TECHNOLOGY TRANSFER AND AGRICULTURAL PRODUCTION

By

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1. Introduction

The definitions of Agricultural Productivity are numerous because of the multidisciplinary nature of the concept. Agriculturalists, agronomists, economists and geographers have defined Agricultural Productivity in different ways based on their views and disciplines. Agricultural productivity is defined in Agricultural Geography as well as in Economics as "output per unit of input" or "output per unit of land area", and the improvement in agricultural productivity is generally considered to be the results of more efficient use of the factors of production, such as physical, socio-economic, institutional and technological.

Technology on the other hand is about the application of science and engineering principles to modify, transform or translocate raw materials into final products which are a lot more refined and more useful to humanity.

When scientific and engineering principles are applied to the processing of materials by biological agents to provide goods and services, that technology is in the strict sense, biotechnology. When such goods and services are in the agricultural or food production sector, then biotechnology narrows down to all aspects of it that can boost food production and prevent hunger. Biotechnology is broadly defined as "any technique that uses living organisms or substances from those organisms to make or modify a product, improve plants or animals, or develop microorganisms for specific uses" (Persley, 2000). This requires the integration of biochemistry, biology, microbiology, chemical engineering, process engineering, together with other disciplines (Fig. 1) in a way that optimizes the exploitation of their potentials (Badejo and Okoh, 2001). A more recent (and less complex) definition of biotechnology is that it is a technique that uses living organisms to make or modify and improve products (Olatunji, 2007).

The roots of Biotechnology were established around 6,000 BC when the Sumerians and Babylonians in the Near East started beer and wine production. Egyptians were baking leavened bread by 4,000 BC. During this period, characteristics of microorganisms were used without any understanding of the processes involved. It was not until the 19th century that Louis Pasteur [1857-1976] demonstrated the fermentative ability of microorganisms. Today, biotechnology has expanded tremendously beyond fermentation processes. Advances in molecular biology, genetic engineering and waste treatment technology have widened the scope of biotechnology. In the agricultural sector, application of biotechnology can be divided into three fields: **crop production, livestock production** and **food processing**. The title of this paper has excluded food processing. As a result, I will be silent on this aspect.

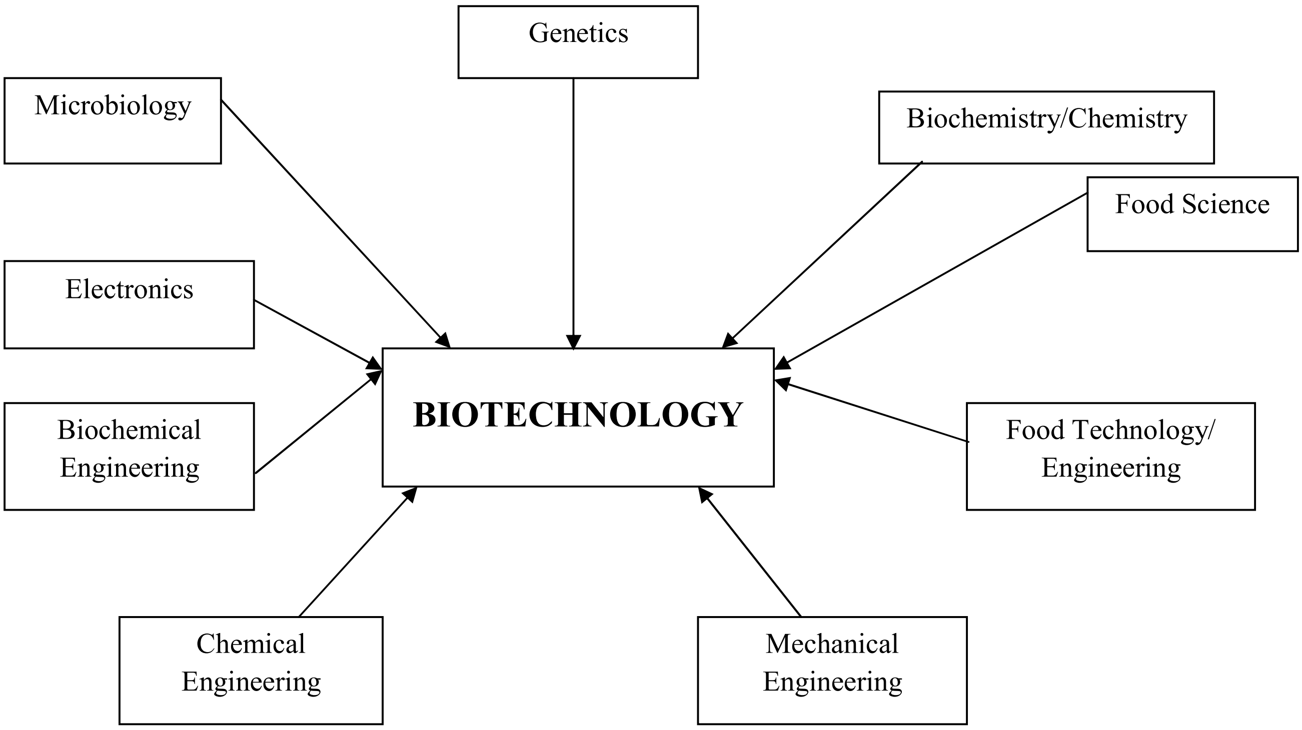


Fig 1. The Interdisciplinary Nature of Biotechnology. [after Lubberding, 1990].

This discourse will therefore focus on the transfer of biotechnological techniques from countries with advanced technologies to countries with less-advanced technologies with a view to querying the rationale behind such transfers against the backdrop of the diverse indigenous biotechnological techniques in such recipient countries on the one hand and providing justification for such transfers where they boost agricultural production without removing the elements of sustainability.

In an earlier paper by Badejo and Okoh (2001), a clear distinction was made between those biotechnological techniques that are completely alien to most developing countries and those that have already been in practice for a long time. Modern and indigenous biotechnologies that produce similar products were compared in order to expose the areas where improvements are needed in indigenous biotechnology. This discourse takes off from where this earlier paper stopped, not as a continuum, but with considerable overlap in respect of the shortcomings of biotechnological techniques which remain unresolved a decade after.

2.0 Crop Production

It is on record that crop production in the world has been enhanced as a result of biotechnological techniques such as tissue culture, microbial inoculation of plants, diagnostic tests, protoplast fusion and plant genetic engineering.

