\textsuperscript{5} for the production of clean planting materials which are in high demand. Application of tissue culture techniques in the horticulture industry is barely existent and this opportunity can be taken up to supply clean planting materials. This system needs the assistance of molecular tools to ensure that the clonal materials that is produced maintain their genetic integrity with the application of fingerprinting techniques. The systems available in other countries where planting materials of vegetatively propagated crops are replaced after a number of seasons can be adapted and enforced in Ghana. This will keep the disease pressure down and ensure high production levels. Previous studies using sweetpotato have revealed that when clean tissue culture produced planting materials are used the yield is 30 per cent higher than when regular planting materials are used. This practice must, therefore, be encouraged. The government can enforce laws that will ensure that growers replace their vegetatively propagated crops with certified clean tissue culture produced planting materials. This will also help check the spread of diseases and create jobs. The law too will help keep laboratories producing the planting materials in business and the private sector should be encouraged to take advantage of the opportunity.

There, however, exist the challenges of availability funds for the rapid development and adaptation of biotechnology tools to serve all aspects of agriculture. The establishment of effective collaboration can help identify sources of funding that can be tapped for the biotechnology sector. Policy development, government contribution to science and technology as well as regional collaboration are required to aid and promote biotechnology.

There is also a big gap of knowledge in all sectors of society as to what biotechnology is and what it can offer to the agriculture sector. To date some of the science and agriculture textbooks at the basic education level talk of biotechnology as fermentation only. Knowledge about modern biotechnology is greatly lacking and this poses a big challenge that needs to be tackled from the grassroots. There is need to organize training sessions
for the science and agriculture science teachers and seek opportunities to revise the information in the school textbooks to include some current issues on modern biotechnology. Policy makers and journalists also need to be well educated in the field of biotechnology to enable them to draw informed conclusions on related issues. This will help break the communication gap between policy makers and the researcher in the laboratory. This will create the opportunity to carry out studies on how countries which are ahead of Ghana in biotechnology issues manage to educate the various stakeholders and adapt them to improve our system.

The ability to share regional projects, personnel and research findings is also very vital for the advancement of biotechnology for agriculture enhancement in Ghana and the sub-region. Within the African sub-region regional research areas can be identified to share funds and research findings. Regional training can be organized to build capacity. The equipment supply and maintenance system as well as sources for laboratory consumables can be explored and strengthened. Along these lines inter-regional policy development will lead to the promotion of biotechnology.

In this present day of technological advancement one of the big challenges that the faces the laboratories in Ghana as we develop biotechnology, is the reliable supply of electricity and water. Presently, the availability of a borehole that serves the CSIR-Crops Research Institute has helped deal with the water supply problem, and this is a step in the right direction since there exists a lot of good quality cheap underground water that can be tapped. The underground water can also be tapped to irrigate farm lands. That way it can stop the reliance on rain water for crop production. Advantage need to be taken of this great opportunity. Tapping of underground water technology needs to be modernized and the cost also needs to be reduced to encourage several others to use that option. Standby generators are used in the incidence of interruptions in power supply. These are, however, very frustrating and expensive. Therefore, concrete solutions need to be evolved. Alternative sources of energy should be explored in Africa to reduce the over dependence on hydro power and the use of fossil fuel for our energy needs. There is need to tap the solar energy and channel it for use in the laboratories. Wind energy can also be used as an alternative to the energy from the local electricity producers. A pilot project in one of the institutes of the CSIR has demonstrated this. There are, therefore, opportunities for these technologies to be developed to boost the application of biotechnology.
in agriculture development because the high cost of electricity and water is a great challenge to the competitiveness of local industries in Ghana.

The availability of reliable and constant supply of laboratory consumables also pose a challenge since these are not produced locally. This provides an opportunity for producers and suppliers to explore this market and supply the needed items. In line with this, local alternatives can, where possible, substitute the imported products. This will also go a long way to provide jobs and create worth.

