Food Security and Biotechnology in Africa

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MODULE 3: PUBLIC RESPONSE TO THE RISE OF BIOTECHNOLOGY

Unit 3: Benefits and Risks of Biotechnology (6 hrs)

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INTRODUCTION

There have been many controversies over crop biotechnology with a measure of support by the public but also some concerns. It is important therefore that scientists engaged in the new innovation in agriculture should be aware of the public perception of their work. These controversies are best understood not by seeing it as a simply two-sided opposition, but as the convergence of several long standing struggles over the trajectory of food use and food production as they relate to these technologies.

Because food consumption is both a biological necessity and rich in cultural significance, any new way of preparing or producing food is likely to have ethical and implications (Thompson and Hannah, 2008). Technology can affect safety and access to food which raises questions of fairness and equity about the entire system of producing and distributing food. Risk assessment of agricultural and food technologies is not a new concept. Each innovation in food production has come with its own set of potential risks. These have ranged from increased pesticide exposure in conventional agriculture to higher pathogen exposure in organic farming. The risks associated with GMOs are similar to those of crop hybridization, the keystone of the green revolution. Any effort aimed at creating a better crop will be followed by potential consequences. These are causes of major public concern of the science of crop biotechnology. It is feared that because of the esoteric science involved these perceived risks will be higher than in conventionally bred plants. Risk assessments of biotechnology do consider potential effects to the environment and human health.

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Ecological effects that are being debated include increased invasiveness and volunteerism (an agricultural problem where uncollected seeds from last year's crop germinate and grow within the current crop), intra and extra-specific hybridization, adverse effects on non-target organisms and resistance management. In USA, assessing the biosafety of GM foods have relied on the principle of substantial equivalence, that is, GM food is as safe as its genetic precursor, which is generally regarded as safe.

Ecological Biosafety-Addressing issues of invasiveness and volunteerism of transgenic crops

As new genes are discovered and used by the biotechnology industry, crops will have suits of new abilities and will be grown in new geographic regions. In case of some crops like alfalfa, sunflower, and rice that have some weed like character, some have argued that their contained transgenic and novel traits could allow the crop itself to become weedier and invasive (Regal, 1994). This of course will not be a problem in crops that are highly domesticated and exotic to regions where they are grown, because they do not have the traits needed to permit survival outside agriculture (Warwick et al., 1999). Intraspecific hybridization can occur when transgenic crops are grown in close proximity to non-transgenic varieties. The agricultural practice of saving seed from the previous year's harvest allows transgenic materials to be unintentionally persistent. Corn and other grain crops that are wind pollinated have the potential to pass genes to the adjacent specifics whether the crop is a GM or conventional variety. This is a problem for organic farmers who must ensure that their products are not GM but who can suffer economic losses if transgenic materials are found in their products.

Fitness enhancing genes can be dispersed within the same species with no hybridization barrier, which can lead to higher number of GM individuals than are expected by the regulatory agencies. It could also lead to transgene stacking if the transgene is allowed to accumulate leading to new and potentially unintended situations. Hybridization between closely related species can be a mode of transgene flow into wild populations (Raybould and Gray, 1993). Crop plants with weedy wild relatives are of particular concern. Interspecific hybridization depends on several conditions to allow gene flow between related species. The crops must have some naturally occurring wild relatives growing near cultivation.