The aim of **Tissue Culture** which was non-existent until the 1950s is to regenerate whole plants from single cells in the laboratory and later transfer the plant to the soil. In meristem culture, embryonic cells at the tip of a plant are isolated and cultivated *in vitro*. This simple technique has been used to micropropagate cultivars and to cultivate virus-free plants from virus-infected plants. It has also been used to improve plants that grow slowly and it has been possible to select cells with specific characteristics from any part of the plant, manipulate the media in which they grow and as a result, produce plants with characteristics different from the parent plant. Tissue culture technology has been tried on more than 50 plant varieties among which are cocoa, grape, lemon, banana, cassava, sweet potato and yam. In many cases, regeneration of whole plants from cells remains elusive. In almost sixty years of tissue culture research which requires absolutely sterile workplace, it continues to remain labour intensive, time consuming and extremely costly. Unfortunately, my position in 2001, ten years ago, that application of tissue culture in developing countries will bring about an increase in the cost of food remains unchanged.

Tissue Culture Technology

The technique of **microbial inoculation of plants** is particularly useful in the areas of improved plant nutrition and pest control. Because soils are often low in nitrogen content, good plant growth often means supplementing soil nitrogen with fertilizer nitrogen which is expensive to produce and therefore too costly for many small scale farmers to buy. Fortunately, some plants can form mutually beneficial relationship (symbiosis) with microorganisms which convert atmosphere nitrogen to ammonia, which is then used by the plants to make protein (Roskoski, 1992). Nitrogen fixing bacteria, mycorrhiza fungi and plant growth-promoting rhizobacteria are various biological agents whose artificial inoculation into the soil can increase the nutrient status of soils. Microorganisms that are capable of fixing atmospheric nitrogen include the blue-green algae (Cyanobacteria); soil bacteria such as *Azotobacter* and *Rhizobium* and Actinomycetes. These nitrogen fixers possess the enzyme nitrogenase, which converts atmospheric nitrogen to ammonia. In order to be able to achieve this, *Rhizobium* enters into symbiotic relationship with leguminous plants from where it receives products of photosynthesis and to which it donates ammonia which the plant uses to synthesize proteins (Dixon, 1987; Postgate, 1990). Artificial inoculation of *Rhizobium* into the soil therefore ensures the synthesis of proteins from atmospheric nitrogen by crops. A study carried out in Obafemi Awolowo University three decades ago revealed that some *Rhizobium* strains increased the yield of some legumes by between 64 and 251% (Odeyemi *et al*, 1982).

It has been suggested (Okafor, 1994) that if nitrogen fixing bacteria could be engineered into tropical cereals and other crops, their yields would increase without the need for the current heavy expenditure on fertilizer importation. The financial gains accruing to those involved in fertilizer importation in some African countries is probably an important factor affecting the exploitation of the *Rhizobium* inoculants alternative.

In Nigeria, nitrogen fixation occurs naturally on a large scale in groundnut, which was an important export crop in the 1960s. Cowpea was also widely grown during this period when Africa contributed as high as 90% of the world's cowpea production (Dobereiner and Campello, 1977). The decline in the production of these leguminous foods in Nigeria has reduced the protein intake of Nigerians where many people have been predisposed to fatal diseases as a result of malnutrition and unbalanced diets (Odeyemi and Okoronkwo, 1985).

Some microorganisms are natural pesticides. *Bacillus thuringiensis* for example is an aerobic spore-producing bacterium, which produces a proteinaceous crystal toxic against many insect species (Davison, 1988; Macdonald, 1989). The fungus *Collectrotrichium gloeosporioides* has also been used effectively as a microbial herbicide in rice and Soya bean farming (Broerse, 1990). *Trichoderma* is a commercially-produced fungal inoculant which is used to control plant diseases caused by root pathogens (Baker, 1989; Campell, 1989). The use of microbial inoculants in pest control is being encouraged worldwide because of its advantages over the use of chemicals. Some of these advantages include low cost of production, low operator risk and less negative impact on the environment. One disadvantage of microbial inoculants is their sensitivity to environmental changes in the field (Broerse, 1990). For example, commercial *Bacillus thuringiensis* spores are inactivated rapidly by sunlight and variations in moisture and temperature in the field could affect the development, invasive ability, virulence and survival of microbial pathogens in agroecosystems (Carruthers and Haynes, 1986). As a result, special protectants and adjuvants have been formulated to prolong the residual activity of various microbial inoculants in the field (Matanmi, 1995). In order to increase the effectiveness of biocontrol agents in the field, research and development on them is top on the priority list of international agricultural institutions. It is pertinent to stress here that research and development on microbial inoculants (natural pesticides) do not cost up to one tenth of the amount spent on chemical pesticides (Broerse, 1990).

Generally, the advantages of microbial inoculant technology, which has not been well developed in many developing countries, are better yields, lower costs and reduced dependence on agrochemicals. Most of them are not difficult to produce. According to Davison, (1988), unsophisticated fermentors of modest volume can be used to produce significant quantities of inoculants whose prospects for improved agriculture in less intensive, low-input agricultural systems are very good.

All I am saying is that unlike tissue culture technology, **microbial inoculation of crops for increased production** is a biotechnological technique whose transfer from countries with advanced technologies to those with less advanced technologies should be aggressively intensified.

Another biotechnological technique of note which employs one of the most technical and complex biotechnological processes is **genetic engineering.** It is simply the direct human manipulation of an organism's genome using modern DNA technology and it involves the introduction of foreign DNA or synthetic genes into the organism of interest. The introduction of new DNA does not always require the use of classical genetic methods. Sometimes traditional breeding methods are used to propagate recombinant organisms. Organisms that are generated through the introduction of recombinant DNA are considered to be genetically modified organisms. In 1972, almost four decades ago, Paul Berg created the first recombinant DNA molecules by combining DNA from the monkey virus SV40 with that of the lambda virus (Jackson *et al.* 1972). In 1973, the first genetically engineered organisms, a bacteria (*E. coli*) was produced/created by Herbert Boyer and Stanley Cohen by inserting antibiotic resistance genes into the plasmid of the bacterium (Cohen and Chang, 1973; Arnold, 2009). A year later, (i.e. 1974), Rudolf Jaenisch produced/created a transgenic mouse by introducing foreign DNA into its embryo, making it the world's first transgenic animal (Jaenisch and Mintz, 1974). In 1976 Genentech, the first genetic engineering company was founded by Herbert Boyer and Robert Swanson. A year later, the company produced a human protein (somatostatin) in *E. coli*. Genentech announced the production of genetically engineered human insulin in 1978 (Goeddel, 1979). Insulin-producing bacteria were commercialized in 1982 and genetically modified food has been in the market since 1994. In 1980, the U.S. Supreme Court in the Diamond v. Chakrabarty case ruled that genetically altered life could be patented (US Supreme Court Cases, 2010). The insulin produced by bacteria, branded *humulin*, was approved for release by the Food and Drug Administration in the United States in 1982 (Time Magazine, Nov, 1982).

