MOI UNIVERSITY

INAUGURAL LECTURE

FROM GENES TO GENETICALLY MODIFIED CROPS: The Future of Food Production, Sustainable Environment and Human Health in Africa

FROM GENES TO GENETICALLY MODIFIED CROPS: The Future of Food Production, Sustainable Environment and Human Health in Africa

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1.0 Introduction

Invited guests, ladies and gentlemen, it gives me great pleasure and I consider it an honour, to stand before this august audience today to deliver my inaugural lecture. I feel privileged by the opportunity accorded to me by the University to be the first Professor of Moi University to deliver the first Inaugural Lecture. Secondly, I congratulate the University for initiating the Inaugural Lecture Series to allow Professors to share their knowledge and experiences with members of the public as well as the academia.

In this inaugural lecture, I will share my thoughts with the University community and the public in general on the challenges facing food security situation, management of sustainable environment and human health in Africa, and the use of Genetically Modified (GM) crops as complementary possible alternative solution to food insecurity. The lecture will provide an overview on how GM crops are produced in laboratories around the world, and what these novel crops generated through genetic engineering, portend on the future of food security, environmental sustainability and human health particularly in Africa and the developing world in general. The lecture will also cover the development of genetic engineering technology in East Africa and specifically at Moi University. It will also highlight future global trends in this exciting technology.

I feel greatly challenged by the debate on the relevance of GM crops to food security and malnutrition, the African poverty situation, environmental sustainability and human health. Africa's debate on GM crops has suffered from misinformation, lack of focus on critical issues and awareness by the general public on what these crops really are. I consider the development of Africa to be among the most pressing issues that should pre-occupy the great minds in Africa and the entire global scientific community. I strongly believe that molecular biologists like me have a duty and indeed moral responsibility to explain to the public the significant contribution that GM crops would make towards alleviation of poverty, food insecurity, malnutrition, environmental degradation and poor human and livestock health in Africa. In this way, I believe, the public will be provided with correct information for appropriate decision-making as they explore various alternatives and roles that GM crops could play in overcoming these challenges.

It must be made absolutely clear that although the opponents of GM crops have expressed concern on their use and development, it is important to note that GM crops are not

identical and therefore should specifically be treated on a case-by-case basis and each either accepted or rejected on the basis of potential risks it poses, or the benefits that may accrue from its use. GM crops, like all other new technological products, may have some risks associated with their use. For example, over the years, adoption of new technologies, such as use of aeroplanes, motor cars, cell phones or fertilizers has always suffered from the fear of unknown but the decision to use them has depended on the cost-benefit analysis. Thus, the blanket condemnation of GM crops or their universal acceptance may not be wise without a cost-benefit comparison supported by scientific data and social justification.

Again it must be emphasized that major constraints facing production of staple food crops and cash crops in Africa such as pests, diseases, declining soil fertility, drought and weeds are complex and have no simple effective solution in the conventional management options available to farmers. This is why agricultural experts the world over, agree that GM crops can complement existing efforts and make developing countries achieve food security; improve human health and attain environmental sustainability in Africa.

1.1 Challenges of Poverty, Food Insecurity and Malnutrition

In the 21st century, world agriculture faces the following three major challenges: (i) how to produce enough food to feed the fast growing human population; (ii) how to reduce the ever increasing rural and urban poverty and (iii) how to sustain the environment and maintain biodiversity (McCalla 2000). In this century agriculture is facing unprecedented challenges including feeding an additional 2 billion people over the next 30 years from an increasingly fragile natural resource base (FAO 2004) and urban populations that demand a wide range of quality agricultural food products while questioning to know how they have been produced and their safety. These challenges appear insurmountable in Africa where the per capita food production has been declining and this is further worsened by the high post-harvest losses that often reach 40% or more in Africa.

