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Case Study

The current status of cereals (maize, rice and sorghum) crops cultivation in Africa: Need for integration of advances in transgenic for sustainable crop production

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Adebayo Oluwakemi O.
and
Ibraheem Omodele*

Department of Biological Sciences, Landmark University, Omu-Aran, PMB 1001, Kwara State, Nigeria.

*Corresponding Author Email: deleibraheem2007@yahoo.com
Tel.: +2348139427707

Cereals still remain the most consumed staple food in homes of most African countries. African production of majorly consumed cereals such as maize, rice and sorghum, is not proportional to the demands, hence they have to be imported from other continents like Asia, America, Europe or Australia. Africa natural resources and climate that favor more biomass production than most other continents; vast arable land and relatively cheap and abundant human work force are current been under utilized. Although the amount of land devoted to cultivating cereals is increasing, it has not translated into increase crop yield due to environmental factors such as drought, high soil salinity, diseases and pests activities, and poor field and crop management. The traditional farming practices have done little in overcoming these challenges, thus the need to exploit the enormous advances in molecular and biotechnological transgenic approaches in order to produce crop varieties that will be able to cope under these adverse circumstances and produce better yields. This article thus showcases how this could be achieved in Africa.

Key words: Abiotic stress, biotic stress, genetically modified crop, malnutrition, poverty, cereal production, cereal consumption, cereal export, cereal import

INTRODUCTION

Cereals belong to the monocotyledon family Poaceae (Cereals; http://en.wikipedia.org/wiki/Cereal). They are group of grass crops that produces edible grain seeds, and are made up of endosperm composed of the carbohydrate molecules, germ (embryo) that contains the genetic contents and bran (seed coat) made contains the proteins and other essential vitamins; (Figure 1). Thus cereals and cereal-based foods are rich sources of energy, protein, vitamins, and minerals for wide world population (Cereals; http://en.wikipedia.org/wiki/Cereal).

Among the world cultivated cereals are maize, wheat, rice, barley, sorghum, millet, oats, rye, triticale, buckwheat, fonio and quinoa (Cereals; http://en.wikipedia.org/wiki/Cereal). However only maize, rice, sorghum, millet and fonio are well suited for cultivation in Africa; other cereals have to be imported from neighboring continents. Even with this, Africa production of these cereals cannot meet up with the growing demands for food in the continent. This may have been well connected to Africa ever growing uncontrolled population, inadequate man power and non availability of technologies for mechanized farming, changes in geographical terrain and increasing soil infertility, non availability of irrigation systems and current global climate change that has altered farming seasons.

Maize, rice and sorghum are dated to have originated from Central America, Asia and Africa respectively. Maize and rice were as cultivated since 4,500 BC (Before Christ) while sorghum was as far back as 4,000 BC (History of Agriculture;http://en.wikipedia.org/wiki/History_of_agriculture). Maize (also referred to as corn) is the most staple food for vast majority of Africans and it provides a great

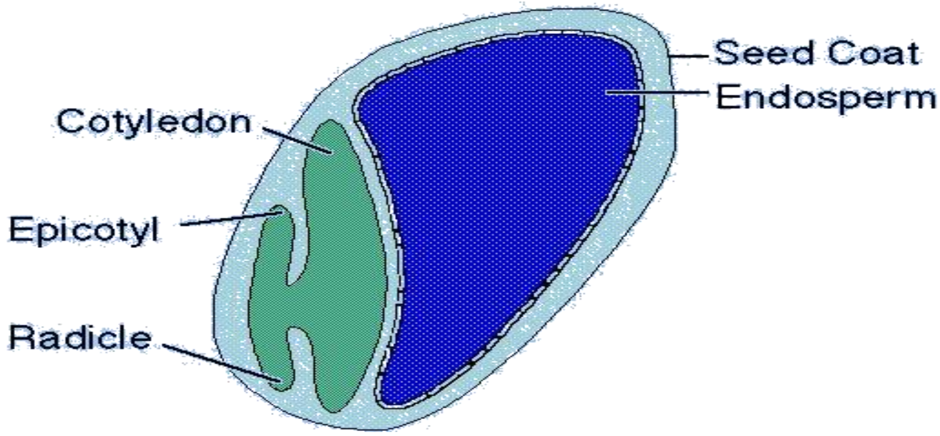

Figure 1: A typical structure of a monocotyledon seed (Adapted from Koning, 1994)

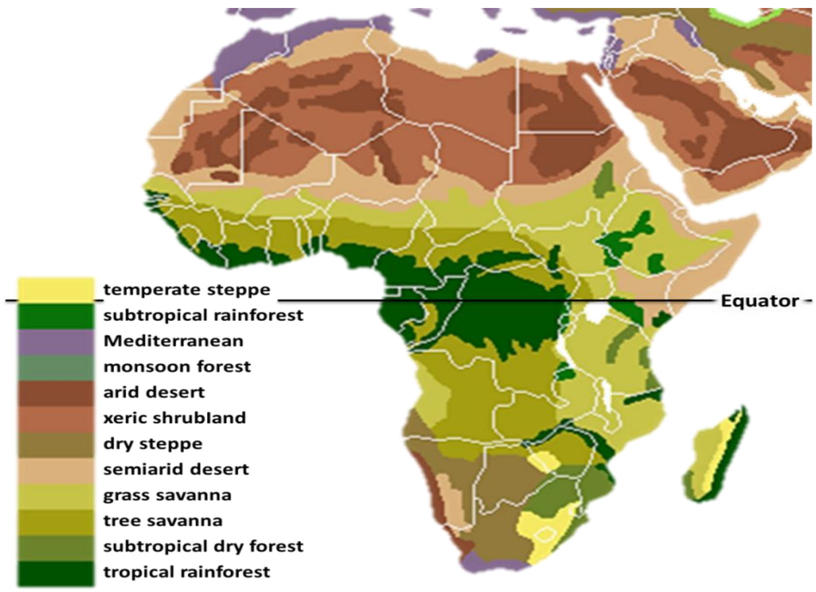

Figure 2: The various types of vegetation in Africa (Wikimedia: Vegetation in Africa; http://commons.wikimedia.org/wiki/File:Vegetation_Africa.png)