If genetic material from another species is added to the host, the resulting organism is called **transgenic**. If genetic material from the same species or a species that can naturally breed with the host is used, the resulting organism is called **cisgenic** (Jacobsen and Schouten, 2008). Genetic engineering can also be used to remove genetic material from the target organism, creating a **knock out** organism (Capecchi, 2001). In Europe, genetic modification is synonymous with genetic engineering while within the United States of America it can also refer to conventional breeding methods (Maryanski, 1999). The term *genetic engineering* is gradually giving way within the global scientific community to more specific terms such as *transgenic* or *cisgenic*.

The most common form of genetic engineering involves the insertion of new genetic material at an unspecified location in the host genome. This is accomplished by isolating and copying the genetic material of interest using **molecular cloning** methods to generate a DNA sequence containing the required genetic elements for **expression**, and then inserting this construct into the host organism. Other forms of genetic engineering include **gene targeting** and knocking out specific genes via engineered **nucleases** such as **zinc finger nucleases** or engineered **homing endonucleases**.

In India, the agricultural development policy up till the 1960s was based on strengthening the ecological base of agriculture and the self-reliance of peasant farmers. In 1961, the Ford Foundation launched an intensive Agricultural Development Programme in this country. The aim of this programme was to "release Indian Agricultural from the shackles of the past" through the introduction of modern intensive chemical farming (Swaminathan, 1983). This marked the birth of the Green Revolution in India. Indian farmers and researchers soon discovered that the native varieties of wheat did not respond well to intensive fertilizer applications. This led Norman Borlaug, the 1970 Nobel Laureate to develop, through plant breeding experiments, high yielding varieties [HYVs] of wheat in India. Borlaug's "miracle seeds" were designed to respond well to chemical fertilizer and they were so successful that they were said to have transformed India from "a begging bowl to a breadbasket". The term high-yielding varieties have been criticized because the new seeds do not produce high yields on their own. The only difference between them and the old ones is that they are highly responsive to fertilizers and irrigation water [Shiva, 1991]. Unknown to the ordinary Indian farmer, water was responsible for a very high percentage of the increased yield of the new HYVs. This is due to the fact that nitrogen uptake by the plants as a result of artificial fertilizer input upsets their carbon/nitrogen balance, causing metabolic problems which the plants react to by taking up more water. Increased yield therefore did not mean increased nutritive value of wheat produced. Within a few years of introduction of Borlaug's HYVs, nearly half of the wheat planted in India came from the new seeds. This reduced genetic diversity in Indian agriculture and made agroecosystems highly vulnerable to pests and disease. Although the marketable output of wheat increased significantly, other outputs, which include using the unharvested biomass as fodder for animals and organic fertilizers for soils, were considerably reduced. There was indeed a decrease in ecosystem productivity due to the over-use of resources.

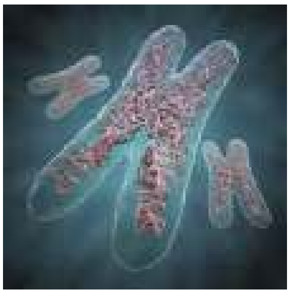
This situation which was regarded as the Green revolution's most celebrated success story turned sour two decades after. The Punjab region in India became riddled with discontent and violence. Instead of abundance, the soils became beset with diseased soils, pest-infested crops, waterlogged deserts and indebted and discontent farmers (Badejo and Togun, 1998). The irony of this is that Norman Borlaug was awarded the Nobel Peace Price in 1970! This situation is not peculiar to India alone. Similar situations have occurred in all nations who jettisoned their agricultural development policies that were based on strengthening the ecological base of agriculture and the self reliance of peasant farmers for the so called "Green Revolution". In spite of all these revelations, Borlaug in 2002 declared that only genetically modified food crops can stop world hunger (Tulloch, 2010).

One of the reasons why Norman Borlaug's invention failed is that local farmers had to be buying seeds every planting season. This is not in line with cultural beliefs in many parts of Asia and Africa. Multinational companies based in countries with advanced technologies benefit from seed trade tremendously. Mander and Goldsmith (1996) had warned that the focus of multinational corporations is profit, not philanthropy, which according to Okoh (2001) has unfortunately been influencing the focus of many research schemes in less developed countries.

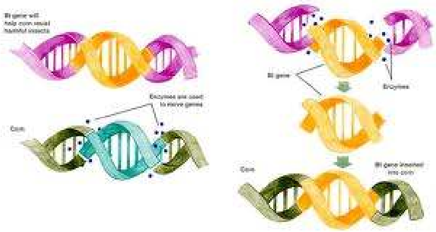
3.0 The many faces of Genetic Engineering

The conventional system of plant breeding to produce HYVs has been replaced by genetic engineering. It starts with DNA extraction and the location of a gene from a plant. Using synthesized antisense-RNA, the expression of this gene is blocked so as to detect its purpose when the phenotype of the plant whose gene is blocked is compared with the one whose gene is not blocked. Thus selected genes can be transferred from one organism to another to produce a desired effect. Since 1983, plant biotechnologists have recorded a high degree of success in transferring single genes that control agronomically important traits such as resistance to viruses, insects and herbicides from one plant to the other (Sasson, 1989). Through this technique of gene transfer, it has been possible to reduce the time-span needed to develop a new plant variety from about 10-20 years to about 5-10 years (Broerse, 1990). This conventional farming will spare the developing world farmers from low productivity, poverty and hunger (Gresshoff, 1996). The problems with the application of this technique in developing countries are enormous. The reagents and enzymes needed are very costly and because of their unstable nature, they cannot be stored for a long time. The laboratory must be well staffed and fully equipped (UNDP, 1989). Such laboratories are mainly located in industrialised countries although their research mandate is specifically directed towards developing countries.

Before the middle of the 20th century, man had harnessed the power of the **atom** in making bombs and generating nuclear energy. The destructive consequences of these inventions of man are well known. By the turn of the century, man had realised the power of **genes** to the extent that if care is not taken, genetic engineering and all its attendant undesirable shortcomings will become a very mainstream part of our lives. The disadvantages of genetic engineering is two-fold:

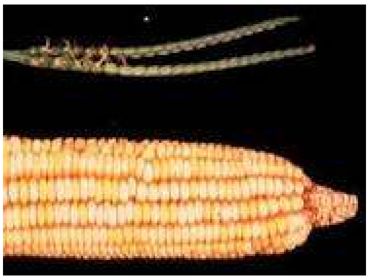


Chromosomes – weapons of Genetic Engineering



DNA Helixes

Danger of Genetic Engineering



High Yielding Variety – Can the grain germinate if planted?