FOOD SAFETY

If one believes that eating GM foods could be dangerous, one will also be inclined to believe that it is unethical to put people in a position where they might eat them especially without their knowledge. What is at stake in the positions of opponents and proponents of biotechnology is not an issue of ethics, rather, the disagreement is about whether there are hazards associated with the consumption of GMOs, and over the likelihood that any potential hazards will actually manifest themselves in the form of an injury to human health. Given that there are disagreements over the nature and extent of food safety risk, future action on the approach to the innovation should be based on the best available science –relying on consequence based justification. Thus, if GMOs have some demonstrable benefits of some sorts, like improving cost efficiency of crop production and increased wealth for farmers and seed companies, then it would be wrong albeit, ethically to prohibit GMOs without some sort of evidence that they pose a hazard to human health. According to Thompson and Hannah (2008), baseless concerns ought be allowed to stifle innovation when technological and economic stultification that is not in the public interest would result. The best available science should be able to provide the necessary conditions in the risk governance approach to conclude that the situation deserves such baseless uncertainties. Even under the best situation of strong scientific agreement on hazard, mainstream risk governance suffers from problems often associated with the utilitarian or consequentialist form of ethical reasoning (Saner, 2000). For instance, any approach to ethics rationalizing some chance of some hazardous outcome in terms of benefit to the general public will be vulnerable to criticism that stress individual rights. For example, the widely acclaimed risk of allergenicity associated with GMOs. Genes make proteins and any protein is a potential allergen. Therefore, one cannot exclude the possibility that genetic engineering of foods may introduce proteins into foods that will cause allergic reactions in some portion of the population. Since food allergies are not well understood, and since they may affect small percentages of the population, there is much uncertainty in the effort to characterize the likelihood of allergic reactions before GMOs are released for public consumption. Thus, limited hazards could be condoned for multiple technological and economic benefits to many. To those who advocate labelling of GM foods, the ethical justification is derived from the ethical logic of informed consent;

people should be free to take whatever risk they choose, but they should not be put in a position of risk without adequate notification and an opportunity to choose otherwise.

Much of the opposition to GM foods in Europe arises from the widespread consumer doubts over their safety due to the perception that GM foods are unnatural and unhealthy. Reports did not find any evidence in support of these doubts but there have also been little or no convincing refutations as well as evident benefits to the consumers from existing GM foods on grocery shelves. According to Timmer (2003), this could change if preserving the identity of non GM foods proved to be extremely costly so that substantial price discount can be offered on foods containing GM ingredients.

From the society of toxicologists, the available scientific evidence indicates that the potential adverse effects arising from biotechnology derived foods are not different from those created by conventional breeding practices for plants, animals and microbial enhancement. Continuing, they claimed that it is the product itself rather than the process through which it is made that should be of focus in safety assessment. (Toxicological Sciences 2003). The principal responsibilities of toxicologists are to define, and characterize the potential for natural or manufactured materials to cause adverse health effects and to assess as accurately as possible the possibility and level of risk for human and animal health or for environmental damage under a defined set of conditions. Several issues have been raised concerning the potential toxicity associated with GM derived foods and food products including the inherent toxicity of the transgenes and their products and unintended (pleiotrophic or mutagenic) effects resulting from the insertion of the new genetic material into the host genome. Unintended effects of gene insertion might include an over-expression by the host of inherently toxic or pharmacologically active substances, silencing of normal host gene or alterations in hosts metabolic pathways. It is important to realize that with the exception of marker genes, the process of genetic engineering does not, in itself create new types of risks. It is important to note that most of the hazards listed above also apply to conventional crops. The following issues need addressing in view of the claim of toxicity by GM crops;

Is The Transgene toxic? Can it be transferred from the genome to the consumer?
Humans consume a minimum of 0.1 to 1 gramme of DNA each day (Doerfler, 2000). Consequently, the transgene in a genetically engineered plant is not a new type of material to our digestive systems and it is present in very minute quantities. In corn the transgenes represent about .0001% of the total DNA (Lemaux and Frey, 2002). Dietary DNA is not itself toxic, however, exogenous nucleotides have been shown to play important beneficial

role in gut function and immune system. Also, there is compelling evidence for the incorporation and expression of plant derived DNA, whether as transgene or not, into the genome of consuming organisms. Although much remains to be learned about the fate of dietary DNA, in mammalian systems, the possibility of adverse effects arising from the presence of transgenic DNA in foods either by direct toxicity or gene transfer, is minimal (FAO/WHO, 2000).

Does the product Encoded by the transgene present a risk to consumers or handlers?

The potential toxicity of the transgene product must be considered on case by case basis. Particular attention must be paid if the transgene produces a known toxin as in *Bacillus thuringiensis* (Bt endotoxin or a protein with allergenic properties). The safety of most Bt toxins is assured by their easy digestibility as well as their lack of intrinsic activity in mammalian systems (Siegel, 2001). In case of production of allergenic proteins, even though eating of non GM foods does not exclude allergenicity, issues that need addressing will include; do the products of novel genes have the ability to elicit allergic reactions in persons already sensitized to the same protein. And will transgenic techniques alter the level of expression of existing allergens in the host plant.