Prevalent hunger and malnutrition confront African developing world agricultural experts and they are responsible for about 54% of child mortality cases in developing countries. Over 71 million people in the horn of Africa alone are food insecure and thus regularly

receive food aid (Wanjohi 2006). Today, 70% of the poor in Africa live in rural areas where agricultural productivity is among the lowest in the world. For example, African mature beef cattle of 4-5 years hardly weighs 300 kg as compared to 400 kg at one year realized in exotic ones; African best cows produce 300 litres/lactation compared to 5000 litres/year in developed countries. Average maize yield in Africa is only about 1.7 tonnes/ha compared to 4.0 tonnes/ha while sweet potato yields 1.6 tonnes/ha compared to 14 tonnes world average (Wambugu 2000). This kind of productivity is too low to feed and sustain the rural communities' livelihood.

Several factors that contribute to the deplorable state of food insecurity in Africa. First, African farmers have continued to use traditional and rudimentary ways of farming characterized by low investment in agriculture and arguing that input cost are high. However, this trend in farm input costs is not likely to change soon and therefore crop yields in small-hold farms will remain low and continue to decline.

Secondly, the increase in human armed conflict resulting from perennial social, economic and political struggles has led to forced migration and is partly responsible for food insecurity in Africa. Refugee trends are increasing in Africa and the African Union (AU) seems to be unable to stamp out civil strife and hence the food insecurity in such areas will still remain fragile in the years to come and hence the supply of emergency food aids will continue**.**

Thirdly, natural calamities or pestilences such as drought, weeds, insect and pest invasion and brain drain coupled with low and/or declining soil fertility are common in Africa. These limit any chances of producing adequate food through conventional farming practices unless new technologies are incorporated into the farming domain. Fourthly, the world economic order which dictates a free market economy often allows subsidy of agricultural production in developed countries but precludes the same in developing countries while encouraging competition and exportation of such comparatively cheaply produced agricultural products into Africa is unlikely to change soon and present situation of food aid and relief emergencies (FAO 2004) may continue into the future.

Fifth, population growth rates in most African countries exceed 3% per annum and are among the highest in the world (ICTSD 2006). Worse still, the world's estimated 10

billion people by the year 2050 (Mc Calla 2000) will mostly be in Africa and other developing countries where already about 850 million people go hungry daily or are malnourished.

1.2 Environmental Challenges

Environmental degradation represents the third global challenge, which is much more in Africa than in any other continent (Senelwa 2006). The major environmental problems facing Africa include soil erosion, soil fertility depletion, overgrazing, deforestation, and devastation of crops by insect pests and diseases. Consequently, the available arable land per farming has been declining due to these environmental problems. Soil depletion is prominent and owing to small farm sizes and the resultant low agricultural productivity in such farms a lot of forests have been cleared for agricultural production and this has led to greater genetic erosion and loss of biodiversity.

A second major environmental challenge in Africa is the shortage of energy sources (Annon. 2006). Although Africa is well endowed with fossil fuel and renewable energy sources from its forests and crops, most are unexploited and more than half of fossil fuels produced are exported, leaving very little for home use and industrial development especially in the rural areas (Senelwa 2006). Third challenge is environmental pollution and combination of agricultural products by pesticides. Pests, diseases and weeds are among the major causes of low crop yields accordingly for between 10-40% yield reduction but when pesticides are used, they contaminate agricultural products and pollute the environment leading to loss of markets for Africa's horticultural and other export commodities to the developed world, notably Europe.

1.3 Human Health Challenges

Africa faces a myriad human health challenges. Eighty percent of infectious diseases are found in sub-Saharan Africa. Malaria alone, kills two million people and reduces the gross domestic product (GDP) of sub-Saharan Africa by 1% every year. The scourge of HIV/AIDS affects more than 36 million people worldwide and 70% of these are in Africa. These diseases and many more affect agricultural productivity among the African population and lead to underdevelopment, recurrent poverty and food insecurity.

Malnutrition and undernourishment aggravate health problems in Africa. According to FAO (2004) statistics, more than 842 million people in the world, most of them in the rural areas of Africa, are chronically hungry and suffer from micronutrients and vitamin deficiencies (Wambugu 2000). This situation reduces their immunity and exposes them to a variety of ailments.

What are the alternatives to the challenges?