source of carbohydrate, protein, vitamins and minerals. It is also widely used in animal feed and used for various industrial applications. Rice is also widely consumed like maize, and its said to account for about 1/5th of all calories consumed by humans and its consumption is becoming more popular among Africa indigents as maize current is been used for bioethanol production (Asif and Muneer, 2007). Although Africa production of sorghum is gradually reducing, it is still said to be the 5th and 3rd cultivated world and Africa cereal crop, respectively (Anglani, 1998). Sorghum is well adapted to Africa arid regions that are prone to harsh weather conditions, as it can tolerate harsh environmental conditions such as drought, salinity and high temperature (Anglani, 1998).

The rapidly ever growing Africa population also demands increase in food supply to meet up with this challenge. Its been predicted that by 2050 Africa population is expected to double by increasing from about one billion to about two billion, and out of the ten countries in the world with very high average annual growth rate, eight are in Africa (World Population; http://en.wikipedia.org/wiki/World_population). Thus Africa as a continent needs to act fast in ensuring future higher food demand is met by sufficient supply.

Africa has well diverse soil vegetation and climatic conditions that could support numerous cereal crops (Figure 2; Reader, 1998). This is divided into highly productive agricultural zones where there is favorable and reliable rainfall, doesn't get too cold and thus are able to produce cereal crops at enormous quantity. Examples are the tropical and sub-tropical rain forest and sub-tropical dry forest. The second zones have flexible climates and could support various varieties of cereal crops (depending on their adaptation and tolerance to the climatic conditions), such as drought adapted cereals (sorghum) or cold adapted cereals (wheat, barley). Examples are the tree and grass savannah, temperate and dry steppe, Mediterranean, semi-arid and arid desert.

Africa often suffers drought episodes in the arid desert region leading to excessive crop loss and consequently lower yield. Only cereals that are drought resistant or tolerant could only survive and are thus the mostly cultivated in this region. Example of such is sorghum, and some drought tolerant maize and rice.

World versus Africa cereal production, consumption, export and import

Agriculture remains the oldest profession that sustains human existence. Without agriculture there is no food, nothing for human to feed on and consequently no life. Maize, rice and sorghum accounted for major cereals consumed in most average homes in Africa and many other developing nations around the world. The production of these cereals varies from one continent to other, and this have been driven by the human consumption, industrial needs and as a source of revenue generation; and all these are been influenced by soil fertility, government subventions and policies, and environmental factors, which often dictates annual production yield. Other cereals aside from these three grains that are important in other continents (such as barley, oats, rye) have very low significance in most average homes in Africa. Maize seems to be mostly staple food consumed by human or for other uses owe to its worldwide distribution, relatively lower price (compared to the other cereals) and various kinds of grains with inherent biological characteristics (FAO 1992; FAO 2000).

The world cereal use in 2014/2015 is predicted at 2,459 x 10^6 tonnes, about 1.7 % more than the 2013/2014 predictions (FAO 2013a; FAO 2013b). This increase is assumed will be related to use of cereals for feed, which is expected to rise by 2.6 % to about 874 million tonnes. Although the industrial use of grains (majorly for biofuel production) is foreseen to remain stable, human direct consumption is expected to increase by 0.9 % in 2014/2015 to 1,104 million tonnes resulting in world per capital consumption steady at about 153 kg (FAO 2013a; FAO 2013b).

Figures 3, 4 and 5 show an output of top ten World and Africa producers, domestic consumption, exporters and importers of 2014 year ending, for maize, rice and sorghum respectively. Figures were generated from data obtained from http://www.indexmundi.com/agriculture/. www.indexmundi.com is an internet site with complete data on world countries profiles which include commodities data, trade statistics, countries facts, charts and maps complied from multiple sources. From these figures, USA, China, India, Brazil, EU-27 and Mexico account for the major production of these cereals, while small amount is contributed by African countries such as South Africa, Egypt, Nigeria and Ethiopia. This disparity has no other reason than the adoption of far better and sophisticated mechanized agricultural systems in the developed countries. Ironically most of the maize, rice and sorghum production are consumed by these same developed countries, Africa consuming very low amount with Egypt, Nigeria, South Africa, Cote D' Ivoire, Ethiopia and Sudan been the major consuming nation of these cereals. The high consumption rate of the developed world may be related to the advance technologies in theses economies that allowed other products to be manufactured from these cereals, which are subsequently exported, use as feed stocks in animal feeds and/or for biofuel production. Moreover the very high population of some of these countries also accounts for the high consumption rates of these cereals. Since the major producers also hugely consume these cereals very small amount is left for export with African countries been the major benefactor of these. The major exporting nation are USA, Brazil, Ukraine, Thailand, India, Viet Nam, Argentina and Australia, with South Africa and Egypt been African countries that export just very low quantity of these cereals (Figures 3, 4, 5). Countries such Japan, China, Mexico and Korea Republic may be importing some of these cereals, however these is to augment their local production, compared to many African countries (such as Egypt, Nigeria, Algeria, Morrocco etc.) that rely heavy on import in order to meet the local food demands(Figures 3, 4, 5).