Unexpected and potentially undesirable pleiotrophic or mutagenic changes in the genome of the host do occur, however, these would be revealed by their effects on the development of the host, or by the extensive testing of its chemical composition compared with isogenic untransformed plants (Kuiper, et al., 2001).

Does the possible transfer of Antibiotic resistance marker genes from the ingested GM food to gut microbes present a significant human hazard?

Development of resistance to antibiotics by pathogenic bacteria is a significant human health issue. However, no contribution to antibiotic resistance in gut bacteria arising from antibiotic markers in biotechnology derived foods has been documented. It is believed, given the efficient destruction of the resistance gene in the human gut and the very low intrinsic rate of plant-microbe gene transfer, that any contribution from this source is expected to be extremely small. Genes for resistance to Kanamycin and related antibiotics already occur quite commonly in the environment, including in the flora of the human gut, which naturally contains about 1 trillion (10^{12}) Kanamycin – or Neomycin resistant bacteria (Flavel, et al., 1992).

What is the effect of the transgene and it products on non-target organisms?

In addition to the general concerns over the human health/ safety of GM foods, additional attention is needed when the gene product is pesticidal or otherwise may be toxic to non-target organisms that may consume it. The effects of each transgene product that is designed for pesticidal effects must be evaluated on a case by case basis against target and non-target organisms and under specific field growth conditions for each transgenic crop. In plants transformed with Bt genes to control lepidopterans, toxicity to non-target lepidopterans would be expected if exposure occurs by feeding on the transformed crop. Particular concerns have been expressed over the potential toxicity of the Bt toxin in corn pollen to the Monarch butterfly after initial laboratory studies showed increased mortality in larvae fed on leaves dusted with transgenic pollen**.**

Some genetically engineered crops affect crop ecosystems but the long term significance of any of these changes is unclear. Two consequences could potentially occur from reported alterations of soil ecosystems (K.K Donegan et al., 1995); decrease of plant decomposition rates and of carbon and nitrogen levels which could affect soil fertility. Similarly, declining species divert of soil microorganisms in some cases can cause lower community divert and productivity above ground (van de Heijden et al., 1999). The continued effectiveness of particular herbicide tolerant transgenic crop is also uncertain. Herbicide tolerant weeds may evolve through the transfer of herbicide tolerant traits by way of gene flow from transgenic plants or as a consequence of increased use of restricted number of herbicides.

Does genetic transformation adversely affect the nutritional quality of GM crops?

Food and Drug Administration is the US organ charged with assuring that the nutritional composition of biotechnology derived food is substantially equivalent to that of the non-modified foods. Studies are carried out to determine whether nutrients, vitamins, and minerals in the new food occur at the same level as in the conventionally bred food sources (Sidhu et al., 2000). A typical example is the case of Roundup Ready Soybeans. Here the protein, oil, fibre, ash, carbohydrate, and moisture content and the amino acid and fatty acid composition in seeds and toasted soybean meal were compared with conventional soybeans. Fatty acid compositions and protein or amino acid levels were compared and special attention was given to checking the levels of anti-nutrients typically found in soybeans such as trypsin inhibitors, lectins and isoflavones.

Ethical significance of the environmental impact of crop genetic Modification.

Environmental risk is one of the key categories of risks associated with crop genetic modification. Unlike food safety risks, which can be addressed conceptually in terms of individual choices and rights, environmental risks cannot typically be addressed through policies that allow individuals to apply their own values to whether a risk is acceptable or not. Environmental risks necessarily involve political decisions thereby drawing in environmentalists and sociologists. Complex and well developed constituencies contest a wide array of issues along environmental implications of crop genetic engineering.

Major challenges to developing countries

Poor countries need to invest public resources to improve their scientific capacity to evaluate appropriately GM crops fit for their local environments and consumer needs /attitudes. This capacity is a necessity even it is only for regulatory and safety purposes as the current scientific approach to these issues is conducted on a crop by crop, or even trait by trait basis. Currently, it is only China that appears to be pursuing an independent approach to GM technology with respect to the country's own needs. Most countries are heavily influenced in their approach by external pressures especially from European countries or the US and vocal NGOs.