When the Early Man was faced with nearly a similar problem he turned to "the gene alternative" and unwittingly selected genes and gene complexes that determined quantity and quality of products in crops and livestock and in this way he got rid of hunger. Thereafter, plants and animals breeders improved yields by careful gene selection techniques. However, considering the yield plateau and declining crop yields experienced by farmers in Africa, conventional breeding may not give quick solutions and hence a need for a more robust technique to manipulate genes for improved crop and animal yields. This is possible through GM technology.

Genetic modification is complementary to conventional plant breeding and enables plant breeders transfer desired genes among species that do not interbreed. It is precise and transfers only the gene of interest into an adapted variety at a faster rate thereby reducing the time required to produce a variety. It also allows production of novel products of pharmaceutical interest in plants which could make the price of the medicinal drugs cheaper and allow farmers to share the income from such technological inventions.

GM crops are often produced through gene transfer involving distantly related organisms including viruses, bacteria, fungi, plants and animals. The may often contain segments of vector DNA, desired gene, an appropriate promoter with correct initiation and termination signals, and a reselectable marker gene such as Kananmycin. These segments of foreign DNA in GM crops should not cause too much apprehension in their use, unless it can be shown scientifically that they pose danger. In the Book of Genesis (Genesis 1: 26) it is written: "then God said, let us make man in our image, in our likeness and let them rule over the fish of the sea, and the birds of the air, over the livestock, over all the earth and over all the creatures that move along the ground" In this context, human beings were given a free hand to use all life forms and indeed the genes and gene complexes that make them for the good of humanity.

2.3 Genetically Modified Crops Debate

2.3.1 Benefits of GM Crops

GM crops have become the focus of a global war of rhetoric (Stone 2002). Supporters of GM crops hail them as essential to addressing food insecurity and malnutrition in developing countries and accuse the opponents of "crime against humanity" for delaying the regulatory approvals of life saving innovations (Paine et al. 2005). On the other hand, opponents claim that GM crops will wreck havoc in the environment, worsen poverty and human hunger and finally lead to

The use of GM crops results in high productivity or yield per unit area of land through better management and control of diseases, pests and weeds.

Cultivation of herbicide tolerant GM crops could lead to drastic reduction in the amount of chemicals/pesticides used in the environment. The use leads to significant reduction in the amount of pesticides estimated at 224,300 metric tones of active ingredient, which is equivalent to a 15% reduction in associated environmental impact of pesticide use on these crops (Monsanto 2001, James 2006).

Secondly, their use could lead to a reduction in carbon dioxide gas emission and hence minimize climate change. This could be achieved through a significant reduction in the amount of fossil fuel burnt during farm operations such as ploughing and harrowing. In addition, future expansion in the cultivation of GM crops such as maize, soybean and other non-GM crops for bio-fuels will substitute for fossil fuels and also re-cycle and sequester carbon (James 2006).

Tangible economic gain from the four most widely grown transgenic crops (maize, soybean, cotton and canola), from 1996 to 2005, was US$ 27 billion. Notably, out of 10.8 million farmers that planted GM crops in 2006, 9.3 million (90%) were small, resource-poor farmers from developing countries which confirms the significant role of GM crops in poverty alleviation in developing countries.

GM crops have many human health benefits. For example, Golden rice that was engineered (Paine et al 2005) to provide beta-carotene, the precursor of Vitamin A, as well as increased production of GM papaya (Fitsch et al 1992) have helped the world to

fight blindness which affects over 200 million people and is responsible for 2.8 million cases of blindness in children under five years of age (FAO 2000a).

Another benefit of GM crops is in the Pharmaceutical Industry. GM crops could be useful in the manufacture of recombinant vaccines and other important recombinant proteins such as insulin, hepatitis B and human growth factors (Kumar et al 2005). This may replace present source of insulin produced by multinationals using recombinant bacteria and produce large quantities of pharmaceutical products thereby making them relatively cheap and also allow farmers share profits.

2.3.2 Concerns over Genetically Modified Crops

GM crops contain antibiotic marker genes and promoter sequences derived from viruses or distantly related organisms which could lead to human health and animal problems if eaten, or confer comparative advantage to the wild plant and bacterial populations in their natural environments and this could render antibiotics currently used to manage the diseases useless (Robinson 1999).