Based on the expectations from larger importing African countries such as Egypt, Nigeria, Algeria, etc, cereals import for Low Income Food Deficit (LIFD) countries is proposed to rise to 78.7 million tonnes in 2014/15 marketing years (FAO, 2013a). LIFD countries are countries which are classified based on their per capital gross national income (GNI) and also as related to high gross imports compared to low gross exports, according to World Bank assessment and such countries that may require foreign direct assistance (FAO, 2013a). About 54 countries globally have been classified as LIFD countries, out of which 37 are in Africa; an approximate 70%. This thus makes many Africa countries more of a food import dependent rather than an export, wherein many are over dependent on direct foreign aids from donor agencies, mostly from Europe and USA (FAO, 2013a).

Traditional cereals cultivation practices in africa: need for inclusive transgenic approaches

In order for Africa to survive the enormous ever increasing food demand and be able to feed herself and even export, she must learn and adopt appropriate and adequate farming practices.

Farming in Africa is still predominantly of subsistence

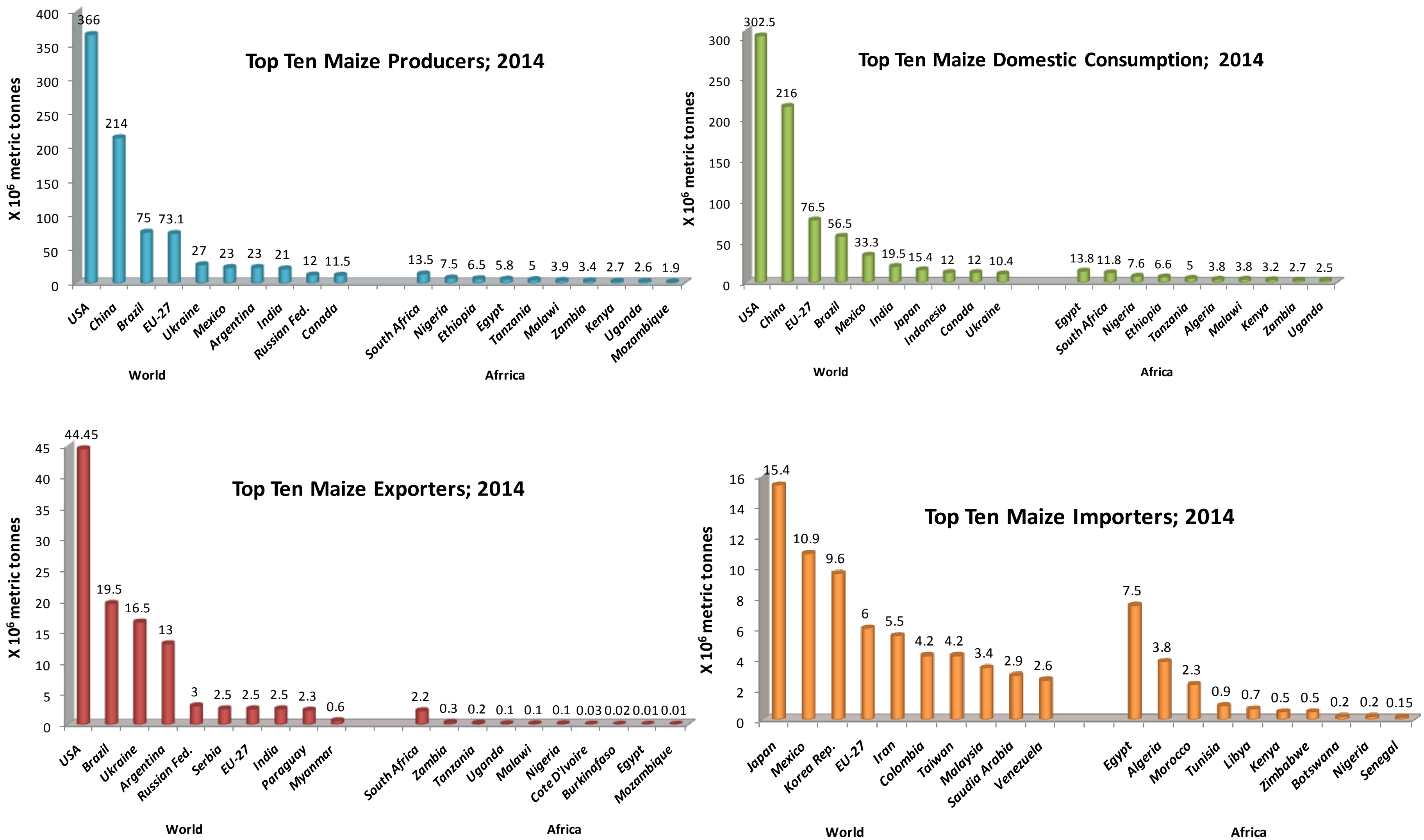

Figure 3: An output of top ten World and Africa maize producers [a], domestic consumption [b], exporters [c] and importers [d] for the year 2014 ending.

