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BIOTECHNOLOGY:
The Silver Bullet for Agricultural Productivity

BY

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Professor of Agricultural Biotechnology

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The Vice Chancellor, Deputy Vice Chancellor (Administration) , Deputy Vice Chancellor (Academic), Registrar, Provosts, Deans, Members of Senate, Heads of Departments, Distinguished Guests, Esteemed Colleagues, Dear Students, Ladies and Gentlemen

Introduction

With sincere reverence and heartfelt gratitude to the Almighty for this opportunity, honour and privilege He has given me today, may I present to you the 228th Professorial Inaugural Lecture. The first inaugural lecture from the Department of Animal Science was in 1978 given by Prof. A.A. Adegbola (which was the third in the University), the seventh was given by Prof. E.B. Sonaiya in 1998; today after 12 years with support and encouragement from the current Dean of Faculty of Agriculture Prof. A. Olayinka, colleagues and students from my Department and particularly my better half who brought me to Nigeria and to Great Ife, I hereby present the eighth inaugural lecture from the Department of Animal Sciences, Faculty of Agriculture, the first to be given by a female professor from the Faculty of Agriculture.

An inaugural lecture is a platform for a professor to address his or her audience in his/her area of specialization and present his/her contribution to scholarship. For the next 59 minutes permit me to elucidate that biotechnology can be the silver bullet Nigeria needs to propel its agriculture to greater heights. Though biotechnology does not present the panacea to a plethora of problems and challenges of agricultural productivity especially in sub-Saharan Africa, let me present some facts and figures I obtained from literature while citing some of my personal research outputs I have accumulated over the last three decades, many of them with my colleagues and students from (1) the Philippines where I originate and where I learned the rudiments of aquaculture and genetics, (2) France, Israel, Germany and Belgium where I did my doctoral and postdoctoral researches in fish and animal biotechnology, (3) IITA (International Institute of Tropical Agriculture) Ibadan where I was opportuned to apply my animal biotech research experience to plant biotechnology, and (4) OAU since joining in 2000. I will break down my odyssey in the field of agricultural biotechnology into two: first, my pre-OAU journey (1970-1999) and the second, at OAU (2000 to date).

Biotechnology is always believed to be the technology suited for developed economies because of its requirements for skilled manpower, sophisticated infrastructure and high investment of financial resources in research; nonetheless it can provide tools applicable in the various sectors of agriculture in developing countries. The applications of these tools in crop production and protection, animal production and health, fisheries/aquaculture, forestry, agro-processing, genetic resources improvement and biodiversity conservation, to address the challenges of various biotic and non-biotic stresses now worsened by climate change can have a positive impact on food security and farmer incomes in sub-Saharan Africa (SSA) (Evenson, 1999). The current trend for biotech development as it applies to agriculture, *e.g.* in crops, livestock, grasslands, forests, woodlands, inland, coastal and marine waters and relates to climate change adaptation in various agro-ecosystems is reviewed with facts and figures across the continent. In addition to nature-based constraints such as prevalence of drought, diverse agro-ecologies, poor soil fertility and unique pests and diseases; Sub-Saharan African agriculture development has to overcome persistent human and institutional capacity building challenges. Moreover, issues affecting human and environmental health (biosafety), indigenous and new knowledge (intellectual property rights), generation and transfer or diffusion of novel and powerful scientific tools to tackle production constraints in food and cash crops which are exacerbated by global warming is discussed. Exploiting the new and relevant innovations and technologies (*e.g.*, biofuels, genomics, GMOs) in SSA must therefore promote climate-smart agriculture, but research capabilities, appropriate national and international programmes and policies must first be strengthened.

"The cup half empty", *Nature Genetics*, June 2009

"Agricultural genetics can help manage shortfalls in the world's food supply", says one of the most prestigious science journal, *Nature Genetics* in its June 2009 editorial; by 2050 supply needs to double since one-sixth of the world's population does not have enough food to sustain life. It further reiterates that agricultural genetics is one of the easier parts of the solution, since genetics' research is easier in agriculture than medicine.

Where does genetics research fit in? *Nature Genetics* stated that the continuation of the Green Revolution will not need creating new knowledge since the imminent changes in climate and land use require dealing with drought and saline soils. It further declared those rational breeding schemes, molecular marking, transgenic technology and recognition of the genetic resources of locally adapted crop strains could all help give farmers access to well-tested and robust crop lines. Furthermore, the new discoveries by the crop genome revolution can help guide adaptive co-evolution *i.e.,* crops selected and bred by modern biotechnology tools as mentioned above for changing climate and increasing population. An example is the newly discovered rice gene by the Chinese scientists employing molecular genetics tools that could simultaneously control the crop's yield, plant height and number of days to flowering. They found that the three traits appear in individual rice breeds, strong individually or weak simultaneously.

Some basics of molecular genetics

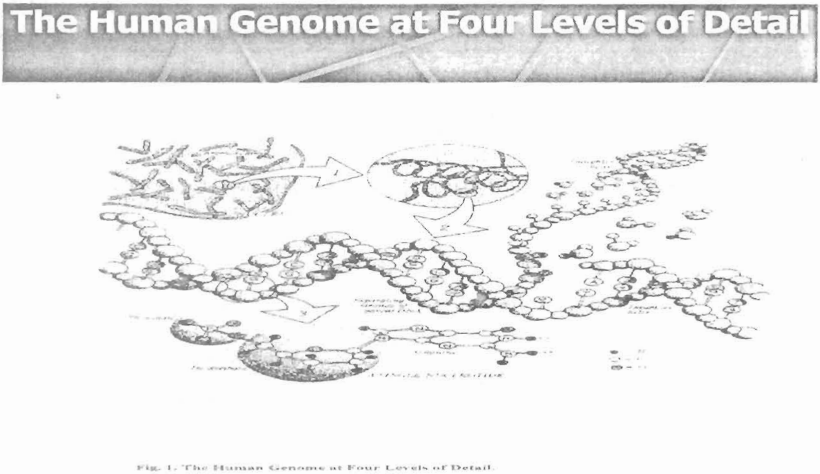


Fig. 1: The genome at four levels of detail: cellular, chromosomal, molecular and nucleotide.

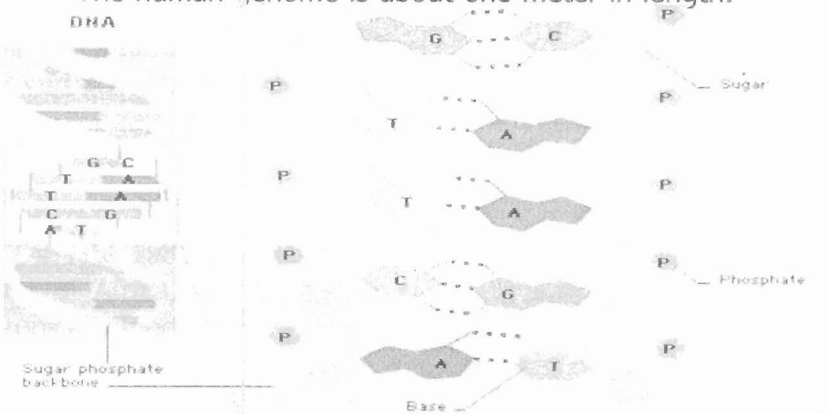
1. At cellular level, a typical eukaryotic cell is normally composed of the cytoplasm and the nucleus that contains the chromosomes that are the structures responsible for the inheritance of traits of an individual to its succeeding generations.

2. At the chromosomal level, the chromosome is a nucleoprotein complex composed of histone proteins and nucleic acid (deoxyribose nucleic acids or DNA, Fig. 2) folded in a solenoid type of structure

3. At the molecular level the DNA is a double helix like a winding ladder with linked sugar-phosphates in the periphery and the

nitrogen bases at the centre forming the rungs of the ladder.

4. At the nucleotide level, the DNA is arranged into alternate pairs of adenine—thymine or cytosine-guanine base combinations whose total sequence comprise the genome or complete genetic make up of human 23 pairs of chromosomes of approximately 3,000,000,000 base pairs. The human genome is about one meter in length.



Source: *Microsoft ® Encarta ® Premium Suite 2004. © 1993-2003 Microsoft Corporation.*

Fig. 2. The DNA structure.

The DNA molecule resembles a ladder formed of sugars and phosphates, and four nucleotide bases: adenine (A), thymine (T), cytosine (C), and guanine (G). The coding information in the DNA is given by the order of the nucleotide bases, and each gene possesses a unique sequence of base pairs. Scientists use these base sequences to locate the position of genes on chromosomes and to

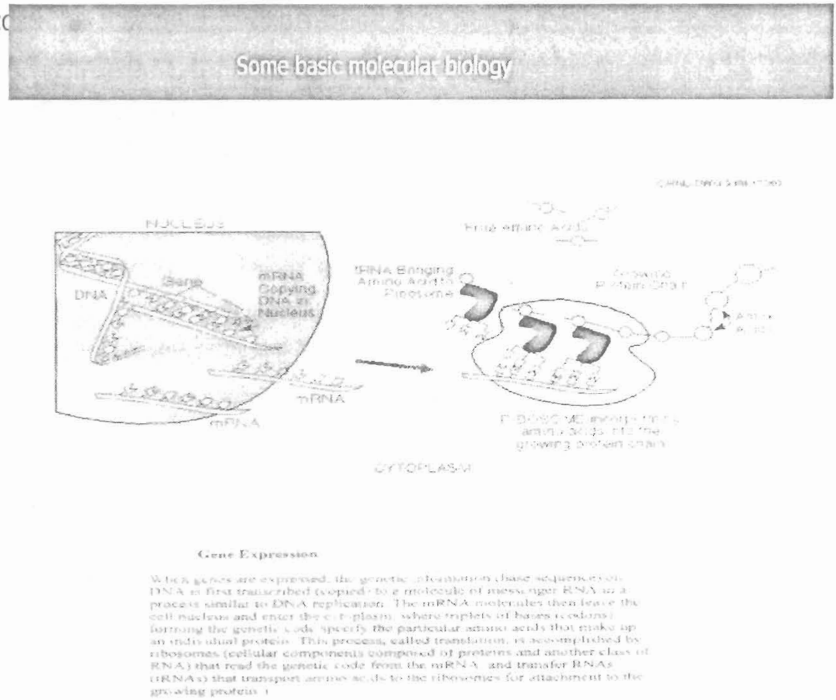


Fig. 3. The DNA functions: replication, transcription and translation

Biotechnology makes use of the cellular molecular processes of the DNA: DNA synthesis (or replication), transcription where another molecule, mRNA (messenger ribonucleic acid) copies the DNA sequence in the nucleus, and translation where the mRNA translates the genetic code to a series of peptides of polypeptides with the help of another molecule, transfer RNA (Figure 3).

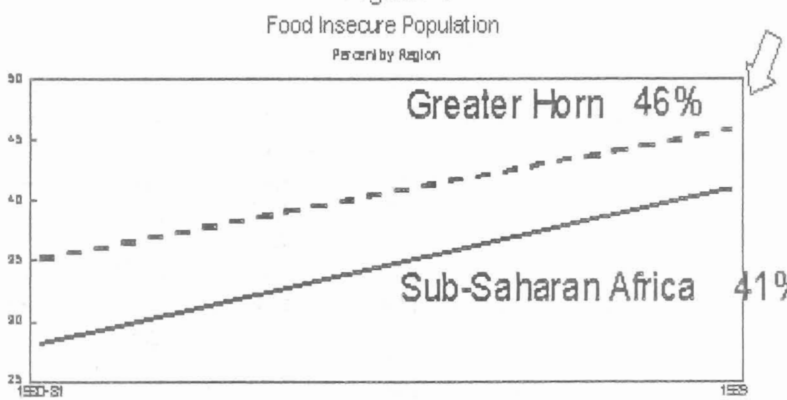
Using these principles, the human genome has been sequenced in 2003 that help elucidate the genetic mechanisms of many human diseases with the development of modern biotechnology techniques, for example the extraction of restriction enzymes in bacteria that can recognize the particular areas in the genome at specific sequence sites thus enabling the cutting of the DNA into fragments, allowing to make libraries of the 3 billion bases and thus, deciphering the basis (genes controlling) of human diseases.