Benefits; Potential and Actual of Crop Biotechnology

Where we are coming from? – Problems with the first green revolution.

The first revolution in agriculture between 1960 and 70s called green revolution was characterized by radical breeding techniques and other input like fertilizers, irrigation and pesticide. It brought about a great increase in cereal yields especially rice and wheat. A quantum jump in the productivity and production of wheat then rice transformed the image of India from a begging bowl to bread basket (Current Science, 2006). The term green revolution was coined by William Gaud in 1968 to describe the enhanced photosynthetic activity of the green pigment, chlorophyll, leading to more grain production. This involved not only effective utilization of solar energy and carbon dioxide from the atmosphere, but also water and several nutrients especially nitrogen, phosphorus and potassium from the soil. Later, Swaminathan of Indian Agricultural Sciences of Indian Science Congress drew attention of the adverse consequences of excessive use of chemical fertilizers, pesticides and irrigation without adequate drainage on soil structure and health. He cautioned over exploitative agriculture keeping in view only the short term gains.

Lessons drawn from the green revolution are that steps taken towards productivity enhancement should concurrently address the conservation and improvement of soil, water, biodiversity, atmosphere, renewable energy sources, etc. The following were some of the shortcoming of the green revolution; the high yield varieties were also input intensive, especially in the use of pesticides and fertilizers. The crops did better in good soils with high degree of water control raising the sustainability questions. Secondly, the green revolution was much about rice and wheat. There were few gains for root crops (cassava, potatoes, yams) traditional legumes, cowpeas, vegetables and fruits including other grain staples suitable for semi-arid regions such as millet and sorghum. Moreover, productivity gains using traditional breeding techniques have apparently been exhausted for rice and wheat. In addition, because of the strong link between agricultural productivity and economy, the overall economic growth is slowing down.

The role of biotechnology in food systems

In the 1990s, the advance in molecular biotechnology made it viable to market genetically modified crop that offered highly attractive commercial qualities. This development was later presented as a solution to the lack of genetic diversity for breeding new cultivars; though initially an innovation for commercialized/industrial agriculture. Thus, the new crops that were developed were for industrial-scale agriculture directed at yield and efficiency (Haperen *et al.,* 2012). These crops were promoted on the platforms of certain beneficial attributes including but not limited to the following:

1. **Reduced environmental impact of pesticide use**

As regulations are considered, the potential risks of GMOs should be evaluated and compared to possible environmental benefits. There are at least three major ways in which genetically modified crops can benefit the environment: they can reduce the need for environmentally damaging practices like reducing the land area needed for agriculture, and produce energy in a carbon dioxide neutral way. Four of the agricultural practices that have negative environmental impacts are pesticides, fertilizers, tillage and irrigation (Hansson and Joelsson, 2013). The current extensive use of pesticides has negative effects on non-target organisms and cause serious health problems among farm workers. Pesticide residues in food and feed can have negative consequences for consumers. The use of pest resistant crop can potentially improve the situation by reducing the use of pesticides as has been achieved through the Bt technology.

Most of the major agricultural plants such as rice, wheat and corn take nitrogen from the soil. Nitrogen fertilizers increase the yield of these crops by increasing the availability of nitrogen. However, fertilizers have negative environmental effects such as eutrophication and contribution to the anthropogenic green-house effects. Plants of the legume family obtain nitrogen from the atmosphere through a complex symbiosis with rhizobia. If this could be transferred to cereals and other non-legume crops, then the use of fertilizers could be reduced with their environmental impacts.

Tillage, though an old agricultural practice, has severe environmental effects (Yao, et al., 2010). It promotes soil erosion, and to the run off surface waters containing pesticides, nutrients and sediments. The loss of nutrients increases the need for fertilizers and cause eutrophication of lakes and coastal areas. Furthermore, modern tillage makes use of fossil fuels, thereby contributing to green-house gas emission. Consequently, the use of varieties that need less tillage would be environmentally beneficial. Also, since tilling is largely carried out to control weeds, the need for tilling is reduced if weds can be controlled by other means like HR crops where glyphosate resistant crops developed via genetic engineering is used.