> *Observation: Cases of resistance to commonly used drugs have been reported in several developing countries even before the era of GM crops. Secondly, recent developments in genetic engineering have allowed production of GM crops without antibiotic marker genes and other sequences (Gleave 2002). Thirdly, it has been reported that some of the antibiotic marker genes (eg Kanamycin) used in GM crops are safe. Finally many studies including that done by Crowley et al and reported in Nature confirmed that GM crops cause no harm to natural habitats.*

The second concern is that the use of food derived from GM crops may increase allergy.

> *Observation: Cause(s) of allergenic reactions are complicated and may not be directly attributable to a single cause such as GM derived foods only. Allergy reactions naturally occur, at 1-2 % in adults and 4-6 % in children, even with most commonly consumed natural proteins such as eggs, fish, soybeans and it is possible to solve this problem simply by proper labeling of GM derived foods and possible allergy reactions, if any, so that sensitive people may avoid such foods (FAO 2004, WHO 2005). This is a normal practice with drugs or non-GMO derived foods that can elicit allergy reactions.*

The third concern is that GM crops could create toxic effects and alter nutritive value of foods or elicit negative changes in chemical composition of foods.

> *Observation: Currently available transgenic crops and foods derived from them have been judged safe to eat and the methods used to test their safety have been deemed appropriate by The International Council for Science (ICSU), 2003, WHO 2005). To-date no verifiable untoward toxic or nutritionally deleterious effects resulting from consumption of foods derived from GM crops have been discovered anywhere in the world (GM Science Review Panel 2003). In addition, millions of people have consumed foods from GM crops such as maize, soybean and oil seed rape without any observed side effects (ICSU 2003)*

Fourth, environmentalists and pressure groups argue that GM crops pose a high risk to the environment from excessive pesticide use since over 99% of land cultivated with transgenic crops contains plants that are herbicide, insect and/or virus resistant transgenic crops (Anno. 1998, James 2006).

> *Observation: Use of GM crops has in fact reduced level of pollution from pesticides (James, 2006).*

Fifth, GM crops could also eliminate non-target insects and other organisms like the GM maize that killed Monarch butterflies that fed on its pollen grains. (Fitt et al. 2004).

> *Observation: The effect of GM crops on the environment is controversial because of the difficulty to gauge the associated risks. Supporters of GM crops while accepting precautionary approach to their use argue that if there are risks at all, their magnitude do not compare with the scale of current industrial pollution or escape of radioactive fallouts (Robinson 1999).*

Sixth, social-economic and ethical concerns have also been voiced by opponents of GM crops who feel that these crops will marginalize small holder farmers and only benefit large scale farmers who can afford to pay for the premium biotechnology derived seeds.

> *Observation: If cost-benefit analysis of GM is favourable, even the small holder farmers will buy the seeds to plant, just like many of them have done with mobile phones. What is required is for the public to form partnership with the private sector to jointly develop the GM crops and in this way, the public sector can regulate the price and shape the direction of the GM technology. Secondly,*

although ethical and moral issues could be controversial, I strongly believe that many lives in Africa could have been saved by GM food relief particularly after ICSU (2003), GM Science Review Panel (2003), and FAO/WHO (2001) had declared food derived from the then available GM crops safe for human consumption.

2.3.3 GM crops debate dialectics

Needs Vs Interest

The sharply polarized debate between supporters and opponents of GM crops should focus on human needs for developing countries while for developed countries on interests. The basic human needs include food, shelter, and safety. In the African context where the basic needs are not yet met, the debate therefore should largely center on satisfying these basic needs. In the developed countries where basic needs are adequately met, the debate may be dominated by enhancing societal interests. Consequently, the nature of the debate in developed and developing nations should be fundamentally different and without confusion.

Need for factual debate

The debate should be scientifically guided and without exaggeration. Proponents and opponents of GM crops have exaggerated the potential benefits and risks in each case. Balanced information based on scientific facts and values of society is necessary to allow stakeholders to decide on their destiny.

Recently, a number of experts groups made useful contributions to the GM crops debate.

(i) In December 2000, after a long deliberation, the American Medical Association (Reported in KUZA, 2001) concluded that GMO derived foods are safe for human consumption.