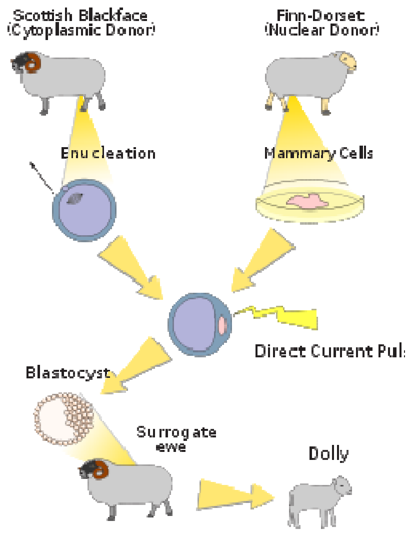
Bizarre examples of products of Genetic Engineering

- Introduction of genetically modified genes may have an irreversible effect **with consequences yet unknown** on the naturally occurring extremely complex inter-related chain which consists of many species inextricably linked in the interwoven food webs in all strata of organismal existence.
- Genetic engineering pre-supposes that man has the right to manipulate the laws and course of nature. The criticism of this border on many moral and religious issues.

This is not to say that genetic engineering does not have its own advantages. Genetic engineering can achieve prevention of disease by detecting people/plants/animals that are genetically prone to certain hereditary diseases, and preparing for the inevitable. Also, infectious diseases can be treated by implanting genes that code for antiviral proteins specific to each antigen. So also, animals and plants can be 'tailor made' to show desirable characteristics. Genes could also be manipulated in trees for example, to absorb more Carbon IV oxide and reduce the threat of global warming. Genetic engineering could increase genetic diversity and consequently biodiversity as more variant alleles which could also be crossed over and implanted into other species are produced.

Genetic engineering is no doubt one of the greatest breakthroughs in recent history. The other two scientific feats performed by man that can rub shoulders with genetic engineering are the **discovery of the atom** and **space flight**. However, the most potentially dangerous for sustainable agricultural production is genetic engineering. Let me share this with you.

- At the Roslin Institute in Scotland, scientists successfully cloned an exact copy of a sheep, named 'Dolly' (July 5, 1993 – February 5, 2003). This was the first successful cloning of an animal, and most likely the first occurrence of two organisms being genetically identical.
- Scientists successfully manipulated the genetic sequence of a rat to grow a human ear on its back. (Unusual, but for the purpose of reproducing human organs for medical purposes)
- Most controversially, and maybe due to more liberal laws, an American scientist is currently conducting tests to clone himself.



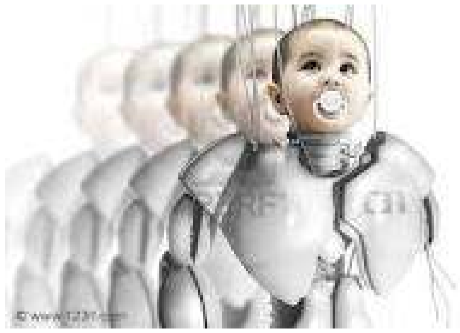
The cloning process that produced 'Dolly'

Dolly's taxidermied remains in the Museum of Scotland

In the UK there are strict laws prohibiting any experiments involving the cloning of humans. I am not sure of the situation in the United States of America. Somebody must stop this scientific madness!

The Bible in *Genesis 1:28*, says humans were appointed by their Creator to rule over *"every living thing that moveth upon the earth"* (*as well as fish and birds* - verse 26). Therefore, if the cloning of animals could benefit mankind (e.g. producing cows that yield more milk that would feed more people), then there seems to be no Biblical reason not to clone animals. On the other hand, cloning of humans is unacceptable for a variety of reasons. The Bible draws a very clear line between the nature of animals and humans. People are created differently ("in the image of God"—*Genesis 1:27*) and separately from the animals. In verses *2:6 and 2:8*, God entrusts humans with dominion over the animals, but humans are never told to have the same kind of dominion over other humans.

Creation of Robots through cloning



Child Robots

Moreover, cloning is in opposition to the Biblical concept of the family. A manufactured human clone could never have two parents. The process of cloning is against the doctrine of the family (i.e. a human being is a product of two other human beings of the opposite sex) as ordained by God in the First Book of Moses *(i.e. Genesis 6:19-20; 7, 1:3;15).*

In a world that increasingly denies the authority of the Bible and its very first book, Genesis, people who view the Creation account as a myth will disregard standards such as the divine institutions of the family and dominion, as well as the sacredness of human life made in the image of God (*Genesis 1:27*). Sadly, human cloning will become more acceptable to those who reject the Creator and His Word.

Reference to human cloning in a discourse on technology transfer and agricultural production is not a digression. Some scientists have mooted the idea of breeding robots to fight in warfronts. If care is not taken, human robots will be candidates for cheap labour in farms. It is therefore deliberate that we all take this pre-emptive step before irreversible damage is done to human existence. Broerse's (1990) declaration that genetic engineering cannot improve agricultural production in developing countries in the short term is still valid. It therefore makes sense for developing countries to focus more on biotechnologies that are not too exotic and can provide short term benefits.

4.0 Livestock Production

Many crop residues and agro-industrial wastes contain heavily lignified fibre, which limits digestibility by acting as a barrier to microbial utilization of cellulose and hemicellulose by microorganisms in the digestive tract of ruminants. This problem can be overcome by degrading the lignin through microbial conversion in the solid state. This biotechnological procedure is called Solid State Fermentation (SSF) and it has been defined as fermentation processes in which microbial growth and product formation occur on surfaces of solid substrates (Sasson, 1989).

SSF is a very simple biotechnological process which performs best under low moisture conditions (Mudgett, 1986). However, technical problems associated with reduction of contamination are yet to be overcome. So also is the problem of huge costs which makes it a non-profitable means of production of animal feed in a country like Nigeria where many fodder grow naturally in the savannah region where livestock rearing is widely practiced (Igboanugo and Badejo, 1998).

Another breakthrough in biotechnology applied in livestock breeding is the production of rDNA vaccines. The Deletion Mutant Vaccine for example removes the gene coding for virulence factors from the genome of a pathogenic organism using restriction enzymes. The organism then becomes non-virulent but it would still be capable of eliciting an immune response (Broerse, 1990). Other rDNA vaccine is about US$ 5 – 10 million and this takes about 10 years! Very few developing countries can afford to invest so much money in this venture. If they do, the cost of meat will be exorbitantly high.