Relevance of biotechnology to African agriculture

"*To feed 10.8 billion people by 2050 will require us to convert 15 million square miles of virgin forest, wilderness and marginal land into agrochemical-dependent arable land. GM crops hold the most important key to solve future problems in feeding an extra 5 billion mouths over the next 50 years.*" Michael Wilson, Scottish Crop Research Institute (SCRI), 1997

In the late 1980s, an estimated 71 million people in the Greater Horn of Africa, or 46 percent of the region's population, were chronically food insecure (Figure 4). This percentage is higher than that for sub-Saharan Africa as a whole and has continued to increase in the past five years. Whereas in SSA, there is a dramatic decrease in food insecurity except Liberia and Sierra Leone which were ravaged by ethnic wars and political instability (Table 1.)

Figure 4



In the late 1980s, an estimated 71 million people in the Greater Horn of Africa, or 46% of the region's population, was chronically food insecure. This percentage is higher than that for sub-Saharan Africa as a whole and has continued to increase because of drought, floods, civil strife, and other natural and socio-economic hazards (Source: [1]FAO. 1982. Technical Report FPA/INT/513).

Table 1. Comparison of undernourishment in Western African countries in 1990-1992 and 2000-2002 (extracted from FAO, 2005)

Table 1. Prevalence of undernourishment in the world (extracts from FAO,2005)

	Total Population (Millions)		No. of Undernourished (Millions)		Proportion of undernourished in total Population	
	1990-1992	2000-002	1990-1992	2000–2002	1990-92	2000-02
WEST AFRICA	175.1	230.3	37.2	36.4	21	16
Benin	4.8	6.4	1.0	0.9	20	15
Burkina Faso	9.2	12.3	1.9	2.3	21	19
Côte d'Ivoire	12.9	16.1	2.3	2.2	18	14
Gambia	1.0	1.4	0.2	0.4	22	27
Ghana	15.7	20.0	5.8	2.5	37	13
Guinea	6.4	8.2	2.5	2.1	39	26
Liberia	2.1	3.1	0.7	1.4	34	46
Mali	9.3	12.3	2.7	3.6	29	29
Mauritania	2.1	2.7	0.3	0.3	15	10
Niger	7.9	11.1	3.2	3.8	41	34
Nigeria	**88.7**	**117.8**	**11.8**	**11.0**	**13**	9
Senegal	7.5	9.6	1.8	2.3	23	24
Sierra Leone	4.1	4.6	1.9	2.3	46	50
Togo	3.5	4.7	1.2	1.2	33	26

Whilst the Green Revolution provided substantial gains for many people in Asia, much of sub-Saharan Africa (SSA) shows no such yield increases (Ejeta, 2010). Almost all of the increase in production can be attributed to increased acreage and reduced fallows. With a growing malnourished population, widespread poverty and major health issues, all agricultural practices that sustainably increase yield, improve health and nutrition, or help to alleviate poverty need to be considered. Set against a backdrop of minimal mechanisation, limited irrigation and low use of inputs such as fertilisers and pesticides, biotechnology could play a significant role (Wambugu, 1999). In particular, genetic engineering could be used to target major agricultural problems affecting African staple crops, such as insect pests of cowpea; nematode infestations of yam and plantain; viral diseases in cassava; parasitic plants invading a variety of crops; drought susceptibility in cowpea; cyanide production in cassava; or poor nutritional properties of yam and cassava. In addition, biotechnology innovation offers new opportunities to explore avenues of progress in areas of major concern, such as health, through development of edible vaccines to protect against HIV, malaria, pneumonia and many gastro-intestinal infections (Keese *et al.*, 2002).

Agriculture has the greatest potentials for bringing the benefits of the biotechnology revolution to the rural poor in SSA. Paarlberg (2008) attributes poverty and hunger in Africa to low land and labour productivity; for farmers in Africa today, productivity is low and poverty high because far too little science has been brought to farming. Currently, only 4 percent of Africa's farmland is irrigated, less than 30 percent is planted to improved seeds, and average fertilizer in use is only 9 kg per hectare, compared to 117 kg per hectare in the industrial world. To enhance land and labour productivity, he posits that African farmers must utilize improved technologies such as improved draft animals, fertilizers and insect and disease resistant crop varieties.

However, Nigeria is leading in number of publications in agriculture (Table 2):

Table 2. The most prolific African nations during the five-year period 2004-2008 in the 21 main fields used in Thomson Reuters Essential *Science Indicators* database. Among the top 5:

Most Prolific African Nations in 21 Main Fields, 2004-08

Top five nations ranked by number of papers / percent of papers in field

FIELD	1	2	3	4	5
Agricultural Sciences	**Nigeria 952/0.95**	South Africa 692/0.69	Egypt 461/ 0.46	Kenya 380 / 0.38	Tunisia 247 / 0.25
Biology & Biochemistry	South Africa 1,242/0.46	**Nigeria 1,004/0.37**	Egypt521/ 0.19	Tunisia505/ 0.19	Morocco200/ 0.07
Chemistry	Egypt 3,634/ 0.62	South Africa 2,059 / 0.35	Algeria 1,065 / 0.18	Tunisia 980 / 0.17	Morocco 866 / 0.15
Clinical Medicine	South Africa 4,183 / 0.41	Egypt 2,584 / 0.26	Tunisia1,587/ 0.16	**Nigeria 1,392 / 0.14**	Morocco 867 / 0.09
Computer Science	South Africa 359 / 0.24	Egypt 240 / 0.16	Algeria 170 / 0.11	Tunisia 163 / 0.11	Morocco 74 / 0.05
Economics & Business	South Africa 507 / 0.69	Kenya 54 / 0.07	Ethiopia 42 / 0.06	**Nigeria 39 / 0.05**	Tunisia 29 / 0.04
Engineering	Egypt 2,311 / 0.58	South Africa 1,385 / 0.35	Algeria 800 / 0.20	Tunisia 752 / 0.19	Morocco 459 / 0.12
Environment / Ecology	South Africal, 707 / 1.29	Kenya 420 / 0.32	Egypt367 / 0.28	**Nigeria 351 / 0.27**	Tanzania 206 / 0.16
Geosciences	South Africa 1,534 / 1.13	Egypt 434 / 0.32	Morocco 294 / 0.22	Algeria 148 / 0.11	Tunisia 141 / 0.10
Immunology	South Africa 518 / 0.86	Kenya 269 / 0.45	Uganda 207 / 0.34	Tanzania 110 / 0.18	Egypt 89 / 0.15
Materials Science	Egyptl, 421/0.61	Tunisia 575/0.23	Algeria 572/0.25	South Africa 524 / 0.23	Morocco 294 / 0.13

Mathematics	South Africa 652 / 0.52	Morocco 444 / 0.35	Tunisia 444 / 0.35	Egypt 368 / 0.29	Algeria 297 / 0.24
Microbiology	South Africa 534 / 0.66	Egypt 243 / 0.30	Tunisia 213 / 0.26	Kenya147 / 0.18	Cameroon 76 / 0.09
Molecular Biology & Genetics	South Africa 276 / 0.20	Egypt 139 / 0.10	Tunisia 113 / 0.08	Kenya 58 / 0.04	Morocco 45 / 0.03
Neuroscience & Behaviour	South Africa 310 / 0.21	Egypt 75 / 0.05	Tunisia 58 / 0.04	Morocco 45 / 0.03	**Nigeria 37 / 0.03**
Pharmacology & Toxicology	Egypt 600 / 0.66	South Africa 375 / 0.41	**Nigeria 235 / 0.26**	Morocco 101 / 0.11	Tunisia 90 / 0.10
Physics	Egypt 1,880 / 0.40	South Africa 1,194 / 0.26	Algeria 933 / 0.20	Morocco 646 / 0.14	Tunisia 601 / 0.13
Plant & Animal Science	South Africa 4,179 / 1.55	Egypt 798 / 0.30	Kenya 784 / 0.29	**Nigeria 602 / 0.22**	Tunisia 527 / 0.19
Psychiatry/ Psychology	South Africa 667 / 0.56	**Nigeria 102 / 0.09**	Egypt 43 / 0.04	Uganda 38 / 0.03	Kenya 30 / 0.03
Social Sciences, General	South Africa 2,107 / 1.06	**Nigeria 331 / 0.17**	Kenya 222 / 0.11	Tanzania 179 / 0.09	Ghana 140 / 0.07
Space Science	South Africa 556 / 0.93	Egypt 86 / 0.14	Namibia 51 / 0.09	Morocco 31 / 0.05	Algeria 24 / 0.04

This brings into sharp focus the role that advanced agricultural technologies including modern biotechnology could play in advancing agriculture for socio-economic development in Africa.

What is Biotechnology?

Biotechnology is an old technology, e.g. wine making by Egyptians since 4000 BC, as well as our fufu (cassava), ogi (maize) and iru (locust bean) fermentation. In general terms, it is the application of scientific and engineering principles to the processing of materials using biological agents to provide goods and services.

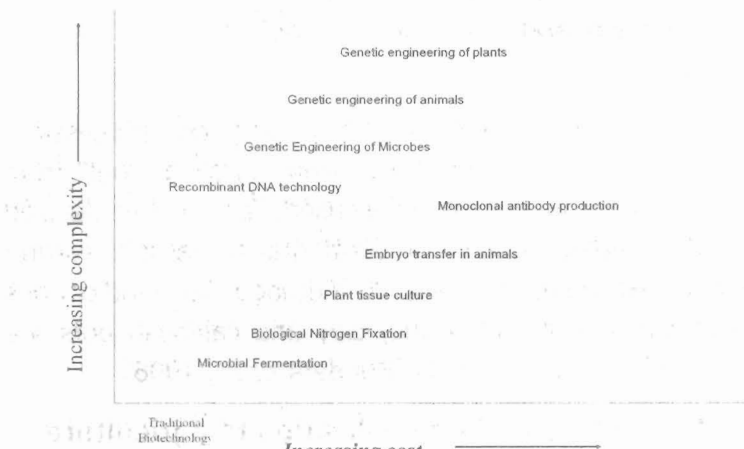
Or, it is a technique that uses living organisms or substances from organisms to make or modify a product

Or, the commercialization of the products of genetic engineering based on the use of new techniques of recombinant DNA technology, monoclonal antibody techniques, cell and tissue culture.

Biotechnology has been defined as the application of indigenous and/or scientific knowledge to the management of whole (or part of) microorganisms, or of cells and tissues of higher organisms, so that these supply goods and services of use to human beings. It is a continuum of technologies ranging from the simple, long established practices such as brewing and baking and the breeding of plants and animals widely used by the ordinary people, to sophisticated molecular techniques that allow the direct manipulation of genetic materials (particularly the DNA, deoxyribonucleic acid) within and between organisms. (Figure 5) Although there are many applications of biotechnology in crop and livestock improvement (FAO, 2004; Omitogun, 2007) that do not include gene transfer, it is the ability to transfer genes among different species that attracted the most controversy.

Agriculture has the greatest potentials for bringing the benefits of the biotechnology revolution to the rural poor in SSA. The recent 2000 and 2005 international biotechnology conferences in Nigeria, Kenya, Ghana and Tanzania have shown the great potentials of biotechnology to influence and benefit plant and animal agriculture, forestry and fisheries in SSA (FAO, 1994). To quote, James Schroeder, former US Deputy Undersecretary for Farm and Foreign Agricultural Services at the US Department of Agriculture (pls. see news clipping, **'*BIOTECH*: Potential tool to solve Africa's food problem'** from Guardian, November 19, 2000), *"Biotechnology offers one of the most promising tools for meeting future demand for an abundant, affordable, nutritious and safe food global supply.*

Until now biotechnology breakthroughs in agriculture have primarily benefited farmers and consumers in developed countries but now it is time to focus on research breakthroughs that benefit African farmers and consumers". There is host of traditional African crops that stand to benefit from biotechnology and genetic improvement. While some people will always focus on the risk of new technologies", he cautioned that there are also risks in not taking advantage of the benefits that new technologies may offer. He said that the need for research has never been greater now that there are more than 6 billion people in the world to feed. "*While sub-Saharan Africa (SSA) is projected to the account only for 25% of the world's population in 2010*", he further added, "*the region is expected to account for nearly 80% of the nutrition gap (domestic supply and minimum nutrition requirement)*".