Due to the shortage of freshwater and to the environmental consequences of many irrigation projects, irrigation has a large part in the environmental problems that agriculture is accused of. Therefore the environmental benefits of crops that require less irrigation would be substantial. The most advanced drought tolerant crop under development is a variety of maize expectedly commercialized in USA in 2012; the water efficient maize programme for Africa (WEMA).

Reducing the Land Area under Cultivation

One of the primary reasons for crop biotechnology is to obtain higher yields at lower costs. The relationship between yields and environmental impact is a complex one. On one hand, higher yields are often associated with intensive land use that has negative environmental effects. On the other hand, higher yields diminish the total area that has to be cultivated in order to produce a given amount of food. If yields are increased, then less land is needed for agriculture and in those way natural habitats could be preserved (Hansson and Joelsson, 2013). According to Beddington (2010), the potential environmental benefit of increased yields may be particularly important in developing countries.

Increased resistance to drought, salinity and high and low environmental temperatures can contribute significantly to increased yields. If sustainable increases in yield and efficiency can be obtained by improved utilization of applied inputs, without harming the environment, then such yield increasing technologies will decrease the need for cropland and offer protection to yet uncultivated or the return of cultivated lands to uncultivated.

Improving human health with Genetically Modified Crops

Concerns over negative health effects of genetically modified crops have been a major factor in appropriation and use of the technology. There are health concerns that have to be taken very seriously. However, there are ways the technology can be **used** to improve health. There are three pathways through which this can be accomplished. Biotechnology can reduce exposure to pesticides, improve the nutritional value of food and integrate pharmaceutical effects into foodstuffs.

Decreased Exposure to Pesticides

Man can be exposed to pesticides either as an occupational exposure where farm workers, farmers and agriculturists are affected or through ingestion affecting the general population. Significant reduction in these **exposures** can be achieved through reduction in pesticide use achievable via the use of genetically modified crops that require less pesticide. The largest positive health effects of reduced pesticide use will be developing countries where the applications are manual, approach that predisposes to exposure. This is achievable through the use of Bt crops. To the consumers, it is also an advantage that Bt maize tends to have lower levels of mycotoxins, toxic and carcinogenic chemicals produced by fungi colonizing crops (Wu, 2006).

Improving the Nutritional Value of Food.

The importance of nutrition in health and disease is not in doubt. The major tool for food related public health is a more well-informed choice of foodstuffs. However, changes in the nutritional composition of traditional foodstuffs can also be important contributor to public health. Such changes often called biofortification can be achieved via conventional breeding of genetic modification (Qaim, 2009). The balance of amino acids in plants is always deficient. Cereals (maize, rice, wheat etc) tend to be low in lysine and legumes (peas, soybeans) tend to low in methionine and cysteine. Maize, canola and soybean with improved amino acids have been developed (Chassy et al., 2004). This is particularly useful in the developing countries where protein malnutrition is common. Oil seeds have also been modified to improve their quality. The most advanced of the projects to improve the micronutrient content of food aims at enriching rice with Vitamin A to prevent deficiency diseases. According World Health Organization (WHO) vitamin A deficiency affects between 250,000 and 500,000 children yearly (Hirschi, 2009), and is responsible for increased susceptibility to infectious diseases, blindness and death. Minerals as iron, calcium, selenium, iodine and vitamins are the important micronutrients whose improvements in crops are sought by biotechnology.

Integration of Pharmaceutical Effects in Food.

A number of edible plants including potatoes, tomatoes, maize, and soybeans have been genetically modified to produce vaccines. On-going research aims at potato based vaccine for hepatitis B, and an edible rice based vaccine targeted at allergic diseases such as asthma and seasonal allergies.

Improvement in fruit and vegetable shelf life and organoleptic quality

Genetic modification has led to improved shelf-life and organoleptic quality in certain crops. The 'Flavr Savr' tomato is the first genetically engineered crop and whole food approved by FDA. It was produced by Calgene and bio-engineered to ripen on the vine, and have a longer shelf-life by having delayed ripening, softening, and rotting process. Delayed ripening of fruits and vegetables can lead to superior flavour, colour, texture, longer shelf-life and better shipping and handling properties. Recently, sweet tasting, firmer, seedless peppers and tomatoes have been produced (Uzogara, 2000).

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