Another technique that has been perfected in the past three decades is Embryo Transfer Technology (ET) (Persley, 1989). ET makes female animals produce more offspring than would be possible with normal reproduction. For example, a cow, which would normally produce four calves in a lifetime, could be made to produce up to 25. This has been successfully practiced by veterinary scientists in Asia and Latin America but the problem of **huge costs** still makes reliance on ET as the hope for increased livestock production in Africa very unrealistic. The problems associated with genetic engineering in animals are more or less the same as the problems in plants. As aforesaid, the first gene transfer was done in the mouse in 1980 and since then, researchers have worked successfully on a variety of mammals, birds and fish (Persley, 1989). Other techniques such as hormone treatment, protoplast fusion and various diagnostic tests involve sophisticated genetic manipulations. It is unlikely that application of these techniques is feasible for large-scale application in developing countries not only now but also in the future.

5.0 Development of Biotechnology in Nigeria

It was only recently that there was a spirited effort by the Federal Government of Nigeria to regulate and control biotechnological research in the country. The National Biotechnological Development Agency (NABDA) was established through Federal Executive Council approval on the 23rd of April, 2001 with the following vision, mission and mandates:

VISION: To employ biotechnology for economic development and poverty alleviation in Nigeria.

MISSION: To promote biotechnological activities that would positively meet national aspiration such as food security, job/wealth creation, affordable health care delivery and sustainable economic environment.
MANDATES: To coordinate, promote and regulate the development of biotechnology in the country. Specifically, the Agency is to, among other things:

- Develop an indigenous critical mass of human resources and infrastructure for biotechnology in Nigeria.
- Develop sustainable exploitation of bioresources for our food & Agriculture.
- Develop mechanism for adequate funding of biotechnology activities through national and international funding Agencies.
- Promote indigenous competence in the development and application of biotechnology-based products and services.
- Develop framework for ethical and profitable uses of biotechnology-based products and services.
- Develop viable and commercial biotechnology and technologies through strategic investments in biotechnology R & D to support innovation and economic development.
- **Promote national and international collaboration between government/agencies and all other stakeholders and interest groups on matters relating to the development of biotechnology.**
- **Develop mechanisms and activities to support the emergence of biotechnology enterprises for the commercialization of biotechnology products.**
- **Develop appropriate legislations, compatible with international regulations, to promote biosafety, social and ethical use of biotechnology and to protect intellectual property, industrial property and farmers' rights.**

I am highly skeptical about the last three mandates not because they are not desirable but because they could be wrongly pursued to the detriment of sustainable agricultural production in this country. Novices could hide under these mandates to encourage the transfer of inappropriate biotechnology into the country with its attendant disastrous consequences. I have no doubt in my mind that the current leadership of NABDA is up to the task in ensuring biotechnological development in Nigeria.

I have visited the website of NABDA and I have seen that the activities of the agency are focused on cutting-edge biotechnology that would promote a healthy environment, ensure national food security and provide affordable health care delivery as well as the alleviation of poverty. The current emphasis on pharmaceutical research should shift to food security because when people are dying of starvation, administration of drugs may be ineffective. Food is the best preventive medicine in the world.

6.0 Technology Transfer as an aspect of Knowledge Transfer

At this juncture, I would like to divide state-based economies in the world into two categories: knowledge based economies with no natural resources; economies with abundance of natural resources but lacking in such capabilities as to exploit knowledge. The former are by far richer than the latter. Singapore is a typical example of the former, while Nigeria represents the latter. In Singapore, agricultural activities are nil. Their wealth is from manufacturing of goods and materials from raw materials that do not grow or are not exploited from their soil. In Nigeria, agriculture was the mainstay of our economy before oil was discovered. There is abundance of natural resources but the knowledge to take maximum advantage of these resources is lacking. Hence the need to import this knowledge from other countries to Nigeria.

Several models of knowledge transfer and utilization have been proposed by organizational learning experts. Nonaka (1991) has postulated that there are two types of knowledge: tacit and explicit. **Tacit** knowledge is subjective and experience based knowledge that cannot be expressed in words, sentences, numbers or formulas, often because it is context specific. This also includes cognitive skills such as beliefs, images, intuition and mental models as well as technical skills such as craft and knowhow. It cannot be codified.

Explicit knowledge is objective and can be codified. It is rational knowledge that can be expressed in words, sentences, numbers or formulas (context free). It includes theoretical approaches, problem solving, manuals and databases. The Nonaka model sees knowledge transfer as a spiral process. Starting with a 2x2 matrix, in which existing knowledge can be in either form - tacit or explicit - and the objective of knowledge transfer can be to convey either tacit or explicit knowledge. Each mode of transfer operates differently.

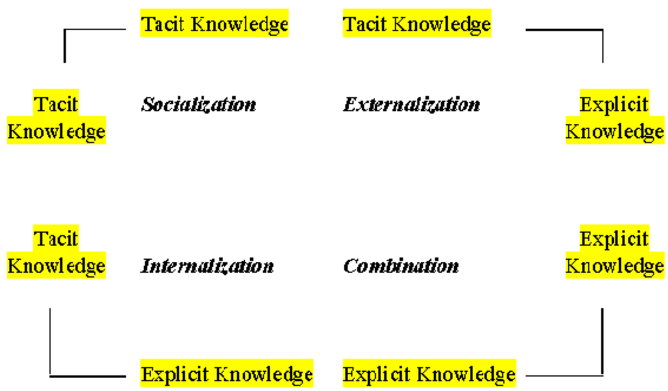


Figure. 1. Nonaka's Spiral of Knowledge

Other Models include the Research, Development, Diffusion (RDD) models, the Problem-solving models, the Linkage models and the Social interaction models.

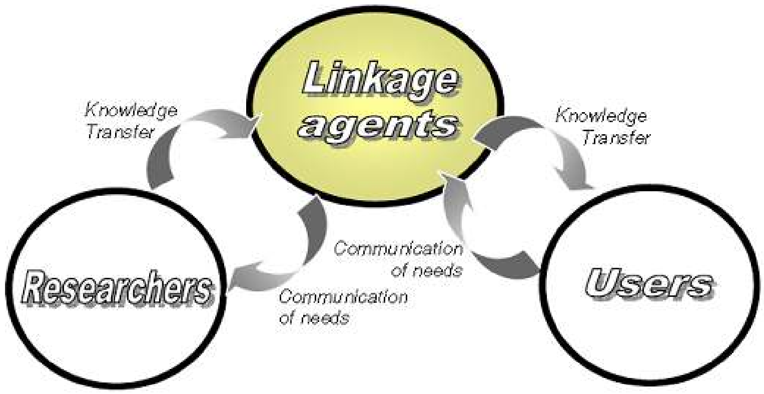


Figure 2. The Linkage Agents' Framework

All the stakeholders involved in transfer of technology from developed economies into Nigeria should first of all be tutored in these basic rudiments of knowledge transfer either formally or informally. Knowledge management literatures abound in our libraries and of course on the information superhighway i.e. the Internet. It is only when these basic rudiments are known by all that the risk of embracing inappropriate technology will be minimized.