Gradient of biotechnologies starting from traditional biotechnologies to modern biotechnologies (Modified after Persley, 1990)

Fig. 5. Examples of traditional methods and uses of biotechnology

In Africa, several agricultural traditional practices reveal biotechnology at work. Shifting cultivation, bush fallowing, composting, crop friendly trees interplanted with yams are all natural practices used by farmers to protect the soil and maintain its fertility. Farmers that practice intensive, intercropping of maize, millet, sorghum, beans, sweet potato, yam, banana, cassava, sugarcane to keep pests infestation low are also using biotechnology. Ash and neem extracts are used to control small worms and bugs and to deter attack by black soldier ants and termites on banana and yam. Farmers practice genetic conservation and diversity by ensuring that there are sufficient seeds for planting and by selecting the best seeds from the last season. For example for maize, a healthy cob with no empty spaces is chosen, and for cowpea, healthy seeds are selected according to size, colour and taste. Farmers also borrow and exchange seeds to maintain genetic diversity. For animals, farmers usually buy or borrow diverse breeds to cross with their own stock. Their basic criteria for selection are size, colour and good stature in chickens, for example, good egg production and resistance to poultry diseases are of greatest importance.

African women have been traditionally practicing food processing. Natural fermentation to prepare "fufu" from cassava, "ogi" from maize and palm wine from palm is widely used. Farmers had devised shredding and pounding equipment, fermentation vessels, stirring and equipment, packaging or wrapping methods. Such indigenous tools like wooden mortal and pestle, clay and calabash pots are gradually being displaced by plastic (Bunders *et al.*, 1996).

Modern biotechnology and its application to agriculture

Modern methods of biotechnology include tissue culture, genetic manipulation, marker assisted selection (MAS), disease diagnostics, etc. The techniques have been useful in different fields and application such as:

Food processing: Techniques as fermentation, enzyme technology and nutraceuticals

Plant nutrition and protection: Biofertilizers, biocontrol agents and diagnostics (immunoassays and DNA probes), monoclonal antibody technology.

Animal nutrition and health: Feed (enzyme technology), digestion, metabolism (genetic modification, drug and vaccine development and diagnostics (immunoassay and DNA probes)

Germplasm improvement and conservation: selection and breeding (tissue culture genetic markers for MAS, germplasm conservation issue culture, isozyme analysis, DNA fingerprinting. Biotechnology offers new methods of assessing genetic diversity and the relationships between different populations or samples. DNA fingerprinting (Thottappilly *et al.*, 2000) is now widely used because it is more sensitive in genotyping a large number of samples at a time than the biochemical analysis by isozymes. Nigeria at the International Institute of Tropical Agriculture (IITA) and the National Centre of Genetic Resources and Biotechnology (NACGRAB) and some other sub Saharan countries have mastered plant tissue culture, although mainly in the laboratory rather than on a regular commercial scale. In addition, biofertilisers and a range of biological control agents, notably *Bacillus thuringiensis* (Bt) are now being produced in some developing African countries, *i.e.,* South Africa, Kenya, and Zimbabwe. In as much as the most of the world's genetic diversity is found in SSA, genetic conservation should therefore be accorded the highest priority, improving research and development capabilities in all these fields in Nigeria should neither be neither very complex nor very expensive. Such fields as the production of high quality enzymes, disease diagnostics and use of genetic markers are technically more complicated. The application as opposed to the production of enzymes, diagnostics and DNA markers is relatively easy. For the time being, for Nigeria and most developing countries, the best option is to obtain these technologies through close collaboration with advanced laboratories that have the necessary expertise and equipment (Sonaiya and Omitogun, 2000).

The genetic resources are the basic building blocks of biotechnology. The Food and Agricultural Organization (FAO, 1996) declared the whole of Africa as the centre of biodiversity for crops such as pearl millet, finger millet, tef, sorghum, Abyssinia oats, *Brassica juncea,* pigeon pea, pea, Niger seed, cowpea, sesame, faba bean, ensette, coffee (Arabica), cotton, kenaf, castor oil and safflower. West Africa is identified as the centre of biodiversity for crops such as fonio, Africa rice, pearl millet, sorghum, yam, cowpea, bambara groundnut, bottle gourd, melon, kola nut, oil palm and date palm. Banana and plantain production in Nigeria contributes 5% of the total global production. These two crops are some of the important crops contributing to food security in West, East and Central Africa.

Sub-Saharan Africa is an important source of animal genetic resources with a wealth of domesticated animal diversity; animal husbandry has been practiced in Africa for over 5000 years. Within the continent, the composition of early livestock was greatly influenced by the constant movement of early herders such as the immigrations of the nomadic people across the North Africa littoral zones. Major changes in climate and rainfall or vegetation had generally caused dramatic changes in the composition of livestock not to mention the traditional management and production systems practiced by the herders. The share of Africa in the world's population and number of breeds is: for cattle, 12% and 15% respectively; goat, 22 and 10%; sheep, 11 and 8%; pig, 2 and 4%; ass (donkey), 20 and 8%; horse, 8 and 8%; dromedary, 17 and 24%; chicken, 6 and 9%; duck, 1 and 13%; turkey, 2 and 19% and domesticated goose, 2 and 8%. Other domesticated animals, which are not yet documented, include rabbits, grass cutters and mouse deer. Out of these breeds or species that are endangered are: for cattle, 9; goat, 1; sheep, 3; horse, 1; dromedary; 1; chicken, 1; turkey, 2; Muscovy duck, 1; domesticated goose; 2; guinea fowl, 4 and ostrich, 2 (Figure 6).

Genetic modification (or engineering): transgenics and nutraceuticals

Genetic engineering holds the promise of a brave new world in which foods can be tailored into "nutraceuticals" that provide not only a better overall nutritional profile, but also address specific medical conditions in both preventive and therapeutic capacities. In Japan several food companies are in nutraceutical research in modifying dietary fibre in wheat and corn, oligosaccharides, sugar alcohol, polyunsaturated fatty acid, peptide proteins in milk and soybean, glucosides and isophenol in tea. Witness the first commercial low-fat milk with added protein and calcium; and the low-calorie sweetener, erythritol made from glucose by *Aureobasidium* yeast which has less than one-tenth the calorie value of glucose and fructose; has no bitter aftertaste and can be used in cooking since it is stable at high temperatures. It is already being manufactured, sold and included in various candies and chocolates in Japan. A number of nutraceutical researchers in Japan are focusing on the staples rice and soybean. Using genetic engineering and selective breeding, the methionine and lysine levels of soybean and rive have been increased to make them more nutritious for people and livestock consumption. Similar research should be done in Nigeria to produce cassava with higher protein content and less toxic cyanogenic glycosides, linamarin and lautostralins (Adewusi, 2009).

Table 2. Africa has the germplasm, SSA is the center of bio- diversity for tef, sorghum millet, Abyssinian oats, pigeon pea, sesame, coffee (arabica), castor oil, cola nut, cowpea, yam, coco yam, plantain, oil palm *etc.*, and important source of animal genetic resources:

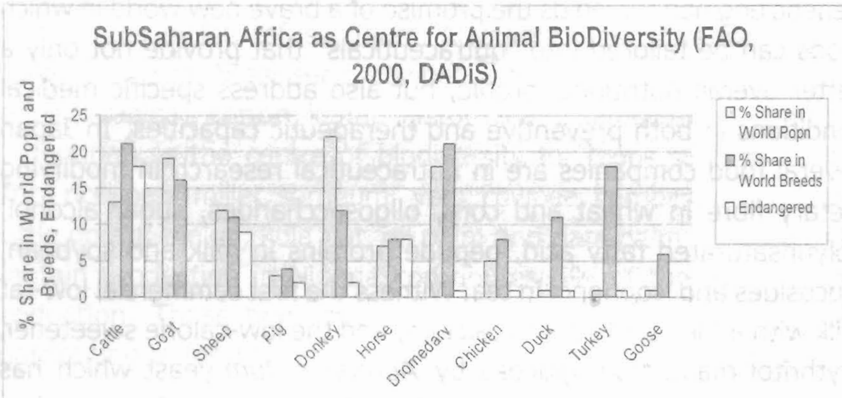


Fig . 6. Africa is the centre of biodiversity for many crop and livestock species, however many of its animal genetic resources are endangered. (Data provided by FAO, DADiS, 2000.).

Biotechnologies, as mentioned above, are used to credit new strains of crop plants and animal diagnostic products, animal vaccines, biological pesticides and herbicides, other biological control agents and for modification of domestic animals used for production of drugs or other pharmaceutical products. Modern biotechnologies have speeded plant and animal breeding. More than 40 transgenic crop plants including maize, rice, soybeans, cotton, rapeseed sugar beet, tomato, potato, alfalfa, cucumber, cantaloupe, squash, oilseed crops and herbicide-resistant cotton, etc. have been developed. Micropropagation of elite clones using tissue culture that are made disease-free using monoclonal antibodies and molecular diagnostic kits are now widely used. Anther culture and microspore culture giving rise to haploids are now being employed to improve varieties facilitating and accelerating breeding.

Genetic modification is the most complicated and expensive of the science-based biotechnologies. Furthermore, it carries controversial risks, not only for the health and safety of immediate users but also for society as a whole, since the environmental impact of organism released in new forms cannot be fully ascertained. The release of GMOs or genetically modified (engineered) organisms or transgenics needs further research and regulation (Glover, 1994). Many industrialized countries have imposed strict controls in this area. In most of these countries risk assessment is conducted on a case-by-case basis, but certain applications in specific crops are evaluated along genetic lines.

Genome revolution: marker-assisted selection and breeding

Molecular genome maps and markers are currently being utilized to identify genes of interest to accelerate conventional breeding programmes by using markers-assisted selection. Using the genetic maps of some crops, several resistance genes in important crops such as maize streak virus, *Pseudomonas* and *Xanthomonas* resistance gene in rice, downy mildew in onions, *etc.* have been isolated by map-based cloning. Efficient biological nitrogen system to enhance soil fertility and rhizobial strains is being genetically engineered. By apomixes photosynthetic patterns can now be manipulated and hybrids can be produced (Keese *et al.*, 2002).

Breeding involves screening large numbers of different lines, selecting those individuals with agriculturally important traits, quantifying the responsible genes and incorporating those genes into elite breeding material through several generations of crossing and back crossing to elite lines. DNA technology can assist in both the selection process by improved pedigree analysis or gene mining for improved genetic variants, and in tagging desirable genes in a breeding programme through marker-assisted selection (MAS).

Within CGIAR centres, such as the International Institute of Tropical Agriculture, or in nationally run seed banks within each country there are large germplasm collections that maintain many thousands of valuable wild and domesticated crop varieties. By quantifying the degree of DNA variation it is possible to develop highly valuable pedigrees that decipher the true genetic relationships. This allows the screening of duplicate copies and to establish a core collection of distant cousins that can serve as a representative sample of the entire genetic diversity present within a species. For example, IITA maintains a collection of more than 16,000 cowpea accessions than can be tested for desirable agricultural traits such as drought tolerance or resistance to the parasitic weed, *Striga*. However, screening 16,000 lines is costly and time consuming. Evaluation with new DNA based technologies can greatly assist the screening process. By establishing a core collection of a few hundred lines of the most genetically disparate groups, screening and selection can become far more cost effective. When useful candidate lines are identified then the pedigree analysis can be further used to report on closely related lines that are likely to also carry the same useful gene but that may have improved characteristics.

Through use of the latest DNA microarray technology the entire genome can be represented as tens of thousands of specific DNA fragments spotted onto a surface just a few square centimetres or in a single drop of liquid. With highly sensitive and specific probes, several hundreds or even thousands of million DNA base pairs of genetic material can be interrogated for the presence of a single DNA variant.

Advances in crop productivity

Food security in SSA still presents a major challenge. Africa's needs are much greater. Therefore, agricultural biotechnology is primarily aimed at increasing productivity. This can be achieved by increasing yield directly through increased photosynthetic efficiency or by redirecting photosynthesis into preferred structures such as seed or tubers. Alternatively, yield increases can be obtained by minimizing losses due to pest and diseases. For example, plants can be transformed with insect, nematode, fungal, parasitic weed, bacterial or viral resistance genes. Indirect benefits may also accrue; an aphid resistance gene not only reduces the aphid load but also lowers the opportunities for the spread of aphid-borne viral diseases. Furthermore, reduction of insect damage results in fewer sites becoming available for secondary infections by fungi or bacteria. Similarly transformation with stress tolerance genes can alleviate losses due to abiotic factors such as drought, high salt or aluminium toxicity. Transgenic technology can also help to reduce the costs of farm inputs such as pesticides and fertilisers, while the use of herbicide tolerant genes can lower labor costs associated with weeding. Increased productivity, by even a few dollars per hectare, will have a far greater relative impact in SSA, where poverty is still persistent, compared to the developed world.