[a], Indexmundi; Corn production by country. US Dept of Agriculture. http://www.indexmundi.com/agriculture/?commodity=corn&graph=production (Accessed 20-12-14)

[b], Indexmundi; Corn domestic consumption by country.US Dept of Agriculture. http://www.indexmundi.com/agriculture/?commodity=corn&graph=domestic-consumption (Accessed 20-12-14)

[c], Indexmundi; Corn exports by country. US Dept of Agriculture. http://www.indexmundi.com/agriculture/?commodity=corn&graph=export (Accessed 20-12-14)

[d],Indexmundi; Corn import by country. US Dept of Agriculture. http://www.indexmundi.com/agriculture/?commodity=corn&graph=impo rt (Accessed 20-12-14)

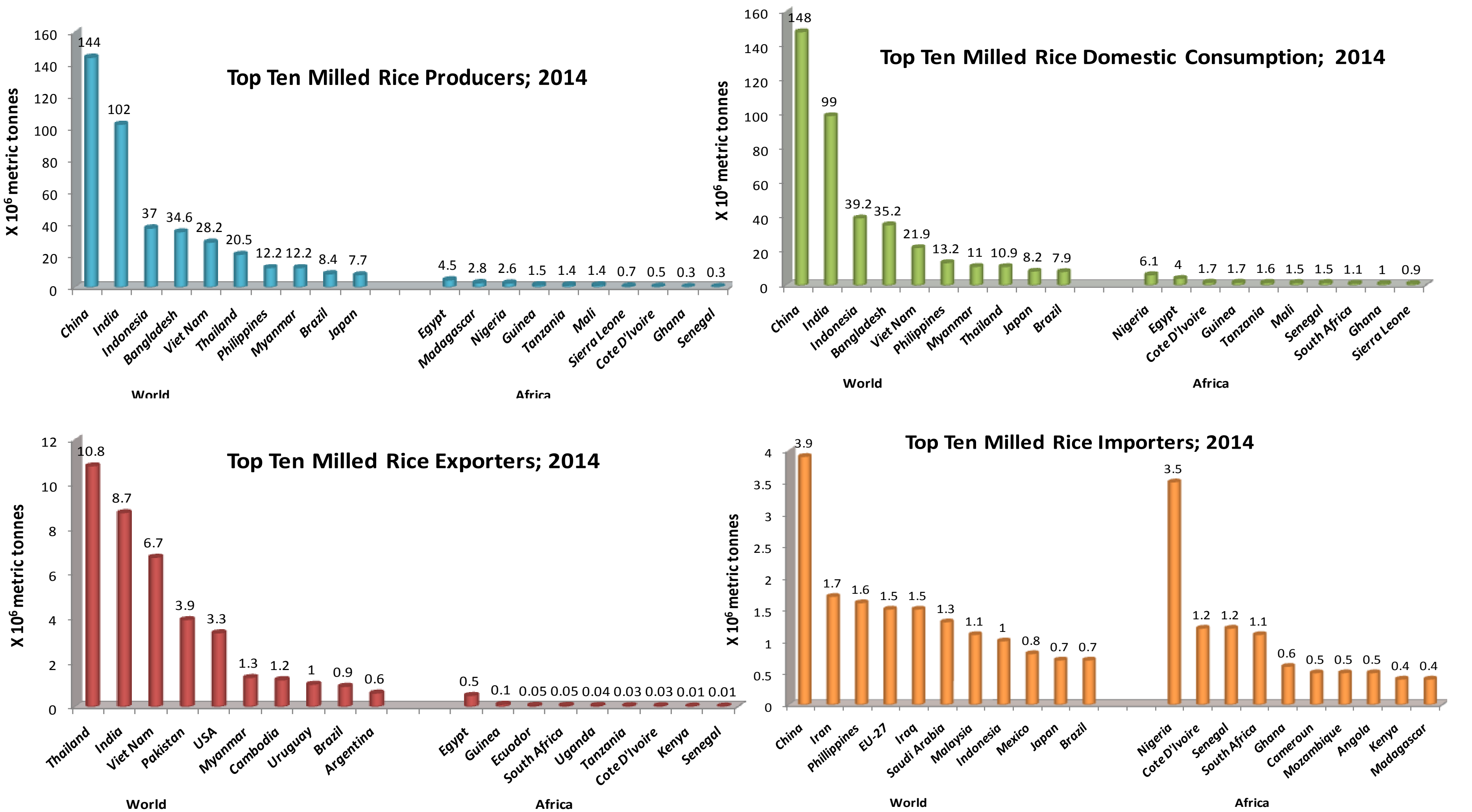

Figure 4: An output of top ten World and Africa milled rice producers [e], domestic consumption [f], exporters [g] and importers [h] for the year 2014 ending.