Nations have boundaries but technology has no finite limit. Nine hundred million people live in developed market economies in comparison with over 5 billion people in developing countries. In recent years, the uneven record of countries in achieving technological and economic transformation has left many questioning how effective knowledge transfer has been and can be. Fostering knowledge transfer between Nigeria and the developed world has been through technical cooperation and research-based development between multilateral institutions, governments and the private sector. These have either not achieved the desired result or are potentially capable of achieving undesired results such as transfer of inappropriate technology. The current high-profile approach is doomed to fail not only because it is expensive, but also because it ignores local wishes and lacks tangible outputs. In a developing country like Nigeria, there are often two systems of knowledge and production operating in parallel: indigenous and modern. When new knowledge is not integrated into indigenous knowledge or production systems, it fails to be useful, despite its potential.

Going back to the Nonaka Model. Transfer of tacit knowledge can be achieved between individuals through socialization. Socialisation involves capturing knowledge by direct interaction with people inside and outside the organization where that knowledge is applied. This depends on having shared experience, and results in acquired skills and common mental models. This is more or less how the Japanese had their breakthrough in the world of electronics and automobile manufacture. The Prime Minister of Japan did not book a state banquet with the President of the United States of America before Japan acquired knowledge from America. A short specialized training in appropriate biotechnology for tropical countries in a laboratory abroad by a right-headed Nigerian could lead to a breakthrough in food production in Nigeria!

Twenty countries have been rated high in respect of "knowledge index" (Table 1). None of these 'Frontier" countries is in the tropical belt. The second group of "Fast followers" consists of 15 countries most of which are in Eastern Europe. Only three countries in this group are from the tropical belt i.e. India, Mexico and Brazil. The third group which is also described as "Fast Followers" consists of 25 countries out of which only three are in Africa (i.e. South Africa, Tunisia and Egypt). Nigeria belongs to the last group of "Lagging Followers" which consists of 13 countries in the tropical belt. This categorization of countries as presented in this table reveal clearly the tropical countries that Nigeria can learn from.

Why is Nigeria a "Lagging Follower"? It is because we have either not benefited from knowledge transfer from the Frontier countries or because the knowledge we received from them is completely useless in respect of the peculiarities of our situation. Of what use is a farmer who wants to adapt the technique of wheat farming in the flat landscape fertile lands of Europe to tomato farming in the undulating landscape and inherently infertile tropical soils? Based on my research experience, **Brazil** and **Malaysia** stand out as tropical countries that we can benefit from in respect of agricultural production and sustainable development.

Table 1. Group Description of Knowledge Index. **(Modified from Jegede (2011).**

Group I	Group II	Group III	Group IV
1. United States	**21. India***	36. Ukraine	61. Kazakhstan
2. Japan	22. Portugal	37. Croatia	62. Moldovia
3. Swedeen	23. Ireland	38. Pakistan	63. Kyrgyz Rep.
4. Germany	24. Poland	**39. Malaysia***	64. Guatemala
5. Switzerland	25. Hungary	**40. South Africa***	65. Peru
6. France	26. Slovenia	41. Bangladesh	**66. Nigeria**
7. UK	27. Turkey	42. New Zealand	67. Panama
8. Canada	28. Australia	43. Belarus	68. Azerbaijan
9. Italy	29. Czech Rep.	44. Thailand	69. Syria
10. Finland	**30. Mexico***	45. Estonia	70. Ecuador
11. Israel	31. Slovak Rep.	**46. Tunisia***	**71. Gabon**
12. Rep. of Korea	32. Greece	47. Phillipines	**72. Benin**
13. Austria	33. Romania	48. Russian Fed.	**73. Congo Rep.**
14. Hong Kong, China	**34. Brazil***	49. Lithuania	
15. Belgium	35. Bulgaria	50. Latvia	
16. Spain		**51. Jamaica***	
17. Netherlands		52. Jordan	
18. China		53. Argentina	
19. Norway		**54. Egypt***	
20. Denmark		**55. Indonesia***	
		56. Costa Rica*	
		57. Vietnam	
		58. Colombia	
		59. **Chile***	
		60. **Venezuela***	

* Countries that Nigeria as a state can learn from.

A situation whereby our President sits in a banquet with the President or Prime Minister of a developed economy (Frontier country) discussing transfer of technology is a good demonstration of the PNP syndrome. The PNP syndrome is a socio-clinical situation where a **P**sychotic builds his castle in the air, the **N**eurotic lives in this castle and the **P**sychiatrist collects the rent (Dr. Adegoke *pers comm*.).

7.0 Evolution of transfer of agricultural biotechnology from developed to developing economies

Bonanno *et al.* (1994) wrote a book on the globalization of agriculture and food. In this book, Christopher Columbus a 15th Century voyager and ConAgra, an American Food packaging company which has been established since 1919 were regarded as two "temporal poles". Columbus symbolizes the era of world explorations during which the global system was established; while ConAgra represents the new emerging global actors - **Transnational Corporations (TNCs)**. Though they are not the only players in the new global economy, TNCs are already the most influential actors in the reorganization of the socio-economic system and are major forces of change. If the era of Columbus is long gone, its legacy remains in the era of ConAgra.

In what appears as a rejoinder to this book, Silva (1997) revealed how over time the degree of development-underdevelopment of science and technology has influenced the strategies used by developed countries to benefit from developing countries' weaknesses built by the scientific and technological gap between them; from the era of economic botany, to the era of agricultural chemistry, to the era of Mendelian genetics, to the era of molecular genetics (Silva, 1996).

According to Silva (1997), *"International cooperation is a complex, multidimensional process. Hence, it is vulnerable to many environmental, social, economic, political, technological, institutional, legal, and ethical conflicts which always emanate from international relations. Unfortunately, not all actors involved in the process are aware of the dialectical interplay between economic as well as political forces shaping it. In developed and developing countries, too many managers and scientists integrating the international cooperation community are naive enough to believe that everything they do is for the good of all societies involved. This false premise has led to many false promises. There are too many contradictions denying the "ideology of philanthropy" which has permeated international cooperation since colonial times."* Many of the present international inequalities which lead to transfer of nothing but wealth from developed to less developed economies have their genesis rooted in the nature and form of lopsided operations from the network of botanical gardens in the time of Christopher Columbus, to the network of agricultural experiment stations in the 19th and 20th centuries, to the present day network of international agricultural research centres and transnational corporations.