Animal health, nutrition and production

Animal health and production have benefited most from biotechnology (Rege, 2002). Monoclonal antibodies for efficient diagnostics of diseases are widely used. Through genetic engineering vaccines for the prevention of viral, bacterial and parasite animal diseases are rendered more efficient and safer. Pathogen specific tailored vaccines exist for pig sours, chicken bursal disease and cattle tick-borne diseases of cattle. An example is the ELISA test developed to combat East Coast fever with over 95% specificity against *Theileria parva*, the causative agent of East Coast fever, a tick-borne disease of African cattle. Endocrine-related vaccines are now available for stimulation of twinning in beef cattle, immunocastration and increasing growth rate in livestock and vaccines that compensate for various stress-induced production losses.

To control or eradicate insects, all-male screwworms, tse-tse flies, ticks and other ectoparasites can now be produced by genetic engineering. To test toxicity of certain chemicals, mammalian tissue culture is used instead of whole animals. Through tissue culture, pesticide metabolism can be studied and analyzed. *In vitro* fertilization and embryo sexing techniques have considerably increased the use of embryo transfer method for cattle breeding and trade. Embryo cloning technologies in sheep, pigs and bulls have been reported in the UK, US, Germany, the Netherlands, South Africa, etc.

To improve animal nutrition, microbial and enzymatic treatment of roughages and genetic engineering of rumen bacteria have great potentials. For example in monogastric animals the production of phosphate by poultry and pigs had polluted the soil and water. This phosphate in the form of phytic acid in their feeds cannot be degraded by these animals and are just excreted and is a major part of manure. In Netherlands, a giant biotech company has produced an enzyme phytase from *Aspergillus* by genetic engineering which convert phytic acid into inorganic phosphate and inositol in pigs and poultry. Similarly, a host of genetically engineered microorganisms to speed and increase milk and lean meat are now being used in sufficient quantities at low cost. For conservation of animal genetic resources tissue and embryo culture, sperm preservation and gene cloning are now being employed in most developed countries.

Biotechnology could also yield significant gains in relation to the health and nutritional needs of livestock (Omitogun and Osoniyi, 2005). Transgenic approaches to fodder crops, such as cowpea, could address factors such as reducing ammonia production that gives rise to bloat in ruminants, decreasing plant lignin content to improve digestibility, better balanced protein composition to counter amino acid deficiencies, and vaccine production. Vaccines against trypanosomes, transmitted by blood sucking tsetse flies, could open up vast tracts of currently unsuitable grazing lands to livestock.

Animal genetic resources (AnGR) conservation (ILRI, 2006)

Animal genetic resources (AnGR) face a double challenge. On one hand in developing countries demand for meat and milk will double by 2030. On the other hand AnGR are disappearing rapidly worldwide especially in developing countries because of gene flows (introduction or migration) from developed economies to developing counties *e.g.* in the form of live animals ("Formula one animals' e.g. Holstein-Friesian, Rhode Island Red and Leghorn chickens, Large White, Duroc and Landrace Pigs), semen or embryo. Over the past 15 years, 300 out of 6000 breeds identified by FAO have become extinct. Many breeds of local importance for food security are not being improved or utilized in a sustainable manner and are in danger of being lost or diluted by crossbreeding.

Conservation and development of local breeds is important because many of them utilize lower quality feed, are more resilient to climatic stress and to local parasites and diseases, and represent a unique source of genes for improving health and performance traits of industrial breeds. It is also important to develop and utilize local breeds that are already adapted to their environments, most of which are harsh, with very limited natural and managerial input. Animals adapted to these conditions are expected to be productive at lower costs, support food and agriculture, and cultural diversity and be effective in achieving local food security objectives.

Local communities depend on those adapted genetic resources in many countries. Their disappearance or drastic modification for example by crossbreeding absorption or replacement by exotic breeds, will have serious negative impacts on these human populations. Presently most breeds at risk of extinction are not supported by any established conservation programme or active conservation though sustainable utilization (breeding plans) and therefore breed extinction rates are increasing globally.

Why conserve farm animal genetic diversity?

The world is losing its AnGR at an alarming rate through increasing losses of breeds of farm animals traditionally kept in developing countries. A full 205 of the world's domesticated animals are threatened with extinction.

Research to save Africa, the biological capital of the world's poorest people is a win-win for all (ILRI, 2006). As modernization loads many farm animal breeds into dustbin of history, genetic engineers are salvaging priceless relics. At the International Livestock Research Institute (ILRI) researches have shown that many of the genes that enable African cattle to survive poor food, little water and tropical diseases are unique, *e.g* the African humpless cattle which were domesticated by Neolithic people in Africa. Another example is the "Red Maasai hair sheep" that has unrivalled resistance to the billon dollar problem of intestinal worms. Another discovery is the salt-water-drinking camel in the Gobi dessert which was found to be a new species. The hidden genetic value locked up in these animals along with an estimated 7616 other often obscure animal breeds of some 40 livestock species around the world, is of growing importance as modern methods of fighting animal diseases falter, the climate warms and markets change. Extinction of any breed or population means the loss of its unique adaptive attributes, which are often under the control of many interacting genes and are the results of interactions between the genotypes and the environment. Saving these breeds will help us cope with the challenge of today and tomorrow.

History of AnGR

Some 12,000 to 14,000 years ago, humans began to domesticate animals and plants and to spread their Neolithic farming across most of the world's terrestrial habitats. Thousands of years of natural and human selection, genetic drift, inbreeding, and crossbreeding have led to the diversity of AnGR we see today which in turn have sustained animal agriculture in diverse environments and agricultural systems. Diversity in AnGR is vital to all agricultural production systems. It provides raw material for breed improvements and for adaptation to changing circumstances. As revealed by recent molecular studies, the diversity found in contemporary local livestock populations and breeds greatly exceeds that found in their commercial counterparts.

The big five global species

Remarkably few animal species were ever successfully domesticated. Only 14 of the 40 or so domesticated mammalian and bird species provide 90% of human food supply from animals. On a global scale just 5 of the 40 species of cattle, sheep, pig, goats and chickens- are distributed widely and in large numbers. The world has over 1.3 B cattle –about 1 for every 5 on the planet. The world's sheep population is just over 1 B- one for every six people. There are 1 B pigs, one for every 7 people, and 800 M goats, one for every 8 people. And chickens outnumber humans by 3.5 to 1 worldwide, there are nearly 17 B of them.

Other livestock species- water buffaloes, yaks, horses, assess, camels, llamas, reindeers, ducks, geese and turkeys- have smaller populations but are crucial to the livelihoods and survival of hundreds of millions poor livestock keepers in developing countries and marginal areas. For example, while the number of goat breeds fell drastically in countries of the North during the 20th century as a result of increasing importance of cattle, goats remain of major economic and nutritional significance to smallholders of the South, particularly in dry lands and mountains and other agro-ecologically marginal areas where other domestic animals cannot easily be kept.

With the exception of wild boar (*Sus scrofa*), the ancestors and wild relatives of major livestock species are either extinct or highly endangered. This is a major difference from crop species, many of whose wild ancestors still exist and represent an important source of variation and adaptive traits for breeding.

About breeds

Breeds develop in a dynamic process of genetic change driven by environmental and human selection. Both natural and artificial selection, as well as crossing between stocks and replacement of one stock with another are typical features of breed development in livestock production systems worldwide. In developed countries most breeds are characterized by clear definitions, physical characteristics and strict definitions of the purity of their pedigree, typically regulated by a breed society and backed by law. In developing countries, a breed is commonly defined by local tradition, physical characteristics of the breed, its geographical location or the ethnic tribe that developed it.

Breed refers to a population of animals that share certain defined physical characteristics and are not routinely bred with other populations. Within a breed there may be stocks, strains, varieties, or lines, terms used often interchangeably to describe population within breeds that are typically distinct as a result of human selection.

Crossbreeding

Local breeds have often been diluted by indiscriminate crossbreeding with imported stock often without significant gains in production levels or desirable characteristics, oftentimes leading to total disintegration of local breeds

Moreover, loss of breeds is just one indicator of the loss of genetic diversity in farm animal species: genetic variance within breeds may make up to 50 % of the total variance. Losses within breed diversity through indiscriminate crossbreeding can be as a strong threat to biodiversity as losses of whole breeds.

Disappearing breeds

Globally, in North America, Europe, Caucasus, Latin America and the Carribean the proportion of extinct breeds are known ranging from 20-28 % for mammals and 49-79% for birds. The risk status for Africa is not known for 59 % of mammals and 60% of birds. Population size for African breeds has not been reported for over two-thirds of breed population. And none of these statistics takes into account the erosion of genetic diversity within breeds due to cross breeding, a problem considered by many experts to be a major and increasing threat to livestock genetic diversity.

Rates of genetic erosion

Of the more than 7600 breeds noted by FAO, 190 have become extinct in just the past 15 years and a further 1500 are 'at risk' of extinction. Country reports to FAO's first *State of the World's Genetic Resources* published in 2007, show that 60 breeds of cattle, goats, pigs, horses and poultry have been lost over the last five years, an average of one breed lost each month. Of particular concern are the high rates of loss of indigenous breeds in developing countries, which, coupled with inadequate programs for the use and management of these genetic resources, is reducing livelihood options for the poor.

Causes of genetic erosion

There has been a focused effort over the last hundred years in developed countries in breeding and selection of breeds and strains aimed at maximizing their production potential often to the point of where those breed or strains require expensive and technologically advanced external inputs to survive (Hoffman, 2010). On the contrary, there is no similar focused effort in developing countries with the result that most domesticated and semi-domesticated breeds in the South are more genetically heterogeneous, and although having lower output per animal in terms of milk, eggs or meat, are able to survive with fewer inputs. The result is lower but more stable overall production in their typical environments and a wide range of other services is provided by the local animals.

One of the most significant contributing factors to the erosion of local breeds is the indiscriminate introduction of the exotic breeds and germplasm from developed countries *i.e.* highly specialized animals or semen used in crossbreeding. Wholesale transfers of intensive poultry and pig production systems have been made in recent years in some developing countries especially in Nigeria. Thus, the biggest factors reducing farm animal genetic diversity is globalization of livestock markets based on the few species of breeds of high input, high output animals. Intensive production systems often bring with them erosion of local AGR. When pressure on land resources increases and livestock are kept more intensively, small farmers usually opt for crossbreds that offer higher returns to labour.

Other causes of genetic erosion of farm AGR

- Neglect of multipurpose animals for single productivity traits such as meat, milk or eggs

- Urbanization and intensification of animal production systems
- Political instability and natural disasters, including disease outbreaks, droughts and famine
- Lack of breed characterization and economic valuation data

It is true that the value of majority of our AnGR is poorly understood by both scientists and policymakers, it is certain that the diversity of cattle, sheep, goat, pig, poultry and breeds of other farm animal species represents an irreplaceable source of traits for livestock development in response to changing environment and human needs. The following are among principal reasons for conserving farm AnGR:

- to prevent erosion in populations of current value
- to provide options for adaptation to changing environmental conditions
- to support sustainable animal production systems for food security
- to provide genetic resources for crossbreeding and development of new genotypes
- to meet the demands of new markets for livestock products and services

Now many say livestock agriculture intensification may contribute more GHG (greenhouse gases) emissions (IFAD, 2010). Though Africa's livestock contribution is only 3% (out of 15% global contribution) there are ways to reduce greenhouse gases emitted by livestock (ILRI 2008-09)

1. Reduce consumption of, and demand for, livestock foods in developed countries
2. Improve the diets of ruminants in developing countries

* Providing cattle, water buffaloes, sheep, goats and other ruminant animals in developing countries with better quality diets increases their feed-conversion efficiencies and thus reduces the amount of methane generated in the production of a unit of meat or milk.

3. Help farmers in developing countries obtain and maintain higher-yielding breeds

4. Better match livestock species to environments in all countries

   * Switching species to find those better suited to particular environments and resources could raise animal productivity levels.

5. Impose regulatory frameworks for managing manure in all countries

6. Apply land-use policies that forestall cultivation of new lands community.

7. Provide incentives to adopt mitigation strategies, particularly for poor communities

Finally, successful implementation of livestock mitigation strategies, particularly in poor countries with scarce resources, inadequate rural and peri-urban infrastructure, and inappropriate agricultural policies, will demand a series of smart and equitable incentive systems that encourage people to adopt mitigation strategies and practices.