[e], Indexmundi; Milled rice production by country. US Dept of Agriculture. http://www.indexmundi.com/agriculture/?commodity=milled-rice&graph=production (Accessed 20-12-14)

[f], Indexmundi; Milled rice domestic consumption by country. US Dept of Agriculture. http://www.indexmundi.com/agriculture/?commodity=milled-rice&graph=domestic-consumption (Accessed 20-12-14)

[g], Indexmundi; Milled rice exports by country. US Dept of Agriculture. http://www.indexmundi.com/agriculture/?commodity=milled-rice&graph=export (Accessed 20-12-14)

[h],Indexmundi; Milled rice import by country. US Dept of Agriculture. http://www.indexmundi.com/agriculture/?commodity=milled-rice&graph=import (Accessed 20-12-14)

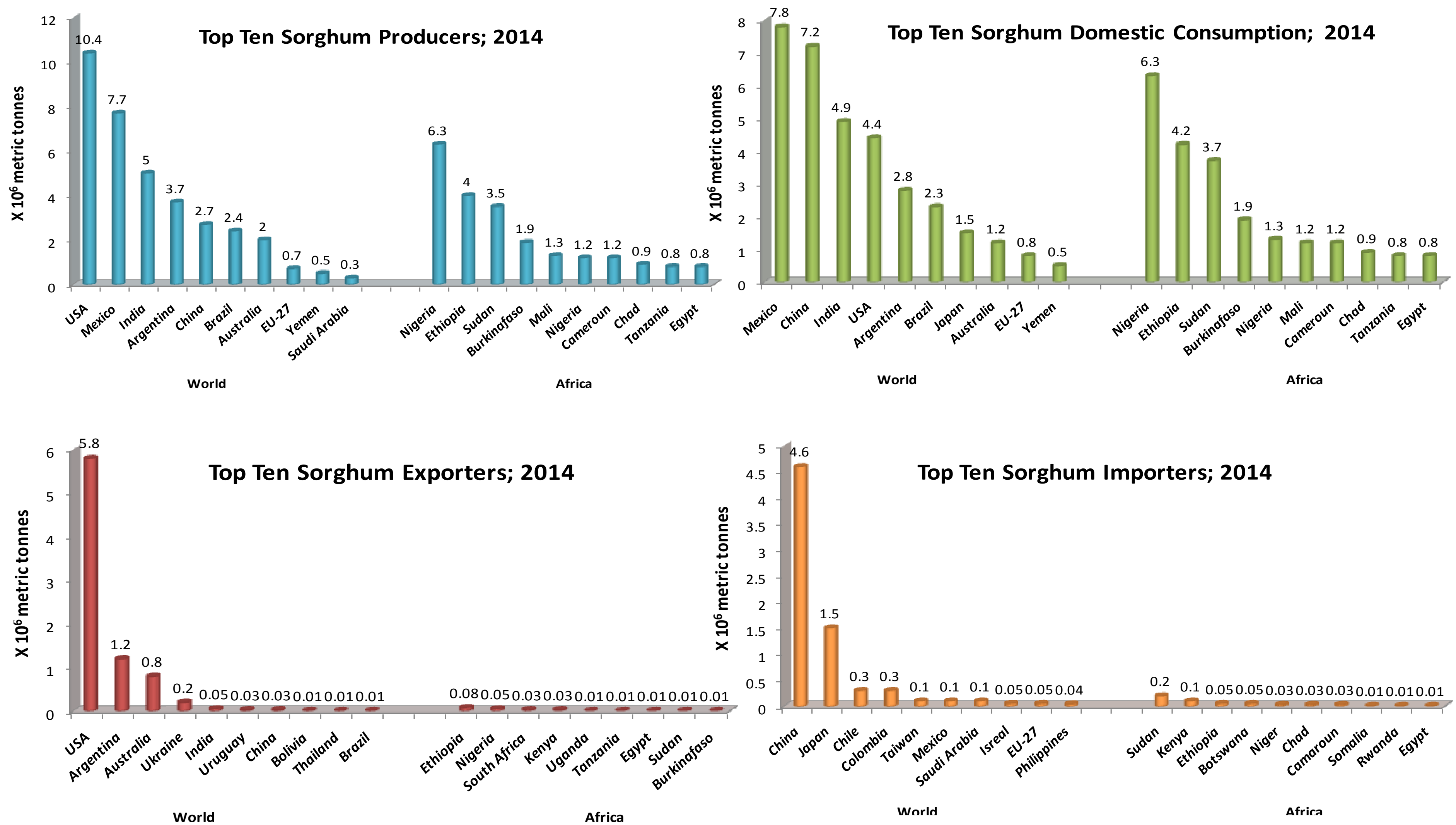

Figure 5: An output of top ten World and Africa sorghum producers [i], domestic consumption [j], exporters [k] and importers [l] for the year 2014 ending.

[i], Indexmundi; Sorghum production by country. US Dept of Agriculture. http://www.indexmundi.com/agriculture/?commodity=sorghum&graph=production (Accessed 20-12-14)

[j], Indexmundi; Sorghum domestic consumption by country. US Dept of Agriculture. http://www.indexmundi.com/agriculture/?commodi ty=sorghum&graph=domestic-consumption (Accessed 20-12-14)

[k], Indexmundi; Sorghum exports by country. US Dept of Agriculture. http://www.indexmundi.com/agriculture/?commodity=sorghum&graph=export (Accessed 20-12-14)

[l],Indexmundi; Sorghum import by country. US Dept of Agriculture. http://www.indexmundi.com/agriculture/?commodity=sorghum&graph=import (Accessed 20-12-14)

type with average homes having few hectares of land to farm with use of obsolete tools. Most farmers employed the mixed farming system that involves intermingling cropping with animal rearing. Although this practice has its own advantages such as ability to build soil fertility by use of animal manure, which consequently may reduce chemical fertilization application, it is a bit more capital intense compared to just single farming as more tools will be needed, which stretches farmers resources as these have to be shared in the development of the crops and animals.