(ii) In a Biotechnology workshop held in Ghana (in November 2000) the experts declared the safety of GM technology and emphasized that prudent use of biotechnology is a major avenue for poverty reduction and solution for food and nutritional deficiency in Africa (KUZA, 2000).

(iii) The available transgenic crops and foods derived from them have been judged safe to consume and the methods used to test their safety have been deemed appropriate by the International Council for Science (ICSU, 2003;).

(iv) The GM Science Review Panel (2003) pointed out that to-date, no verifiable toxic or nutritionally deleterious effects resulting from consumption of foods derived from GM crops has been reported anywhere in the world.

(v) Swedish Medical Experts recently indicated that GMO derived foods are safe and declared that GM foods have extremely low risk compared to insufficient food intake (anorectic), high intake of coffee and tea, and allergy against natural protein in the diet.

(vi) Global land areas planted with GM plants have been rapidly increasing an indication of importance of GM technology in global.

2.3.4 Future Trends

Between 1996 and 2006, the cultivation of GM crops increased by about 13% (12 million ha) each year from about 4.2 million in 1996 hectares to 102 million ha in 2006. In the same period the number of farmers cultivating GM crops rose to 10.3 million making it one of the fastest adopted crop technologies in the recent times. The reasons for this rapid adoption include high farm-gate profitability, high yields and reduction of pesticide use in the environment (KUZA 2006).

Countries in Africa including South Africa, Egypt, Kenya, Uganda, Tanzania, Ghana and others are at different stages of development with regard to the use of agricultural biotechnology tools (Table 3), such as tissue culture, marker assisted breeding and genetic engineering, to improve their agricultural production. South Africa is among developing countries (others are China, India, Brazil and Argentina) having significant cultivation of GM crops mainly GM cotton and GM maize.

Major impediments to the use of GM crops in Africa are many. These include:

i. Lack of a regulatory authority that would undertake stringent measures and assure the public that there is continuous assessment and approval of GM and GM-product.

ii. Other constraints that African countries hoping to venture into growing of GM crops will have to contend with include the lack of national research technical capacity to produce desired GM crops, intellectual property rights policies and robust agricultural input markets.

3.0 Way forward

Demand for food in Africa is acute and is set to increase in the next decade and thus efforts to minimize crop losses via use of agrochemicals will also be on the increase. GM crops viewed as capable of substantially increasing food and agricultural production while reducing the use of agrochemicals is a sure option for Africa. Without adequate food, Africa cannot expect peace. It is apparent that in this decade, any country or continent that ignores innovations in food, medicine and information, risks marginalization.

Rapid adoption and popularization of GM crops in Africa will largely depend on changed perceptions of stakeholders including policy makers, farmers and consumers regarding the risks to human health, their benefits on food security and management of sustainable environment. Scientists must come out and demystify the perceived risks, benefits and explain that careful application of GM crops is not the enemy of mankind and environment, but hunger and malnutrition certainly are.

Adoption of GM technology in Africa will also depend on capacity to utilize the technology and provision of bio-safety framework harmonized with that of the global community. For now, Africa lacks critical mass of GM technology experts, laboratories and overall infrastructure to adequately benefit from the GM technology. Although number of countries in Africa have started building capacity and establishing appropriate bio-safety requirements but a lot is still to be done.

African countries will more likely adopt GM crops particularly if they address problems of their staple food crops such as rice, maize, wheat, cassava, banana, sweet potato, common beans, sorghum and millet and as well as cash crops (cotton, coffee, tea).

However, GM crops cannot solve all the food, environmental and health problems in Africa. The problems of infrastructure, uneven food distribution, inadequate investment in agriculture and agricultural extension services, poor marketing, lack of credit to farmers and political turmoil should all be addressed both at country level and appropriate regional fora.

Concluding remarks

In this lecture I have tried to emphasize the food insecurity and malnutrition, environmental and human health challenges facing Africa in the 21st century, their causes and alternative solutions for scrutiny by stakeholders. Based on the arguments advanced, it is apparent that no single option can solve the myriad of constraints facing African farmers. However, conventional as well as new technologies including use of GM crops can reverse the negative impacts of these challenges and create a healthy environment for a vibrant population in Africa.

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