But the lesson ILRI researchers have learned from their pastoral research may prove to be most relevant here: mitigation activities have the greatest chance of success in poor and hungry communities when they build on traditional institutions and knowledge while building up food security.

Forestry and fisheries applications

For forestry applications, 100 forest species have been propagated by micro propagation and somatic embryogenesis. Superior genotypes are identified by gene mapping without replicated clonal testing in the field. Genetic mapping has identified valuable genes including genes that contribute to quantitative traits and confer insect or disease resistance. By genetic engineering and tissue culture, *in vitro* manipulation of maturation state and early flowering to reduce generation intervals, selection for traits such as disease resistance, tolerance to salinity are now being experimented on.

For fisheries applications, two fields of biotechnology are now in vogue: aquaculture and natural products (involving mostly marine species). Commercially valuable products such as pharmaceutical compounds, pigments, oils, sterols, arginates and agarose are being extracted from microalgae and macroalgae. Aquatic invertebrates such as sponges, *Conus* snails are now being screened for biologically active compounds e.g. neurotoxins that may have anti-carcinogenic and antiviral properties. Moreover, marine bacteria are currently being utilized in bioremediation, *i.e.,* treatment of oil spills and holding tanks in tanker ships.

In aquaculture, chromosomal manipulation by polyploidy in many freshwater and marine species have increased their growth and marketability. Marker-assisted selection as in livestock has improved breeding strategies in many temperate and tropical aquaculture fish such as tilapia and catfish (Delfin and Omitogun, 1999; Omitogun, 2006). Fish growth hormones from genetically engineered microbes are used to improve fuel conversion and growth rate, regulate fecundity, breeding cycles, growth rates, and sex determination in many cultured species. Transgenic fish containing introduced genes from other species are now being experimented on to increase desirable quantities for aquaculture such as growth rate, disease resistance, temperature (freezing) and salinity tolerance and marketability (Gong *et al.*, 2007).

Other biotech considerations: Intellectual property rights issues

Who owns the genetic resources occurring in nature in most tropical countries? For example, an agropharmaceutical transnational company, W.R. Grace has taken out a patent on the synthesized neem extract which is case of intellectual property rights. As in the case of *endod* from Ethiopian soapberries *(Phytolacca dedocardra)*, which is a potent molusciside that kills zebra mussels (*Biomphalaria*) that transmit the human disease bilharsis. The University of Toledo in the US went to Ethiopia and introduced *endod* in hydroelectric power plants infested with mussels and has now applied for patent on the use of *endod.* Similarly, researchers at our university (OAU, Ile-Ife) identified the protein sweetener thaumatin in the sweet berry, *Thaumatococcus danielli,* which is 1,600 times sweeter than sucrose. The gene has been cloned in Europe and US is used for industrial production of thaumatin, which sells for $5,000 per kg, for the production of sweeteners in giant industrial vats. At the University of Ibadan (UI), researchers had identified an active ingredient in the fig *Zanthoxyloides (fagara)* whose extract had been found to reverse the sickling of red blood cells in sickle cell anaemia patients (Awe, 1991*).* Recently, at IITA, a lectin extract from African Yam bean *Spehenostylis stenocarpa* was found to be insecticidal against cowpea major pests as bruchids (*Callosubrucius maculatus),* pod-borers (*Maruca vitrata)* and pod-sucking thrips (C*lavigralla tomentossicolis)* (Omitogun *et al.*, 1999). The gene for this protein has now been cloned at University of California.

In the above examples of cases of intellectual property rights, who really should get the compensation? local scientists, the farmers or those big transnational companies who have the resources to go through the international rigorous patenting protocols?

Other biotech considerations: Biosafety

Another important aspect of biotechnology applications to agriculture that needs to be elucidated is the environmental risks these transgenic species could cause. In the US and other western countries in Europe, *e.g.* Germany the spectre of genetically engineered plants and public concern into the environment resulted in widespread bans, moratoria or other statutory restrictions. In Canada and Europe there is an approved process for all new plant varieties while the US has no such requirements. Regulatory bodies in Canada have been strictly monitoring the field tests of transgenic alfalfa, canola, flax, potato, soybean and tobacco. In the US, USDA (Department of Agriculture), FDA (Food Development Authority) and EPA (Environment Protection Agency) regulate movement and release of genetically modified plants (GMPs). With the current public concern on GMPs that expressed the pesticidal proteins such as *Bt,* these agencies would grant field-testing permit only if a GMPs would not be a pest. Japan is regarded as being cautious in its approach to regulatory field tests. It is evident that these advanced countries have rigorous and strict requirement that a GMPs environmental impact be assessed first before commercialization. In most of these developed countries, before a transgenic plant, animal or microbe is released for testing, information concerning:

a. the rationale for developing the product; its molecular biology and biochemistry;

b. the movement of the genes (pollen dispersal and out crossing potential);

c. the trait and its effect on the plants ecology (effects on fitness in the environment, invasiveness or weediness potential and secondary effects which are defined as the unpredicted effects of genetic engineering such as altering levels of secondary metabolites;

d. safety of gene products towards non-target organisms and uses;

e. the potential for other untoward environmental problems (gene movement by mechanisms other than intraspecific) is made available.

To allay the fears of environmentally concerned groups and individuals worrying about the medical implications of these transgenics (e.g. allergic reactions in some sensitive individuals), separate tests for the transgenic IRC (Insect-resistant cotton) and GT (glyphosate-tolerant) canola in US, UK and Canada, revealed scientific evidences indicating that:

a. movement of genes from plants to microorganisms or to unrelated species of plants is improbable. Many examples of gene flow even between compatible species can be explained by convergent evolution.

b. most genetic changes reduce rather than increase fitness. The wild type competitors are usually more fit, better competitors and hence are weedier. Since most genetic changes compromise the plant in some environmentally significant way, it is not expected that a GMP will have a greater potential of being a pest than any commercial cultivars obtained through traditional breeding and selection.

c. there has never been evidence of crown gall in plants derived from disarmed *Agrobacterium tumefaciens* mediated transformation. This indicates that this bacterium is efficiently eliminated in tissue culture and is not propagated in the seed.

From over 400 fields worldwide and proximate and amino acid analyses of these 2 transgenic plants, IRC and GT, which behave substantially the same as non-modified parental lines in terms of ecology; it was established that they are safe for release and field testing (Mctughen, 1994; Nickson and Fuchs, 1994) .

Biotechnology research projects in some selected SSA countries

Research and development (R & D) efforts in African agricultural biotechnology are not evenly spread across the continent. While some countries such as South Africa have both institutional and regulatory agri-biotech capacity to rival some more developed nations, others, such as Angola, Botswana and the Gambia have not reported any agricultural biotechnology research and do not yet have functioning regulatory systems in place (Glover, 2010).

Table 4 details agricultural biotechnology projects underway in selected African countries. South Africa, Nigeria, Kenya, Zimbabwe and Ghana all have at least 6 institutes with some capacity to conduct biotechnological research. South Africa and Nigeria have the largest portfolios of biotech R & D projects in Africa.

The great majority of agricultural biotechnology research in Africa is on crop improvement, although not all of this rely on the use of genetically modified (GM) technology (Table 4). For example, Nigeria is host to over 60 projects- for example, micropropagation of cassava, date palm, ginger. etc.

Table 3. Biotechnology research projects in leading sub-Saharan countries

	Key Institutes with Research Capacity	Total	Biotechnology Research Program: Type of technology		Area of applications		
			GMO	Non-GMO	Crop	Livestock	Forestry
South Africa	10	92	42	50	58	8	26
Nigeria	7	72	5	67	72	0	0
Kenya	6	36	10	26	31	1	4
Zimbabwe	6	29	2	27	27	2	0
Ghana	6	28	1	27	25	0	3
Uganda	4	25	3	22	21	3	1
Ethiopia	4	22	0	22	9	6	7
Tanzania	4	22	1	21	13	8	1
DR Congo	2	11	0	11	6	1	4
Malawi	4	10	1	9	9	0	1
Namibia	3	2	0	2	2	0	0

Source: (Glover, 2007)

GM crops global commercialization and environmental impact

The global area under GM crops has increased from 1.7 million hectares in 1996 to 125 million hectares in 2008 -a 74-fold increase, of which 63% were in the United States providing herbicide or insect resistance for production of soybeans (81%), cotton (73%) and corn (40%). From survey of the global impact of biotech crops for the period 1996 to 2007: the global net economic benefit to biotech crop farmers in 2007 was US$ 10 billion (US$6 billion for developing countries and US$4 billion for industrial countries). The accumulated benefit during the period 1996 to 2007 was US$44 billion, with US$22 billion each for developing and industrial countries. In the US it is evident the traits provided thorough biotechnology are benefiting some farmers, although biotechnology has had little commercial success to date in horticultural crops, including fruits, vegetables, flowers and landscape plants (even though the first transgenic crops to reach the market were the Flavr Savr tomato, and sweet corn, potato, squash) except papaya transgenic varieties that have achieved a significant market share (about 70% of Hawaiian crop shipped to the continental US is transgenic). Meanwhile, with commercialization stymied in the US because of regulations specific to transgenic crops that significantly increase the cost of development and commercialisation, China is moving forward with the application of biotechnology to improve the efficiency of production and quality of its horticultural products.

As a result of consistent and substantial economic, environmental and welfare benefits, a record 13.3 million large, small and resource-poor farmers planted biotech crops in 2008. It is noteworthy that two of the three countries that planted biotech crops for the first time in 2008 globally were African, and, for the first time, there was a lead country commercializing biotech crops in each of the three principal regions of the continent: South Africa in southern Africa; Burkina Faso in West Africa; and Egypt in North Africa. This broad geographical coverage is of strategic importance in that it allows the three countries to become role models in their respective regions. It also allows more African farmers to become practitioners of biotech and to benefit directly from *"learning by doing,"* which has proven to be an important feature in the success of Bt cotton in China and India.

South Africa boasts a highly advanced agricultural industry based on first-generation biotechnologies and internationally competitive animal and plant breeding capabilities. The country has been involved with biotechnology research and development for over 20 years and has developed a globally competitive biotechnology industry.

In 2003, a survey of biotechnology activities conducted in the country identified a total of 622 research groups involved in biotechnology-related activities, with at least 154 biotechnology products and services (www.africabio.com). Several African nations including Kenya are moving toward release of GM crops. South Africa is now commercializing GM crops. About 1.4 M hectares were planted with transgenic crops with the following traits (Table 4).

Table 4. Commercialisation of GM crops in South Africa

	Number of varieties			
	IR	**HT**	**IR/HT**	**DT**
• Maize	2	3	4	2
• Cotton *	2	1	-	
• Soybean	-	2	-	
• Others: Sorghum, Wheat Cassava**,Potato**, Sugar cane, Banana**, Cucumber**, Squash**, Melon**				

IR-Insect resistance; HT-Herbicide tolerance; IR/HT- both traits; DT-drought tolerance;
**Salt tolerance; **Virus resistance*

ISAAA, 2009 reports that the field trials of Bt cotton on the Makhathini Flats over a 5-year period by the South African Agricultural Research Council resulted in an average yield gain of 349 kg/ ha with Bt cotton. At Rand (R) 3 per kg (US$0.45), this meant an extra profit of R1,047 (US$156) per hectare planted. More extensive studies have reported substantial benefits for small-scale farmers. A similar study conducted by the University of Reading and the University of Pretoria found that Bt cotton yielded about 40% higher than conventional cotton with farmers paying 42% less in spraying costs. This documentation of increased adoption rates included the following milestones:

- Ø Over 90% of cotton seed planted by farmers is genetically modified,
- Ø The number of pesticide sprayings has reduced from 10 to 4 per season
- Ø Women and children now have more time for family welfare and education respectively
- Ø Lower production costs provide farmers with higher gross margins estimated at US$ 70–130 /2 ha of cotton.

It is noteworthy that while farmers continue to increasingly adopt Bt cotton, recent climatic changes manifested through erratic rainfall patterns, prolonged drought spells, and fluctuating international prices continue to pose production challenges (Karembu *et al.*, 2009)

This is even more serious in many parts of Africa since agriculture is predominantly rain fed. Complementing the technology with farmer support services and fortifying current products with additional traits including drought tolerance, will help address these multiple challenges, thus ensuring Africa continues to reap socio-economic benefits and environmental gains from biotechnological applications in the agricultural sector.