The lack of adequate production practices and inputs have been attributed as the main reasons for low agricultural production levels obtained in Africa (Ajeigbe et al, 2010). Cereals varieties with higher grain yield maturity and resistance to several diseases are often been released to farmers in several countries, and these couple with documents and professional/research advices. However there still exists a wide difference between yields on the farm (approximately 25 to 300 kg/ha) compared with experimental farm stations (1500 to 2500 kg/ha), there is therefore a high potential for improvement (Ajeigbe et al., 2010). This potential is attainable if favorable agronomic practices and cropping systems that could take maximum advantage of new and improved crop varieties and technologies that will produce higher yield with lesser use of fertilizers and insecticides, consequently higher profits, are set-up by farmers.

In the traditional intercropping, most farmers plants cereals (such as maize, sorghum) along with legumes (soybean, cowpea, groundnut) in a one-row cereal, one-row cowpea arrangement. The cereal is planted at the onset of rains and the cowpea planted 3 - 4 weeks later when rain is constant. Though mono-cropping is more profitable, many subsistence farmers engage in intercropping in order to produce a sufficient quantity of cereals as planting legumes potential improve the soil fertility. Other models of cereals/legumes intercropping ratios have also been considered, such as 2:2, 1:3, 2:3, 1:4, and 2:4, however 2:4 cereals/legumes (such as maize/cowpea in rain forest zone, and sorghum/groundnut in guinea savanna zone) was found often used by most small and medium scale farmers (Tsubo et al., 2005).

Application of biotechnology in agriculture has assisted tremendously in plant breeding leading to the generation of improved crop varieties and lots of information on crop breeding strategies. It is assumed that the combination of the conventional cropping systems in addition with recent biotechnological advances in agriculture is highly resourceful. Applications of micro propagation genomics/tissue culture technologies have allowed the delivery of many agricultural desirable plant varietal genotypes (Curtis et al., 2004; Dunwell and Ford, 2005). These have involved the development of “Apomixis and Transgenic crops”.

Apomixis is a natural occurrence where specific plant species produces seeds without the need of fertilization. Exploiting the potentials of Apomixis genetics for heterosis breeding and general crop improvement has a significant implication for agricultural research. One of the potential benefits is that it may be possible to develop proper breeding hybrids which retain their physical vigor (such as growth rate, size, and organs development) and yield advantage over generations. Other benefits may include the ability to generate very high vigor crop species in crops that naturally never had hybrid variety, use of seeds in propagation of crops such as tubers that are typically vegetatively propagated (e.g. yam, cassava, potatoes), makes crop breeding easier as they would not be any need for in inbred line production, use of male sterile nor restorer lines (Curtis et al., 2004; Dunwell and Ford, 2005).

On the other hand the development of transgenic crop dated as far back as the early 1800 genetically engineered tobacco plants, have opened a gateway for the generation of crops with improved yield and tolerance (at times resistance) to lots of environmental factors (Dunwell and Ford, 2005). Coupled with the huge capital investment and supports from academic institutions and governmental organizations, the 1st cereal crop that was commercially made available was the Bt Maize. Compared to wild type, the Bt Maize has lots of tolerance to insect pest and Abiotic factors (Dunwell and Ford, 2005). The adequate knowledge of transgenic cereal crops will not only bring about improved crop yield but will transcend in fortifying war against World, more importantly Africa food security issues; against the fury of hunger and poverty orchestrated by every increasing population.

Introduction of transgenic or genetic modified (GM) crops have tremendously increase crop production in several developed and even developing countries with an increase from 1.7 million hectares in the year 1996 to 170 million hectares of land in 2012, making GM technology the fastest adopted crop technology in contemporary history (James, 2012; Gupta et al., 2013). Successful production of a GM crops though often takes quiet a long time to develop because for stable transgene production and horizontal gene transfer to occur many molecular and biotechnological techniques are usually needed to be adopted and tested (Gatehouse and Christou, 2005; Bakshi and Dewan, 2013). Many GM cereal crops that carry traits that enhances their productivity and resistance to environmental challenges are been commercially provided by organizations in countries such as USA, EU, China, Australia, Canada, Japan, New Zealand, Philippines, South Korea, Taiwan, Mexico, Russia, South Africa. Such genetic traits confer tolerance / resistance to abiotic factors (such as drought, high soil salinity, heavy metals and non-metal ions) and biotic factors (such as pathogen/insect infestation), herbicide tolerance, improved grain quality and pollination control. Example of such crops among many others include Enogen™, InVigor™ and Mavera-YieldGard™ Maize (with improved grain quality and pollination control); Huahui-1, Basmati-370, M-7and Shanyou 63 Rice, Xtra™ and Power

Core™ Maize (with improved tolerance to insect, other biotic stress and herbicide); Genuity® DroughtGard™ Maize (with improved tolerance abiotic factors) (James, 2012; Gupta et al., 2013).