The field of animal health is another area that can be explored for great opportunities in meat and meat products’ production and job creation. Biotechnology is useful in disease diagnosis, insect pest management, recombinant vaccine production and animal nutrition. Biotechnology can be used to produce enzymes that promote digestion of complex food substances in animal feed and for production of high quality feed meeting dietary requirements of essential amino acids and manipulating gut microflora for improved rumen activity. Rapid increase in livestock production is required to help feed the ever-increasing population growth of human population. Modern biotechnology seeks to augment conventional methods of improving livestock for enhanced productivity. Development of necessary infrastructure and capacity for the application of biotechnology to turn the livestock sub-sector into a vibrant industry in Ghana is needed. Development of diagnostic kits for livestock and poultry diseases including foot and mouth disease, Avian influenza, Brucellosis, Gumboro, African Swine Fever, lumpy skin disease, viral diseases affecting guinea pigs and PPR in small ruminants are also very vital.

Ghana, a developing country in West Africa, is a primarily an agric-based nation. It has plans to move from a low-income nation to middle-income. Industrialization has a crucial role to play. A platform for interaction amongst all stakeholders towards the development of new biotechnologies in industry that can have substantial implications for the improvement of life and business is very vital. The development of cutting-edge technologies for adaptation and modification of biological organisms, processes, products and systems in nature for the production of goods and services will enhance the creation of new products for industry. On developing new industrial processes, including recently discovered oil in Ghana, our local manufacturing industry will become more competitive. Industrial biotechnology should be used to aid systems in cleaning the environment and to reduce the impact of manufacturing waste. The
The development of these technologies will be applied for sustainable production of biochemistrys, biomaterials, and biofuel from renewable resources.

A major challenge that biotechnology has to deal with is the acceptance of the technology and its products. Biotechnology applications in Ghana offer a bright future for the enhancement of agriculture in Ghana. Educating tomorrow's generation in biotechnology holds the key to a better Ghana.

**Conclusion**

Farmers and agriculture underpin the well-being of the world's population. Agriculture is changing continuously: every year for the last 10,000 years, farmers have improved their weed control and water management. In each decade, farmers have won and lost battles with pests and diseases and adopted new varieties of their crops. Exploitation of biodiversity is important to the livelihood of subsistence farmers and commercial growers. Modern genetics, mutation and molecular methods, and plant breeding can benefit producers, consumers and the environment.

Traditionally in Ghana, biotechnology is being used as a tool to give plants new traits that benefit the agricultural production, environment, and human nutrition and health. For the past couple of decades the plant biotechnology has been applied to produce clean planting material, conserve germplasm and rapidly multiply crops with desirable traits. The application of molecular biology has been used to mine for genes and characterize germplasm with preferred characteristics that are of industrial use such as high starch and for bio-fortification. There are a number of industries using crops as raw material. Desirable traits need to be introduced in the crops to meet the demands of the industry. CSIR-CRI has been selected to be a National Center of Specialization for the sub-region under the West Africa Agriculture Productivity Project (WAAPP) and this puts the institute and the CSIR in the focal point to intensify the development of biotechnology tools. There will also be the need for technical backstopping. Partnerships with advance laboratories need to be in place for routine update of the fast advancing techniques in biotechnology. Government support for providing reliable supply of energy and laboratory supplies is crucial. With the passing of the Legislative Instrument on Biosafety in Ghana, the country is prepared to carry out confined field trials on sweetpotato, cassava, maize, and cowpea. It, however, needs training for staff in handling genetically modified organisms.
Endnotes

1 The country is precisely Latitude: 5 degrees, 36 minutes north and Longitude: 0 degrees, 10 minutes east. Half of the country lies less than 152 meters (500 ft.) above sea level, and the highest point is 883 meters (2,900 ft.). Total land area is 238,540 sq. km of which 57 per cent (13.6 million ha) is agricultural.

2 www.ghanaweb

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