In summary, International cooperation may have evolved from the fish-giving model of the medieval, to the seemingly hook-giving model of our own time, but definitively not to the transfer of the art of hook-making model. Over time, we have evolved from the era of exploitation, to the era of cooperation and convenience, to the era of cooperation and competition which has led to many contradictions (Silva, 1997). No developed country will provide technical assistance to a less developed country to the point of the less developed country holding equal scientific and technological capacity and as a result become a competitor.

8.0 Biotechnology, Hunger and the Environmental Question

In the Inaugural Lecture which I delivered on November 09, 2004, I declared that the notion that biotechnology is the magic bullet solution to all of agriculture's ills is not true (Badejo, 2004). The claim by biotechnology companies that genetically altered seeds are essential scientific breakthroughs needed to feed the world, protect the environment and reduce poverty in developing countries has been challenged (Altieri and Rosset, 1999). The prevalence of hunger in a country has nothing to do with the size of the human population. For every densely populated and hungry nation like Bangladesh or Haiti, there is a sparsely populated and hungry nation like Brazil and Indonesia. There are empirical data to confirm that the world today produces more food per inhabitant than ever before. Enough food is therefore available for the world's teeming population. Yet over 14 million people are faced with starvation as a result of sharp declines in food production in their agroecozones due to a variety of ecological factors such as drought, flooding and a variety of political, social and infrastructural factors (Silva, 1997). The real causes of hunger are poverty, inequality and lack of access to food. Too many people are too poor to buy the food that is available that is not evenly distributed globally. Very many people lack the land and resources to grow food themselves (Lappe, *et al*, 1998). Any promise from a developed country to a less developed country that freedom from hunger can be achieved through imported technological revolution in agriculture involving transfer of the scientific wonders of modern biotechnology is false. It is a false promise based on false premise (Silva, 1997). Production technology can never replace distribution policy! If the global distribution policy as disjointed and uncoordinated as it is today cannot guarantee access to excess food produced in the world today to all the citizens of this world, irrespective of their geographical locations, what can biotechnology do?

Moreover, genetically engineered plants have been planted on many millions of hectares globally without proper biosafety standards (Altieri and Rosset, 1999). Ecological theory predicts that the larger scale landscape homogenization with transgenic crops will exacerbate the ecological problems already associated with monoculture agriculture. Unquestioned expansion of this technology into developing countries may not be wise or desirable. There is strength in the Agricultural diversity of many of these countries, and it should not be inhibited or reduced by extensive monoculture, especially when consequences of doing so result in serious social and environmental problems (Altieri *et al*, 1998).

The ecological risk posed by products of biotechnology has not been receiving adequate attention globally. Funds for research on environmental risk assessment are very limited. For example, the USDA spends only 1% of the funds allocated to biotechnology research on risk assessment, about $1-2 million per year. Given the current level of deployment of genetically engineered plants, such resources are not enough to even achieve adequate results. If more funds are made available for agroecologically based agricultural research, such funds would be directed towards finding lasting solutions to all the biological problems that biotechnology is trying hard to solve. More importantly, publicly controlled regulatory regimes for assessing and monitoring the environmental and social risks of biotechnology industry should be put in place so as to ensure public interest and safety, as against profit.

More food can be produced by small-scale farmers located throughout the world using agroecological technologies (Uphoff and Altieri, 1999). In fact, new rural development approaches and low-input technologies spearheaded by farmers and NGOs around the world are already making a significant contribution to food security at the household, national and regional levels in a few countries in Africa, Asia and Latin America. Yield increases are being achieved by using technology approaches that are based on agroecological principles {van der Werf, 1998a & b; Badejo (1998)}, that emphasize diversity, synergy, recycling and integration as well as social processes that emphasize community participation and empowerment (Rosset, 1999). When such features are optimized, yield enhancement and stability of production are achieved, as well as a series of ecological services such conservation of biodiversity, soil and water restoration and conservation, improved natural pest regulation mechanisms as highlighted by Altieri *et al*. (1998).

9.0 Biotechnology and the Concept of Sustainable Agricultural Production

What does sustainable agricultural development mean? Or better still what does sustainability imply? Is it logical? Is it attainable or achievable? Does it make sense? These are the myriad of questions I faced in the late 1980s and early 1990s at brainstorming sessions even among the academia. Fortunately, virtually everybody is now familiar with this concept. As a result, questions have shifted to: How can we achieve sustainability in a situation where we have to exploit the resources to our maximum advantage?

I had to embark on a trip into the realm of Philosophy to be able to answer these questions. According to Oke (1998), *"if a given human population, say **x**, requires **y – 1** quantity of a certain crop at a given time and **z** production technology is used in meeting **y** quantity in such a way that this **y** quantity is within the carrying capacity of the production base that* *can potentially accommodate a steady growth in **x** in perpetuity, then **z** technology could be said to be sustainable. The central idea in the foregoing context can be read mutatis mutandis into other contexts such that we can take as the essence of the term 'sustain' the idea of 'keeping going', the idea of continuation. Two concepts derived from the word 'sustain' which are relevant for our purpose here are those of 'sustainability' and 'sustenance'.*

'Sustainability' is a nominalised derivative of the adjective 'sustainable' which itself is derived from the verb 'sustain'. From the meaning of 'sustain', to be sustainable means to have the quality, nature of characteristic of being sustained. That is, that which is sustainable is that which can be sustained. The desire to sustain a thing, an action or a state may thus be impossible to realize if that thing, is that which by its nature cannot be sustained. We can say, then, that to be sustainable is to be possible to sustain. The possibility of sustaining a thing, as well as the impossibility of sustaining it can, however, be seen in two main dimensions – the logical and the empirical.

*Although something which is logically possible to sustain may be empirically impossible to sustain, whatever is logically impossible to sustain will be empirically or practically impossible to sustain. Logical impossibility thus connotes inherent or necessary impossibility. ... empirical possibility deals with matters of fact, knowledge of which arises from and is grounded in sense experience. … So conceived, empirical possibility is not conceptually or analytically determined. Hence, the empirical possibility or impossibility of **x** can be consistently denied without contradiction. Whether **x** is realized empirically or not, therefore, depends ultimately on whether or not the relevant empirical conditions for its possibility obtain or not. This is in addition to **x**'s logical possibility status.*

To claim that what is logically impossible is possible will be a self-contradiction which, according to Kant (1781) is the epitome of irrationality. Such a self-contradictory claim can be summarily dismissed by those who can analyse well the claim's component terms to exhibit the claim's inherent defect. Only fools and idlers will engage themselves in what is clearly unthinkable and logically impossible. This will be tantamount to trying to deny the logical law of thought called Modus Ponens (Black, 1946 and Copi, 1972).