Effects of abiotic factors like drought, salinity potentially result in over 70% losses in agricultural produce; with Africa been most affected (Acquaah, 2007). Current global climatic change has also contributed immensely as many regions that were not often affected by drought are now experiencing long periods without rainfall, and in regions where irrigation is often into used in the agricultural systems, effect of this prolong drought period has hampered greatly increase in agricultural production yields. Efforts of plant breeders towards genetically engineering plants that are well adaptive to abiotic factors are becoming successful as genes that confers tolerance to abiotic factors have been expressed in cereals, and subjection of these plants to stress have shown their adaptive ability towards these abiotic factors. Examples of such genes among many others that have been expressed in cereals like rice, and maize include Dehydration Responsive Element Binding Protein (DREB), C-Repeat-Binding Factor (CBF), ABA-responsive element (ABRE), Heat Shock Factor (HSF), salt oversensitive kinases, phospholipases, mitogen activated protein (MAP), cold shock protein B (CspB), Late Embryogenesis Abundant (LEA) proteins (Qiu et al., 2002; Katiyar-Agarwal et al., 2003; Shou et al., 2004; Thiery et al., 2004; Zhang et al., 2004; Chandra et al., 2005; Qin et al., 2007; Chen et al., 2008; Kobayashi et al., 2008; Wu et al., 2008; Cui et al., 2011; Hussain et al., 2011; Sammons et al., 2013).

For resistance to insect, cereal crops tissues have been genetically engineered to express Bt toxins which specifically targeted towards controlling insects and really affect other predators or commensally plant organisms. Bt toxin is a protein produced by soil bacteria *Bacillus thuringiensis*. It is crystalline and inactive in *Bacillus thuringiensis* but becomes active upon ingestion in the mid gut of insect, causing pores within the insect gut membrane, resulting in leakage and eventually killing the insect, be it adult or larvae (Schnepf et al., 1998; Soberon et al., 2007). Bt crops was approved by Environmental Protection Agency (EPA) and the Food and Drug Administration (FDA) for commercially cultivation and consumption after years of toxicity and allergenicity studies that showed that Bt toxins could rarely affect human, animal or the environment (EFSA, 2004). USA stated commercialization of Bt maize in 1996, and was successively followed by Canada, Argentina, Spain, France, South Africa, Philipines, China, India, etc, with an approximate of over 35 million hectares been cultivated (James, 2012). The 1st Bt rice was produced in China in 1989 and have since been commercially produced in many other countries (Chen et al., 2011).

The economic and environmental benefits of cultivation of Bt transgenic crops towards sustainable agriculture cannot be overemphasized as there was a great decrease in use of insecticides and has also assisted in curbing other non-targeted invertebrate populations (such as mites, spiders and related species) in Bt crop fields compared to conventional crop fields controlled with insecticides (Marvier et al., 2007).

Resistance of crops towards bacterial, fungal and viral pathogens invasion such *Magnaporthe grisea*, *Xanthomonas oryzae pv. Oryzae*, *Rhizoctonia solani*, *Fusarium graminearum*, *Magnaporthe grisea*, have been succeeded by genetically modifying crops to over express genes of Polygalacturonase- Inhibiting Proteins (PGIPs), Chitinase, 1, 3-Glucanase, OsNPR1, OsAOS2, OsWRKY31, Puroindolines, Bovine Lactoferrin cDNA and Antifungal Proteins (AFP) from Aspergillus giganteus (Nishizawa et al., 1999; Krishnamurthy et al., 2001; Nishizawa et al., 2003; Itoh et al., 2003; Coca et al., 2004; Chern et al., 2005; Moreno et al., 2005; Mei et al., 2006; Yuan et al., 2007; Zhang et al., 2008; Ferrari et al., 2012; Han et al., 2012; Fujikawa 2012).

Accumulations of solutes such as proline, glycinebetaine, trehalose and mannitol have proved tremendously in alleviation of plants from osmotic stress resulting from drought or hyper salinity (Mahajan and Tuteja, 2005). Transgenic plants over expressing these solutes have shown tolerance to these stress conditions. As example, rice plants over expressing the production of glycinebetaine as a result of increased activity of choline dehydrogenase gene (codA) that catalyzes the oxidation of choline to glycinebetaine were shown to recover from salt stress compared to the wild type (Mohanty et al., 2002). The over expression of Ä1-Pyrolline-5-carboxylate synthetase (P5CS) enzyme involved in proline biosynthesis has shown increase in salt tolerance in cereals such as rice, maize and wheat (Kavi-Kishore et al., 2005). Transgenic rice plants over expressing trahalose have been found to tolerate drought more than the wild type (Garg et al., 2002; Jang 2003), and transgenic plants with elevated mannitol-1-phosphate dehydrogenase (mtl1D)that is responsible for the synthesis of mannitol, showed a significant increase in tolerance to osmotic stress (Abebe et al., 2003).

Essential micronutrients vitamins (such as vitamins A, B, E) and minerals (such as iron and zinc) are mostly deficient in major foods consumed in many African homes. Furthermore cereals that are also largely consumed also are not rich sources of fatty acids and essential amino acids (such as lysine and threonine) which are required for human development (Capell and Christou, 2004; Zhu et al., 2007). Cereals qualities have thus been improved by transgenic engineering cereals to over express specific genes or modification of production pathways, in order to enhance the production of these macro and micronutrients. Other approaches have been to decrease the amount of competitive use of these metabolites so they can over accumulate or improvement of uptake and consequently accumulation; in the cases of essential minerals since they are mostly obtained from soil (Grusak and Cakmak, 2005).