In 2008, Burkina Faso for the first time planted approximately 8,500 hectares of Bt cotton for seed production and initial commercialization, becoming the 10th country globally to grow commercial Bt cotton. The other nine countries that have collectively and successfully commercialised over 81 million hectares of biotech cotton (Bt, HT and Bt/HT) in the 12-year period 1996 to 2008 are listed in decreasing order of cumulative biotech cotton hectares; USA (44 M hectares), China (22 M hectares), India (12 M hectares) and Australia (1–2 M hectares), with the balance of five countries Argentina, Brazil, Mexico, South Africa and Colombia each growing less than 1 million hectares.

Located in the Sahel, Burkina Faso is rated as one of the poorest countries in the world. Annual average rainfall is 100 centimeters in the South to 25 centimeters in the North. Almost 40 percent of the country's GDP of US$ 7 billion is derived from agriculture, which provides employment for up to 80 percent of the Burkina Faso's 15 million inhabitants. However, drought, poor soil, insect pests and lack of infrastructure and finances pose significant challenges to the agriculture sector and economic development.

Cotton is the principal cash crop in Burkina Faso. The crop generates over US$ 300 million in annual revenues, and represents over 60 percent of the country's export earnings. Some 2.2 million people depend directly or indirectly on cotton, often referred to locally as "white gold" and "the foundation" of rural economies. Burkina Faso planted approximately 475,000 hectares of cotton in 2008. However, yields are low, at approximately 367 kg per hectare compared with 985 kg per hectare in USA. Crop losses of 30 percent or more are attributed to insect-pests of cotton

At the national level, the annual cost for insecticides for the control of cotton bollworms and related insect-pests is around US$ 60 M per year. However, insecticides are proving ineffective, with losses due to bollworm as high as 40% even with full application of insecticides. As a result of these challenges, Burkina Faso's cotton production decreased to 0.68 million bales in 2007/08 from 1.3 million bales in 2006/07.

In an effort to address the insect pests challenge, the national research institute, Institut de l'Environnement et de Recherches Agricoles (INERA), has been field-testing Bt cotton since 2003 with excellent results. INERA scientists in collaboration with Monsanto incorporated the Bt gene (Bollgard II(R)) into selected popular cotton varieties that are well adapted to the local environment. After rigorous risk assessment and stakeholder consultations, the National Bio-Security Agency approved two varieties of Bt cotton for seed production and commercialisation. The Bt cotton varieties offer several advantages including reduced number of insecticide applications to two, compared with 6 to 8 for conventional cotton, and yields approximately 30 percent higher than conventional cotton. This translates into a more competitive product for the international cotton market and higher profits for resource-poor subsistence farmers, thus making a contribution to the alleviation of poverty. Royalties from the sale of Bt cotton seed have already been negotiated among Burkina Faso farmers, ginners and the technology provider. It is projected that in 2009 approximately 120,000 hectares of Bt cotton will be planted, which is equivalent to 25 percent of the total cotton area in Burkina Faso. This is a significant launch by any standards, and compares favorably with the earlier Bt cotton launches in the USA, Australia, China, and India. The Bt cotton programme initiated and expedited by the Government of Burkina Faso can serve as a model for many other developing countries growing cotton. It is also consistent with the recommendation of the 2008 G8 Hokkaido meeting which recommended the utilization of biotech crops, acknowledging the significant and multiple benefits they offer.

Burkina Faso, as one of the four cotton growing countries in West Africa (with Benin, Chad and Mali) and the second-largest cotton seed producer in Africa, is now in a position to share its valuable knowledge and experience with Bt cotton with its neighbours.

This would ultimately expedite the commercialization process in those countries for the benefit of their cotton farmers. It is noteworthy that these countries are beginning to put regulatory mechanisms in place as a first step towards preparing themselves for the safe and responsible uptake of the technology. The National Assemblies of Mali and Togo for example, passed national biosafety laws in 2008 (James, 2008).

In an effort to generate evidence on the real and potential benefits of Bt cotton in Burkina Faso and indeed the western African region, several socio-economic studies have been initiated estimating that Bt cotton would generate US$ 106 million per year for Burkina Faso based on yield increases of 20 percent and a decreased need for insecticides. The potential payoffs and economic risks of adopting biotech cotton in 5 other countries in West Africa namely; Benin, Burkina Faso, Mali, Senegal and Togo are substantial. The Bt technology needs to be adopted, in order to 'catch up' with major cotton-producing countries in the rest of the world.

Thus, the onus is on governments of cotton-growing developing countries to exercise their authority and responsibility to appraise, approve and adopt Bt cotton at the earliest opportunity. Fortunately, this can be greatly facilitated and accelerated today by learning from the wealth of knowledge and experience of the 9 countries, 6 of them developing that have adopted, commercialised and benefited significantly from this proven technology over the last decade. Bt cotton is no longer the "new" technology with a potential risk as it was perceived to be 11 years ago. On the contrary, the risk is to consciously elect not to use the technology especially for countries that depend on cotton as their major source of livelihood and economic development.

As discussed above, this captures the experiences of the two African countries growing biotech crops commercially. Other countries like Kenya are moving towards officially releasing GM crops with individual varieties of maize and cotton. Kenya is conducting field trials of Bt cotton that have been going on for the last 5 years. The trials have indicated that Bt cotton yielded 25% more and gives higher positive net benefits than the conventional cotton varieties, even though the experimental Bt cotton was not from locally adapted varieties. These results also confirmed a 20% reduction in costs when untreated Bt cotton (06Z604D) was grown, as compared to a conventional variety (HART 89M) treated for all insect pests. This indicates that Bt cotton not only increases yields manifold but also substantially reduces pesticide applications. The latter would reduce pesticide poisoning, thus benefiting people, wildlife and the environment. These results are consistent with widely published data on the benefits of Bt cotton from countries such as India and South Africa. Honourable William Ruto, the current Kenyan Minister for Agriculture states, "*The Government is committed to ensuring that information on biotechnology is accurately and efficiently disseminated to the public for informed decision making regarding adoption and safe application*".

Therefore, biotech crops have improved the income and quality of life of farmers and consumers, and contributed to the alleviation of poverty.

Aside from the benefits described above, biotechnology can contribute towards arresting the effects of climate change, mainly through savings in carbon dioxide (CO_2) emissions associated with fewer insecticide and herbicide sprays and from conservation tillage (herbicide tolerant biotech crops facilitate conservation tillage) (Karembu *et al.*, 2009).

India's experience with GM-cotton is particularly dramatic:

- Ø A record 5 M smallholder farmers planted Bt cotton on 7.6 M hectares in 2008, realizing

  - * 39% reduction in insecticide usage,
  - * 31% increase in yields and
  - * 88% ($250/ha) increase in profitability.

- Ø In 2007, for example, reduced spraying resulted in an estimated savings of 1.1 billion kg of carbon dioxide (CO_2), equivalent to reducing the number of cars on roads by half a million.

- Ø A further 13.1 billion kg of CO_2 were saved by conservation tillage, due to increased soil carbon sequestration, equivalent to removing 5.8 million cars off the road.

While acknowledging that biotechnology will not be the panacea for the myriad of problems facing sub-Saharan Africa's agricultural sector, the efforts being directed towards addressing production constraints cannot be addressed by conventional breeding alone.

Prof. Gebisa Ejeta, the 2009 World Food Prize Awardee from Ethiopia, for his work on sorghum, a staple diet for more than 500 million people in SSA had yielded scientific breakthroughs combining conventional and molecular-assisted breeding for drought-tolerant and Striga-weed-resistant sorghum that enhanced the food supply of hundreds of millions of people in SSA.

In addition, the scientists from University of California declared that "*the distinctions between conventional and nonconventional agriculture are likely to blur in the future, and production willl become more sustainable, as growers integrate the greatly expanding knowledge base of biological processes such as pest dynamics and* *soil-microbe interactions with modern crop biotechnology"* , Bradford *et al.*, 2004.

Biotechnology and biosafety policy and regulatory frameworks in SSA

Several African countries have put in place policies and regulatory frameworks to support the responsible and safe use of biotechnology. The signs of progress have not been limited to regulation; African scientists are gaining recognition the world over for their breakthrough innovations in modern agriculture. For instance, Professor Gebisa Ejeta an African scientist was awarded the 2009 World Food Prize (WFP) for his work on sorghum, one of Africa's most important staples. Earlier, Dr. Monty Jones from Sierra Leone was given the WFP in 2004 for his conventional cum molecular breeding work on African rice that is now grown in many African environments. In 2008, Burkina Faso and Egypt joined South Africa which was the only country on the continent growing commercial biotech crops raising the number of African countries benefiting from the technology to three in just one year.

African countries are developing functional National Biosafety Frameworks (NBFs) to oversee the development and utilization of GM products. Although components of NBFs vary from country to country, these typically comprise existence of (1) a policy on biotechnology, (2) laws and regulations on biosafety, constituting a regulatory regime for biotechnology, (3) an administrative system for handling applications and issuance of permits and (4) a mechanism for public participation in biosafety decision making process. African countries are at different stages of enacting biosafety legislation, ranging from functional, interim and 'work-in-progress' NBFs. Countries that have enacted biosafety laws include; Burkina Faso, Cameroon, Kenya, Malawi, Mali, Mauritius, Namibia, South Africa, Tanzania, Togo and Zimbabwe while Madagascar, Rwanda, Sudan, Uganda and Zambia have elaborate national biotechnology and biosafety policies (Karembu *et al.*, 2009).

Does Nigeria have the resources and capabilities? Can Nigeria cope with the biotech challenges to enhance its agricultural productivity?

- * Can SSA sustain such programmes? *e.g.* do we have capacity for biotechnology ? even the simplest techniques as tissue culture, artificial insemination and cryopreservation?
- * The way forward: not to relent but meet up with the challenges

Nigeria is strategically located in Sub Saharan Africa (SSA) and its contribution to total agricultural production in SSA is very significant. In spite of the growing importance of oil, Nigeria has remained essentially an agrarian economy, with agriculture still contributing significant shares in Gross Domestic Product and total exports as well as employing the bulk of labour force.

Nigeria's crop and livestock resources are very diverse. Where there are cattle, there are sheep and goats that have adapted to the ecological constraints of the Sahel and Sudan Savannah Zones. The rest of the cattle, sheep and goat population that are made up of the indigenous dwarf breeds are found in the Guinea Savannah and forest zones. Various local and exotic breeds of pigs are found in different areas of the country. All over the country there is a large population of poultry, especially the indigenous breeds reared under free-range conditions. Commercial production of poultry and pigs takes place all over the country. In the contrary, fishery in Nigeria is mainly done in the artisanal sector where the coastal and brackish waters constitute the major areas of production followed by inland rivers and lakes. Production from aquaculture is still very low despite the fact that Nigeria ranks first in total fish production in SSA. Nigeria's contribution to the annual fish production in SSA is estimated to be

17 700 mt (the largest, followed by Madagascar, 5 100 mt and Zambia, 4,700 mt) in 1997 coming mostly from *Clarias, Heterobranchus,* tilapia and carp in small-scale aquaculture farms (Machena and Moehl, 2001).

Recognizing that biotechnology can complement traditional science methodologies to improve crop and livestock productivity, the need for baseline information about Nigeria's manpower and infrastructure capabilities to conduct biotechnology research resulted in surveys conducted by the government (NABDA, Agricultural Research Council of Nigeria), IITA and ILRI (Omitogun and Osoniyi 2004) to assess the capacity of national institutions to implement work on biotechnological options and to determine the type of linkages with regional and international institutions.

From the data gathered by personal visits, personal interviews and structured questionnaires Omitogun and Osoniyi (2005) noted that there is a general scenario of slow development of the application of biotechnology tools in increasing livestock productivity in Nigeria because of poor infrastructure and limited or inadequate funding. There is an obvious lack of coordination of biotechnology research in the country, although it was gathered that the government is harmonizing biotechnology research efforts in the country. It is sad to note that well-trained scientists who choose to stay in the country have become redundant because of lack of opportunities to do research that will stimulate and motivate them. Modern biotechnology research is quite expensive and capital intensive, but providing equipment is not enough, many well-equipped laboratories found in some research institutes, universities and polytechnics have become 'white elephants' because of lack of materials or consumables to utilize these equipment. Oftentimes a machine stops functioning for months because of a small accessory that needs repair or replacement. It is also common to hear scientists lamenting that equipment they brought back from a study or research visits like

PCR (polymerase chain reaction) machine or thermocycler can not be used because there is no *Taq polymerase* or dNTPs (dideoxynucleotides) available. The following SWOT analysis (Table 5) gives an overall view of the capacity for animal biotechnology in Nigeria (Omitogun, 2007):

Table 5. SWOT Analysis of Nigerian animal biotechnology resources.

STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
1. Capacity	Not sufficiently trained in DNA analyses Others who lack training join the biotech band-wagon	Trainable scientists and technologists- lesser time to train and may better scientific outlook of doing things	Brain drain, those who stay gets frustrated and lackadaisical; others given administrative posts that stole their time away from doing science and creative work Ill-trained technicians and biotechnologists
2. Equipment availability	Too expensive to maintain Ill-maintained, no structure for fast and less bureaucratic procurement of chemicals and materials	Attractive to both industrial and development investors	Lack of funds to put to maximum use
3. Infrastructure	Oftentimes too much investments in buildings	Space for solar energy utilization. Industries can rent space. Biotechnology innovative collaborations can be forged	Government spending too much money on buildings, no more funds for maintenance. Abandonment after projects funds are exhausted
4. Floral and faunal	Lack of reliable water and		

biodiversity	electricity supply Underutilization, facilities for conservation not sufficient Genetic erosion due to indiscriminate breeding with exotic species	Good sources of genes for insect, disease, pest, drought, etc.– good genetic base for gene isolation and breeding Rich indigenous knowledge in biofertilizers, biopesticides, medicinal, insecticidal plants	Endangered species-threat of extinction

This analysis from 57-sample survey supports the findings of ASTI (Agriculture Science Technology Index, ISNAR & IFRI, 2004) concerning the state of Nigeria's agricultural research system marked by institutional instability, declining funding availability, and general uncertainty. It was also reported that institutes continue to lack appropriate levels of funding for their research activities and the quality of staff at the government research agencies has deteriorated, with many senior scientists particularly those with PhD degrees, moving into the university sector or abroad. From the present survey, it was shown that there is a considerable pool of trained and trainable researchers in the country. Many of them are very highly motivated. Many of the institutions also have facilities that can be upgraded or improved, if given the funding.

A BRIEF SYNOPSIS OF MY CONTRIBUTION TO SCHOLARSHIP (PRE-OAU and there after)

My academic background and experiences in molecular genetics and fish biology have been streamlined towards applications in aquaculture genetics (Galman and Carino, 1979; Galman 1980) breeding and culture (Galman *et al.,* 1987; Galman *et al.,* 1988a, b,) as well as animal (Galman, *et al.,* 1989, 90; Yerle *et al.,* 1991; Omitogun, 2004) and plant biotechnology (Omitogun *et al.,* 1993, Thottapilly *et al.,* 2000). I have been privileged to have enjoyed excellent research facilities through several international research fellowships mostly at international agricultural research centres (IARCs) such as ICLARM (International Centre for Living Aquatic Resources Management now renamed as World Fish Center) based in Penang, Malaysia; 1979-80; INRA (Institut National de la Recherche Agronomique), Toulouse and Paris, France; EMBL (European Molecular Biology Laboratory) Germany and Université de Liège, Belgium, 1989-93; IITA (International Institute of Tropical Agriculture) Ibadan in Nigeria, 1995-97, 1998-2000; ILRI (International Livestock Research Institute: 2002,2005), Ethiopia. This international exposure during my scientific career has enabled me to write significant papers with colleagues of international calibre.

In the area of fisheries biology and biotechnology

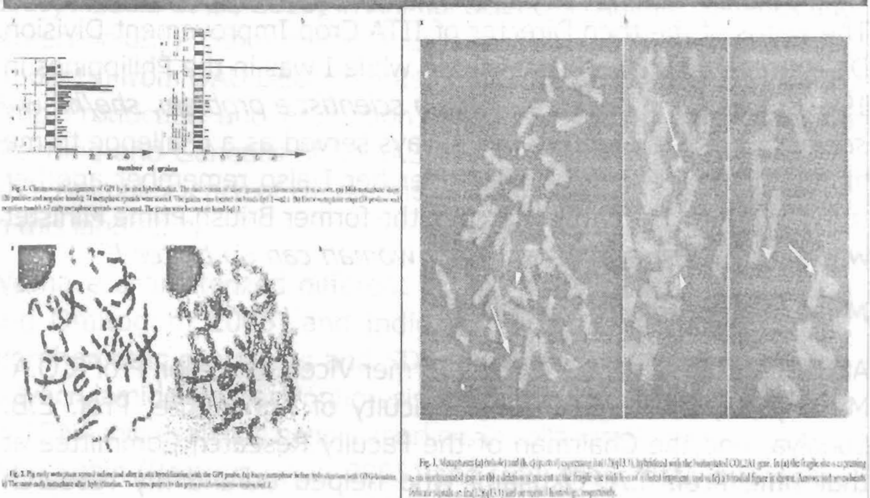
For my M.Sc. and Ph.D. research projects, I studied the developmental and biochemical genetics of *Oreochromis niloticus*, an important African indigenous fish that has become commercially important in Asia, (Omitogun and Aluko, 2002) my research findings (Galman and Carino, 1979; Galman, 1980; Galman and Avtalion, 1983; 1989) have become an important tool in chromosomal manipulations in tilapia and all-male production (Galman *et al.,* 1987 a, b) by applying hybridization and hormone treatment.

On returning to the Philippines as Associate Professor in 1991 after a 3-year postdoctoral period in Europe, I was awarded a research grant from the University of the Philippines Natural Science Research Center(NSRC) Diliman, Metro Manila where I established a cytogenetics laboratory and developed protocols for the culture of tilapia and human blood and cytogenetic banding techniques to identify tilapia chromosomes (Eugenio *et al.,* 1992) and human chromosomal abnormalities. With the Lung Center of the Philippines we started the primary culture of lung cancer cells. This laboratory at NSRC became the foundation of a Biological Services Laboratory that now renders services such as cytogenetic analyses of children with congenital disorders and DNA fingerprinting for forensics, fire victims identification, etc.

In the area of pig gene mapping

While a postdoctoral scientist at INRA, I produced a high resolution karyotype of the domestic pig *(Sus scrofa domestica)* which had been useful in fine gene mapping in porcine genome (Galman *et al.,* 1991; Yerle, *et al.,* 1991a, 1992) and gene synteny studies (Yerle *et al.,* 1991b). Our research team localized the malignant hyperthermia (halothane) gene loci in chromosome 6 of the domestic pig, *Sus scrofa* (Figure 7) (Yerle *et al.,* 1990a, Yerle *et al.,* 1990b; Yerle *et al.,* 1991; Yerle *et al.,* 1992) which has contributed to the development of DNA probes in Europe in genotyping stress-resistant and susceptible pigs (stress syndrome causing blackening of the carcass pork meat).

Fig. 7. Halothane gene was localized and order established in pig chrpmosome 6 using high resolution chromosome techniques, blood lymphocyte culture, radioactive and nonradioactive fluorescent *in situ* hybridization (Galman *et al.*,1991; Yerle *et al.*, 1991, 1992)



In the area of cowpea genetic engineering and plant biotechnology

On returning to Nigeria, I was opportuned to get a job at IITA Biotechnology Research Unit (BRU) as Molecular Biologist (1995-2000). *"DNA is DNA",* said Dr. George Thottapillly, the then Head of BRU, *"we will give you a try, to apply your experience in animal molecular genetics to plant biotechnology".* I isolated an insecticidal lectin from an indigenous African legume African yam bean *(Sphenostyles stenocarpa)* (Omitogun *et al.,* 1999) with a view of pyramiding into cowpea gene pool for resistance against its major insect pests. With a Ph.D student, we purified by affinity chromatography and sequenced this protein (Omitogun *et al.,* 2001).

With colleagues from IITA, we cloned a cowpea detoxification gene *cytochrome p450*, which was submitted and was accepted in a United States gene bank database **GenBank Accession No. AY 157934 and AY157935** gb-admin@ncbi.nlm.nih.gov.

The words of the then Director of IITA Crop Improvement Division Dr. Margaret Quin who sent for me while I was in the Philippines in 1994 still linger in my ears, *"Give a scientist a problem, she/he will solve it".* This statement has always served as a challenge to me till today, though when I remember her I also remember another Iron Lady, Mrs. Margaret Thatcher, the former British Prime Minister who said *" What a man can do, a woman can do better !"*

My current research at OAU

At OAU, with the foresight of the former Vice Chancellor, Prof R.O.A. Makanjuola, the then Dean of Faculty of Agriculture, Prof. E.B. Sonaiya, and the Chairman of the Faculty Research Committee at that time Prof. T.A. Okusami who helped defend my research proposal before University Research Committee (URC) Panel of Professors, Heads and Directors, I was given one (1) million Naira grant (11812 AVT) in 2004 and from this grant, I established a Biotechnology Laboratory at the 6th Floor of the Faculty of Agriculture. With another supplementary grant, I established a Wet Research Laboratory at the basement of the Faculty for fish breeding and nutrition studies. Today these 2 laboratories have acquired several modern equipment including a BioRad Protein and DNA Electrophoresis System which have been useful for many post graduate researches of students not only from Faculty of Agriculture but also from the Faculty of Science as well as other universities such as University of Ibadan, UNAAB (University of Agriculture, Abeokuta), LAUTECH (Ladoke Akintola University of Technology, Ogbomoso), LASU (Lagos State University) and OOU (Olabisi Onabanjo University, Ago-Iwoye), Federal University of Technology, Akure and University of Ado Ekiti. With the vision of the above-mentioned administrators and URC that biotechnology would be a potent tool in modern science and agriculture, I started teaching agricultural biotechnology to undergraduate and postgraduate students from the Faculties of Agriculture and Science. To date, I have produced 4 M.Sc. graduates (Betiku and Omitogun 2006; Oluwole and Omitogun, 2007, 2008, 2009; Olaniyi and Omitogun, 2009, 2010; Adeola and Omitogun, 2010; Adeola *et al.*, 2010) in Animal Sciences (Animal Genetics and Biotechnology). Other post graduate students (4 Ph.D. and 1 M.Sc. students) from OAU Departments of Microbiology (Torimiro, 2009), Crop Production and Protection (Oladejo, 2010), 1 from Animal Breeding and Genetics of UNAAB (Adeleke, 2009) and two others from Animal Science of UI, did their protein electrophoretic profiling in this laboratory.

We have characterized different populations of catfish (Nlewadim and Omitogun, 2005) and indigenous pigs using meristic and morphometric characters and SDS-PAGE (sodiumdodecylsulphate-polyacrylamide gel electrophoresis) electrophoretic protein profiling, and DNA microsatellite genetic markers in collaboration with scientists from Spain (Ramirez *et al.*, 2005) and from these data established their genetic relationships or degrees of genetic relatedness and heterozygosities or genetic diversities (Figures 8, 9, 10,11)

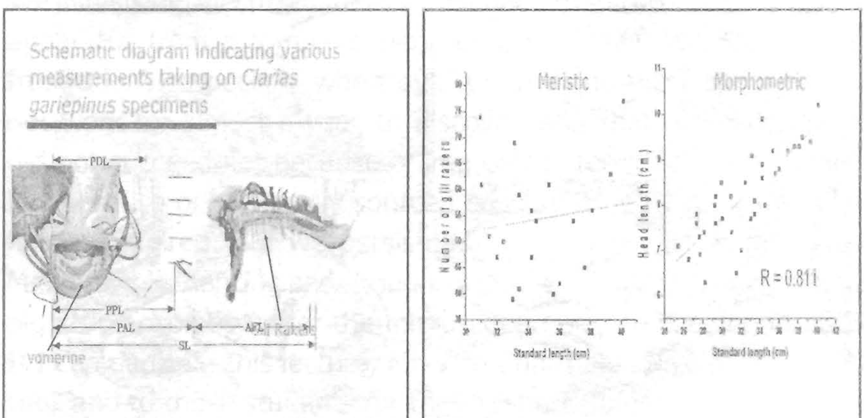
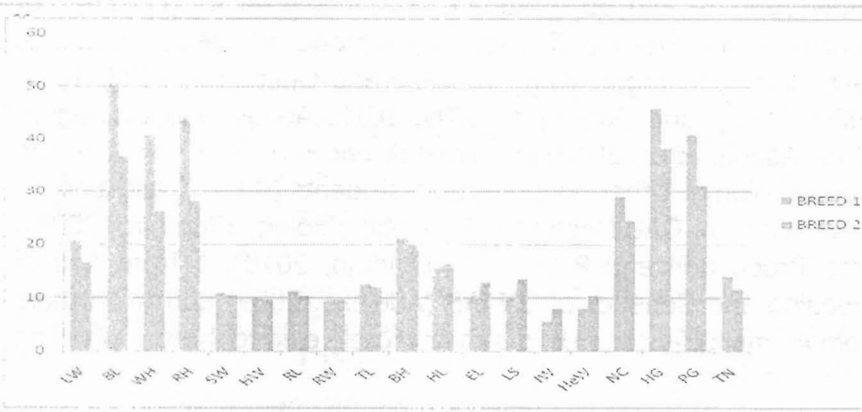


Fig. 8. Morphometric and meristic characters were taken from different populations of African giant catfish (*Clarias gariepinus* Burchell) to compare their genetic diversities (Source: Betiku and Omitogun, 2006)



Breed 1-Crossbred pigs Breed 2-Local breed (from three locations)
LW-live weight; BL-body length; WH-wither height; RH-rump height; SW-shoulder width; HW-hip width; RL-rump length; RW- rump width; TL-tail length; BH-breast height; HL-head length; EL-ear length; LS- length of snout; IW-interorbital width; HeW-head length; NC-neck circumference; HG-heart girth; PG-paunch girth; TN-teat number

Fig. 9. Similarly in pigs from four populations, meristic and morphometric characters were taken to compare pure indigenous breeds and cross breeds.