*On the other hand, to claim that what is empirically impossible is empirically possible will be a distortion of reality as it is currently conceived. Such a distortion of reality is called an illusion or myth. ... Sustainability is, as we have analysed it, a dispositional term, a state of possibility and a conditional state. It thus pertains, veiledly ambivalently, to states into which a thing can enter, or at which it can be, as well as those it can actuate. Thus, the sustainability of **x** can be understood both as the possibility of **x** to be sustained, and as the ability of **x** to sustain or to give sustenance to either itself or to **y**.*

Agricultural lands are an inexcisable part of nature which is knowable only empirically and therefore can never be completely known at once. Every element, as well as every form of life, involved in an agricultural land is known empirically to be perishable and exhaustible. Thus, plants and plant life, animals and animal life as well as relations existing between the elements, logically can cease to be. In fact, they have always been ceasing to be in one form or another, over time as experience reveals to us, both qualitatively and quantitatively. This feature of mutability of existence in rerum natura implies the contingency of life in that realm. Thus any existing agricultural land is only an accident. It is possible that it did not exist, either at all or as it existed or exists. This means that under a different set of conditions, an existing system might never have existed, or might go out of existence, or might undergo theoretical limitless changes both in quality and quantity of its components. This implies that there is no necessity in nature. The origination, existence, sustenance, improvement, decay, degeneration and cessation of anything or phenomenon in nature are all not unconditional. There cannot, therefore, be a logical dismissal of the possibility of anything, process or phenomenon in nature. It is therefore, logically possible to sustain any natural system or situation or modifications of it. This however is not to say that any system or situation ***will*** *be sustained or* ***should*** *be sustained, 'Can' does not here imply 'will' or 'ought'.*

All agricultural lands are uncontroversially ultimately modifications of natural environments. They are, therefore, logically possible to sustain. It will thus not be a logical contradiction to say that an agricultural system is sustainable. Similarly, it will not be logically contradictory to deny the sustainability of an agricultural system. Thus, since the sustainability of an agricultural system is not logically necessary, the claim of sustainability is not self-evidently or analytically, absolutely or unconditionally true. The claim is one about which experts can intelligibly, and not merely verbally, disagree. In this regard, the empirical conditions of sustenance constitute the truth-functions of the claim of sustainability. These conditions are those which natural scientists should discover, specify, investigate, simulate and actuate in varying circumstances.

From the foregoing one can validly conclude that the concept of sustainability in agricultural lands is realistic. The concept is neither logically invalidated nor empirically empty. As a concept, sustainability in agroecosystems is both rationally intelligible and empirically investigatable. It will therefore, not be an exercise in futility or absurdity to want to embark on a study of how agricultural lands could be sustained.

Agricultural lands, as modifications of natural systems, are viable not only in thought but also in reality. The idea is concretely rooted in physical experiences and observable data. Having established the possibility of the end or goal, it is now left to researchers to provide the means or methods for sustaining any given agricultural land.

Experience has shown that if they are not continually maintained, things and systems in nature could deteriorate. This must have been observed about the agricultural lands to have given rise to the question of whether and how such systems could be made to continue to function indefinitely without regression in either quality or quantity. A primary and ultimate challenge of man is therefore how to break nature's tendency to self-destruction so that the continued existence of the human race could be guaranteed with an ever-improving quality of life. This draws attention again back to the issue of **global food security**.

The task of preserving the human race and raising the quality and span of life is solely that of man himself. Man has to help nature to help him. To sustain himself, man has to help nature to sustain itself. Man, as the sole dynamic self-conscious force in nature and the causative agent in development, must devise effective and efficient ways of controlling nature, by prodding it, pleasing it, soothing it and cooperating with it, so that it could remain sustained for the continued sustenance of man. This should be the beginning and the end of our sciences. Doing this well will guarantee that conditions which are inimical to the sustenance of our agricultural lands and ultimately to our own survival are not allowed to occur or where they occur, they are not allowed to persist. The conceptual reality of sustainability in agricultural lands will therefore become a practical reality only when human beings take their collective destiny in their own hands and promote only those conditions that will enhance their survival.

Finally, we are not to expect that nature is aware of our desire to survive or that it will freely work for the realization of that desire. We are to acknowledge that nature might be inclement to us and obstructive of our desires. We must, therefore, accept it as our responsibility and destiny to make nature supportive of our desire for survival. We must therefore tenderly lobby Nature, coax it, persuade it, cajole it, entice it, placate it and exploit it without corrupting it, all in ways that will have to be clearly worked out and diligently followed by all. These ways must definitely exclude transfer of inappropriate technology from developing economies to less developed ones in whatever form.

10.0 Conclusion

It has been demonstrated in this discourse that not all modern techniques of biotechnology in **crop and livestock production** are desirable in developing countries. **Microbial inoculation of crops** is a biotechnological technique whose potential for **increased agricultural production** should be aggressively intensified as opposed to tissue culture, genetic engineering and solid state fermentation whose technical problems, high cost of operation and inability to ensure sustainability make them highly undesirable. It is recommended that Nigeria and other developing countries should as a matter of priority and expediency identify other areas of appropriate biotechnology that could be improved upon to be synergistic with our indigenous biotechnology so that the gains of the exercise will be affordable to the present citizenry as well as future generations. A sustainable agricultural system must be **ecologically sound, economically viable, and socially responsible**. These three dimensions of sustainability are inseparable, and thus, are equally critical to sustainability on the long run. The issue of biotechnology transfer should also be approached by government agencies with caution by employing simplistic means such as the Nonaka Model rather than bogus bureaucratic and extremely costly options that will never produce any results in favour of the recipient country.

Finally, just as governments of developing countries should be looking for non-exotic ways to boost agricultural production in their localities, there should be a concerted global effort to **"remake the world"** by distributing excess food evenly throughout the globe so that such excesses are accessible to those who by reasons which may not be their fault have unproductive agricultural lands.

That famous Jamaican born musician, Jimmy Cliff, has summarized it all in his 1975 song "Remake the World"

"Too many people are suffering
Too many people are sad
Too little people got everything
While too many people got nothing

Remake the world
With love and happiness
Remake the world
Put your conscience in the test
Remake the world
North, south, east and west
Remake the world…"

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