High prominence among the genetically modified cereal for improved quality is the golden rice which was developed in other to augment vitamin A provision especially in children in developing countries, where over 4 million are at a risk of suffering from partial or total blindness as a result of vitamin A deficiency (Ye et al., 2000; Paine et al., 2005; Aluru et al., 2008). Engineering β-carotene a precursor of vitamin A into rice led to the production of rice grains which are yellowish in colour and are such named Golden rice that often contains as much as 37μg carotenoid/g of seed (Ye et al., 2000; Paine et al., 2005). Expressions of similar genes have been carried out in maize producing an average of 60μg carotenoid/g of seed (Zhu et al., 2008). The commercial introduction of Golden rice has lately been receiving international attention, and it is been pursued by International Rice Research Institute (IRRI), with the hope that it will help in alleviating vitamin A deficiency predominantly in women and children from developing world which Africa takes a majority share (IRRI, 2014). Other essential vitamins such as vitamin B_9 (folate) and vitamin E (α-tocochromanol) have been over produced in cereals by genetically engineering over expression of GTP cyclohydrolase 1 (GCH 1) and Arginine decarboxylase (ADCS 1) genes to produce about 100-fold increase of vitamin B_9 in rice endosperm (Storozhenko et al., 2007), and ρ-hydroxyphenylpyruvate dioxygenase (HPPD) and 2-methyl-6-phytylplastoquinol methyltransferase (MPBQ MT) genes in maize endosperm to produce about 3-fold increase of vitamin E (Naqvi et al., 2011).

Deficiency of iron is very rampant in many developing countries with a very high percent of the population at risk of hemolytic anemia (Wikipedia: Iron-deficiency anemia; Anemia - In-Depth Report - NY Times Health). Accumulation of iron in rice endosperm was found to improve by over production of ferritin by introduction of phytase gene from Aspergillus fumigates (Lucca et al., 2002) and enzymes Nicotianamine Synthase (NAS) and Nicotianamine Aminotransferase (NAAT), which are involved in the synthesis of phytosiderophore; a chelating agent that facilitates increase in plant absorption of iron (Zheng et al., 2010; Gomez-Galera et al., 2012). Over expression of Osnas1, Osnas2 or Osnas3 results in over 19μg/g of iron in the endosperm (Johnson et al., 2011).

Genetic engineering of cereals to over express lysine rich pea legumin and porcine α-lactalbumin in rice and maize respectively, showed a significant increase in lysine content [Sindhu et al., 1997; Bicar et al., 2008], so as the incorporation of seed storage protein from *Amaranthus hypochondriacus* in maize produces more essential amino acids (such as lysine, isoleucine, threonine, tryptophan) than the wild type (Rascon-Cruz et al., 2004).

On the other hand there still exist lots of controversies whether sorghum should be genetically modified in other to produce varieties with can tolerated drought, high soil salinity and other environmental risk factors, improved nutritional quality value in terms of essential minerals (iron and zinc), vitamins (A and E) and amino acids (lysine) (Monsanto:Sorghum; http://www.monsanto.com/products/pages/sorghum.aspx ; GMWATCH , 2014). However for the sake of many malnourish Africa children and the present food scarcity, it will be imperative that these projects are allowed to continue, it will be at the prerogative of the consumers to either opt for the wild type or the GM sorghum varieties. To date no GM sorghum variety is yet to be released to farmers.

CONCLUSION

Globally natural resources are depleting, while the ever increasing human population are constant in need of food, water, energy and shelter. Many technologies are been put in place to salvage these situations, however many African countries are still far behind in catching up with the rest of the world. The introduction of biotechnology in order to boost agricultural products have been well received and are currently been implemented in developed nations, bring about increases in agricultural yield. However many African nations are more of import dependent economy, and of most dishearten is food importation, in which if the proper agricultural strategies as been practiced in developed countries are put in place couple with the natural vegetation that Africa is blessed with, Africa by now should be the food basket of the world.

Under the spectre of current climate change, optimal growing conditions are become more difficult to sustain. The rising temperatures, increasing incidences of drought, poor soil quality and high soil salinity, pathogens and pest infestations have caused dramatic losses in agricultural yield (Bartels and Sunkar, 2005). Availability of suitable land devoted to agriculture is thus under seriously constraint as only small portion of world's land surface is devoted to agriculture, majority of it are either as perennial desert or dry lands. Thus in order not to encroach upon land required for forests, protected habitats or for urbanisation, the available arable land must be utilized in an improved manner that will allow use of less water and chemical inputs. This could be achieved by cultivating genetically modified (GM) crops that have increased innate ability to tolerate and survive under these harsh environmental conditions, with improvement in essential vitamins and minerals.

The commercially available GM crops such as the drought tolerant rice and maize, the Bt rice and maize crops have already boosted agricultural yields and these crop lines should be introduced to more farmers in Africa (Sankula and Blumenthal, 2004; Brooks and Barfoot, 2005). With the right government policies coupled with Africa reasonably stable climatic/weather conditions as compared to other continents that often experiences erratic weather conditions, which have adversely affected and shifted planting seasons, Africa should be in position to feed herself and export to other nations in the world. With this approach, the issue of food scarcity and malnutrition in children and pregnant women will also be eradicated. It will also lead to increase revenue generation after sales of agricultural products, consequently reducing poverty among the citizenry and improving Africa economy.

There have been speculations on GM crops, such as the level of safety and possible toxicity and allergencity on overall human health, environmental consequences and other socio-economic issues (US Environmental Protection Agency, 2002; Mendelsohn et al., 2003; James, 2009; Brookes and Barfoot, 2010). All these however have not been thoroughly substantiated, thus the adoption of cultivation of GM crops will depend largely on the fact that farmers and the general public are ready to embrace this technology, and that GM can result in safe cereal crops, and consequently providing enough food of far better quality for us all.

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