Fig. 10. After taking the morphological measurements of the pigs, blood samples were taken for SDS-PAGE electrophoresis.

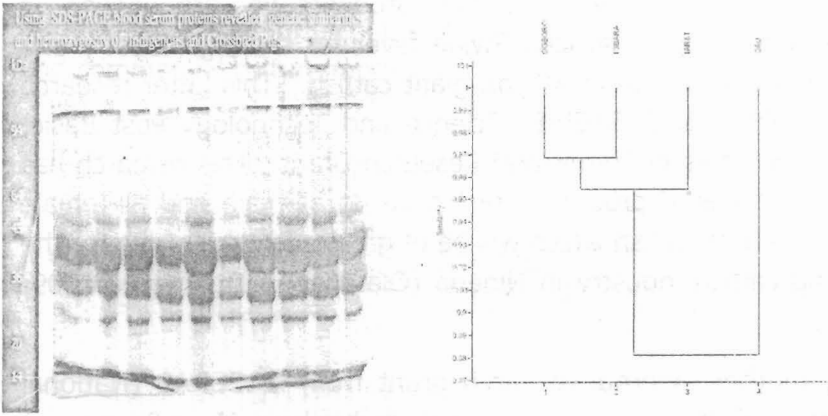
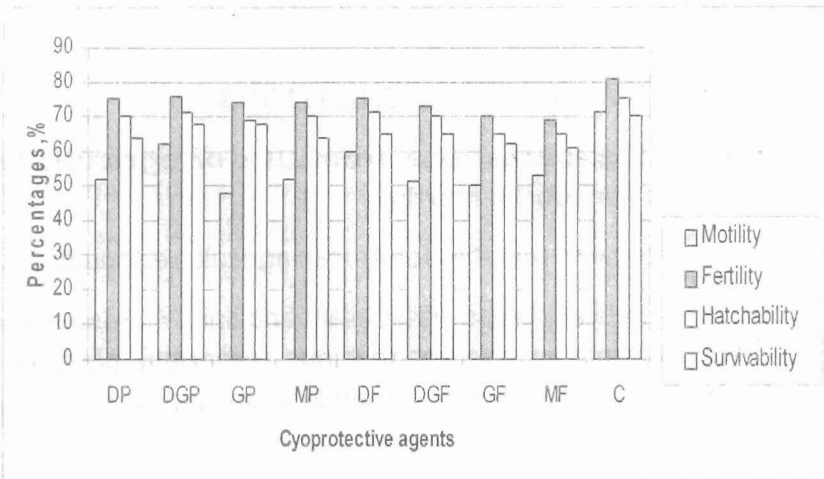


Fig. 11. SDS-PAGE profiles were scored (a) and phylogenetic relationships were determined (b) pinpointing one population in Ogboro that can be used for conservation purposes for the genetic improvement programme planned at IART for indigenous pigs (Adeola and Omitogun, 2010).

All of these students seriously struggled to get chemicals and do photomicrography in various Departments in the University and at IITA, Ibadan. We successfully did 72-h lymphocyte culture without a CO_2 incubator and laminar flow hood using improvised inverted glass aquarium which we fumigated and sterilized with a U.V. lamp. We initially did electrophoresis with a hand me-down electrophoresis apparatus from a former supervisor from Israel. We had a lot of frustrations, especially when our cultures and electrophoresis did not work for almost a year, to discover later that our experiments did not succeed not because of improvised facilities as we thought but because of the locally sourced consumables which were either fake or expired. But we persisted. I remember vividly the joy of Mrs. Oluwole, dancing and shouting when she first saw the indigenous pig chromosomes under the microscope one late evening in 2005. If I can dedicate this lecture, Mr. Vice Chancellor Sir, I dedicate it to URC and to these students for their resourcefulness and resilience.

Currently, I am supervising 2 Ph.D. students who are working on the epidemiology of African Swine fever for the pig industry and genetic manipulation in African giant catfish. This latter research won a World Bank STEP-B (Science and Technology Post Basic) IOT (Innovators of Tomorrow) Research Grant. This research has great potential in producing fast growing all-male and all-female populations of catfish which will be of great economic value for the thriving catfish industry in Nigeria (Olaniyi and Omitogun, 2009; 2010).

With another external research grant from NACGRAB (National Centre for Genetic Resources and Biotechnology, Moor Plantation) Ibadan, we started a cryopreservation research project of Catfish semen in 2005. It was not easy in the beginning doing research without regular water and light supply, but thanks to this NACGRAB and URC grants, we are able to work with available facilities such as a storage water tank which we installed on the roof-top of the Faculty and liquid nitrogen from the Central Science Laboratory. We also procured a stand-by generator. With these grants we were able to construct another fishpond near the dam at the Teaching and Research Farm as well as a catfish hatchery with re-circulating and filtration water system in the Wet Laboratory. What is promising is our research breakthrough to store semen up to 3 to 8 months (Oyeleye and Omitogun, 2007; Omitogun *et al.,* 2006; Omitogun *et al.,* 2010) though with low fertility and hatchability rates which could be improved if liquid Nitrogen is available regularly (Figure 12). Our economic study pointed out that we can sell cryopreserved sperm with a net cost value of ₦100 per 1.5 ml. eppendorf tube compared to the ₦1000-1500 cost of male broodstock (Omitogun *et al.,* 2010). It is the practice of farmers to slaughter male fish breeder for the induced spawning of catfish thus causing wastage of male broodstock and consequent loss of valuable genetic resource. This can be obviated with cryopreserved sperm that can last for months or refrigerated sperm for a couple of days to one week with extenders and commercial culture medium.



DP= DMSO + PBS, DGP = DMSO + 5% glucose + PBS, GP = Glycerol + PBS, MP = Methanol + PBS, DF = DMSO + GFR, DGF = DMSO + 5 % glucose + GFR, GF = Glycerol + GFR, MF = Methanol + DFR and C = Control (fresh sperm used to fertilize the eggs from the same batch)

Fig. 12. Comparison of different cryoprotectants combination on motility, fertility, hatchability and survivability rates. (Omtogun *et al.*, 2010)

One significant output of this cryopreservation research is the extension of the technology to other animal semen like poultry (Adebisi and Omitogun, 2009). This will be useful especially in conservation of indigenous animal genetic resources especially poultry (Woelders *et al.*, 2005) and other mammals that are in danger of extinction or for rare or valuable breeders and broodstock.

Another significant output of my collaboration with colleagues at IITA was a Memorandum of Understanding (MOU) signed in 2006 between IITA and OAU for a joint continuing programme in biotechnology research and teaching. Under this MOU and with financial support from URC and NABDA (National Biotechnology Development Agency), a lecturer of the Department of Crop

Production and Protection was able to conduct his Ph.D. research from 2006 to early 2010 (Opabode, 2010) on cassava starch genetic modification in a world class biotechnology laboratory such as the one at IITA.

CONCLUSIONS AND RECOMMENDATIONS

Priorities and expectations from use of agricultural biotechnology for food security

Biotechnology research priorities for African agriculture should:

- develop genetically broad-based plant and animal varieties and breeds resistant or tolerant to biotic (especially pests and diseases) and abiotic (e.g. desertification and soil erosion) stresses.
- increase efficiency in the conservation and enhanced used for natural resources including genetic resources and systems.
- reduce use of farm inputs such as pesticides and fertilizers.
- develop plants adapted to marginal land and problem soil conditions, and
- test already available genetically engineered organisms for degradation of toxic waste and detoxification of chemical residues on produce or land).

In summary:

"*Biotechnology represents technology in a seed and as such requires little change in cultural perception and agricultural and health practices compared to many innovations brought to Africa in the past ...*

The establishment of an enduring biotechnology for agriculture, food and health industry, indigenous to the region, could be invaluable to development, provided it realises the fruits of the new tools and *products, is mindful of the risks, and embraces the interests and needs of the many",* (Keese P., O.G. Omitogun and E.B. Sonaiya, 2002).

Moreover, agricultural biotechnology must be environmentally friendly and socio-economically viable and attractive (Omitogun, 2010). There are some socio-economic, environment, legal and policy concerns. These include restricted access to biotech products and techniques due to tightening of intellectual property rights, risks, and the widening gap between developed and developed countries in exploitation of the new biotechnologies. There is therefore an overriding importance of sound research and development policies in line with the national development plans.

Nigeria in particular should not lag behind in the application of these novel agricultural technologies and through a national policy that will determine which technology package is suited for the African farmer and environment, and provide financial and infrastructural support for the sustainability of such adapted technologies, Nigeria will not be confined further to the periphery of world development, if not "outside the global gene exchange programme", as Professor. M. Awe of University of Nsukka, lamented.

For Nigeria, one of the top 10 oil producers of the world and known to be endowed with rich natural and human resources, yet lagging behind in the adoption of modern biotechnology tools to improve its food, health, industrial as well as agricultural productivities, it is expedient to implement sound research and development policies in line with the national development plans.

The goal of poverty-focused development should be:

a. intensification- higher output of quality agricultural, food and health industrial products coupled with less wastages and improved penetration into national and'global markets,

b. to ensure responsible stewardship of natural resources including plant and animal genetic resources; while not neglecting

c. to protect and nurture indigenous biotechnology and the critical mass of well-trained Nigerian scientists, technologists and students with the mindset for excellence (and patriotism).

Nigeria should continue to promulgate (or execute through the National Biotechnology Development Agency) the national policy that will determine which biotechnology package is suited for Nigeria and provide financial and infrastructure support for sustainability of such adapted modern agricultural genetics and (bio) technologies to help ensure food security in the country, and feed its own people as well provide food for its hungry African brothers.

For OAU, if we have a Centre of Excellence in Information Technology, we should also have a Biotechnology Resources Centre (since both are engines of modern development as remarked by former President Chief Olusegun Obasanjo in 2005) that will be engaged in Biotechnology Research Innovations for the Growth, Development and Empowerment of Nigeria (which I gave the acronym BRC-BRIDGE Nigeria in a proposal we submitted in 2009 for STEP-B funding). If one day some funds for a kind of research centre like this could be available, it will go a long way in creating a critical mass of future biotechnologists who can do research to enhance agriculture productivity in the country with (bio)technology tools that will ultimately propel the country to industrialization - a parenthesis in the word *"bio"* because biotechnology is interdisciplinary and multidisciplinary which means inputs from engineers, scientists, technologists, social scientists, lawyers, etc. are necessary. Then, OAU can be a pivotal centre of excellence in biotechnology propelling the silver bullet for agricultural productivity in the country.

Mr. Vice Chancellor, Sir, I have many more to say but time will not permit. Please remember many small biotechnology laboratories in many faculties trying to survive and the many postgraduate students especially in science-related faculties who need help.

Thank you for your audience and for listening.

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