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Review

Maize: Panacea for hunger in Nigeria

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Maize (*Zea mays*) is always preferred to other crops, and it is fast becoming an industrial crop in Sub-Saharan African countries. Nigeria has been divided into low, medium, medium to high and high maize production potential groups. Traditionally, maize was mostly grown in forest ecology in Nigeria but large scale production has moved to the savanna zone, especially the Northern Guinea savanna, where yield potential is much higher. Maize yields in Nigeria is still very low due to biotic, abiotic agronomic factors like soil infertility, pests and diseases, drought, unavailability of improved germplasms, weeds, unremunerative prices, uncertain access to markets etc. Maize pests and diseases in Nigeria include downey mildew, rust, leaf blight, stalk and ear rots, leaf spots and maize streak virus, Striga attack, stem borers, termites, storage insects, beetle etc. Collaborative research efforts in Nigeria led to development of agronomic package for maize production for different farming systems. There are different readily-available ethnic maize dishes in Nigeria and due to lower cost and high starch contents, maize is commonly used as roughage feed for livestock, and also included in poultry feeds. Importance of maize as an easily harvested crop food with potential to mitigate food insecurity and alleviate poverty cannot be over-emphasized in the developing world.

Key words: Agronomy, ethnic foods, food insecurity, fertilizer, maize, sub-sahara Africa.

INTRODUCTION

Agbado (corn) sweet *agbado* (corn)
Loveliest food of the raining season
Strictly loved by old and young
The joy of the raining season
Oh come, how often do I see you come
The green oblong leaves.

Maize has always been preferred to any other crop, including cassava because most of the world's civilizations developed around grains rather than tuber crops (Fakorede, 2001). Maize is an astonishing plant, with an astonishing capacity to surprise humans. For instance, one seed planted can produce over 500 kernels in return. It is a plant that utilizes sunlight effectively and outstrips yield/hectare of other grains. Indeed, maize, which is fast becoming an industrial thereby, making it the first crop to be harvested for food during hunger period.

Although, maize did not originate from Africa, it was introduced to the continent in the 16th century, and by the 19th century, it had spread all over the continent. It is, perhaps, the most important cereal crop of significant economic importance in African countries that has replaced sorghum and millet. It is a staple food crop

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grown in diverse environments and consumed by people with varying food preferences and socio-economic background in Africa. Its taste has been easily accepted by the local population and therefore, it has been rapidly replacing traditional starchy foods like cassava. It is also an important crop when food items need to be transported to not self-sufficient population countries.

Other reasons for rapid adoption and expansion of maize include the facts that, it gives one of the highest yields per man-hour of labour spent on it; it provides nutrients in a compact form and it is easily transportable; the husks give protection against birds and rain; it is easy to harvest and does not shatter; it stores well if properly dried; it can be harvested over a long period first as immature cobs, but can be left standing in the field to maturity before harvesting; cultivars with different maturing periods are available. Also, in terms of taste, many people prefer maize to their local cereals (Purseglove, 1972; Pingali and Heisey, 1999; Verheye, 2010).

Importance of maize cannot be over-emphasized in the developing world, including the potential to mitigate the present food insecurity and alleviate poverty. Maize is a preferred staple food for over 900 million poor consumers, 120-140 million poor farm families and about one third of malnourished children (CIMMYT and IITA, 2010). In sub-Saharan Africa, absence or shortage of maize invariably leads to famine and starvation. It is estimated that by 2025, maize would have become the crop with the greatest production in developing countries and the world, and by 2050, the demand for maize in developing countries will double (CIMMYT and IITA, 2010). Due to the fact that maize is highly responsive to production inputs; its food and industrial uses are many, and its production potential can hardly be matched by any of the other major cereals. It is therefore, definitely a solution to hunger, which can salvage the famine population. As the popular Yoruba saying in Nigeria goes: *Igba gbogbo ni agbado ngba ni* (maize saves at all times).

The origin of maize is controversial (Galinat, 1988) due to the fact that modern maize is so far removed from ancestral form, which has its original form of seed dispersal through self-propagation. In addition, no wild race of maize currently exists, hence prototypes of maize have been difficult to reconstruct. Until recently, there were two major schools of thought regarding the origin of maize. The first one posited that Teosinte was the ancestor of maize, while the second one expressed that the cultigen was derived from hypothetical wild maize (Norman et al., 1995). Moreover, over the years, the former theory has become generally accepted (Doebly, 1990).

IMPORTANCE OF MAIZE

Maize is the world's most widely grown cereal, as it is grown in a range of agro-ecological environments, and more maize is produced annually than any other grain. It is the most important cereal crop in the economy of African countries, and is one of the most important commodities used for food aid. Owing to the fact that it is cheaper than other cereals (such as rice and wheat), it is more affordable to the vast majority of the population, and therefore, occupies a prominent position in the agricultural development agencies of several countries in Africa. It is an important staple food for more than 1.2 billion people in Sub-Saharan Africa (SSA) and Latin America. All parts of the crop can be used as food and non-food products (IITA, 2009) and as a versatile crop; maize has been put to a wider range of uses than any other cereal. Maize is widely consumed as food in many parts of the world, and it is a staple food in developing countries, particularly in continents of Latin America, Asia and Africa. It is also a basic ingredient for some indigenous drinks and food products. In the developed world, maize is largely used as livestock feed and raw material for industrial products, while in developing countries it is mainly used as food.

Maize is a staple food for about 50% of Sub-Sahara African population (IITA, 2009). It is an important source of carbohydrate, protein, iron, vitamin B and minerals. As food, the whole grain, freshly green or dried, may be used or may be processed traditionally by wet and dry milling methods to give a variety of food products. Preparation and uses of maize alone or in combination with other food material as staple food or snacks in Nigeria include the followings: *ogi* (in hot and cold forms), *tuwo*, *donkunnu*, *maasa*, Couscous, *akple*, *gwate*, *nakia*, *egbo*, *abari*, *donkwa*, *ajepasi*, *aadun*, *kokoro*, *elekute* etc. (Abdulrahaman and Kolawole, 2006) (Figure 1).

Maize as livestock feed

The bulk of the concentrated feed to farm animals consist of grains, and maize is the most important and preferred one due to its low cost (compared to other cereals), low fiber content and high starch content which consist of concentrated energy food that gives highest conversion of dry substance to meat, milk and eggs. Maize stover, which is the plant residue after the ear has been removed (contains 30 to 40% of the plants total nitrogen, 75% of the potassium, sulphur and magnesium and almost all the calcium) is used by many farmers in developing countries as roughage feed for livestock (Dowswell et al., 1996).

Silage maize is important feed in temperate areas (United States, Canada and Europe), and consists of entire plant, which is cut, chopped and placed in a structure for anaerobic fermentation so as to allow for storage. In 2005, of the 42% of the world maize produced in United States, 58% served as feed; while 17% went into industrial uses and ethanol production (FAO, 2006).

Maize can be processed into different products for

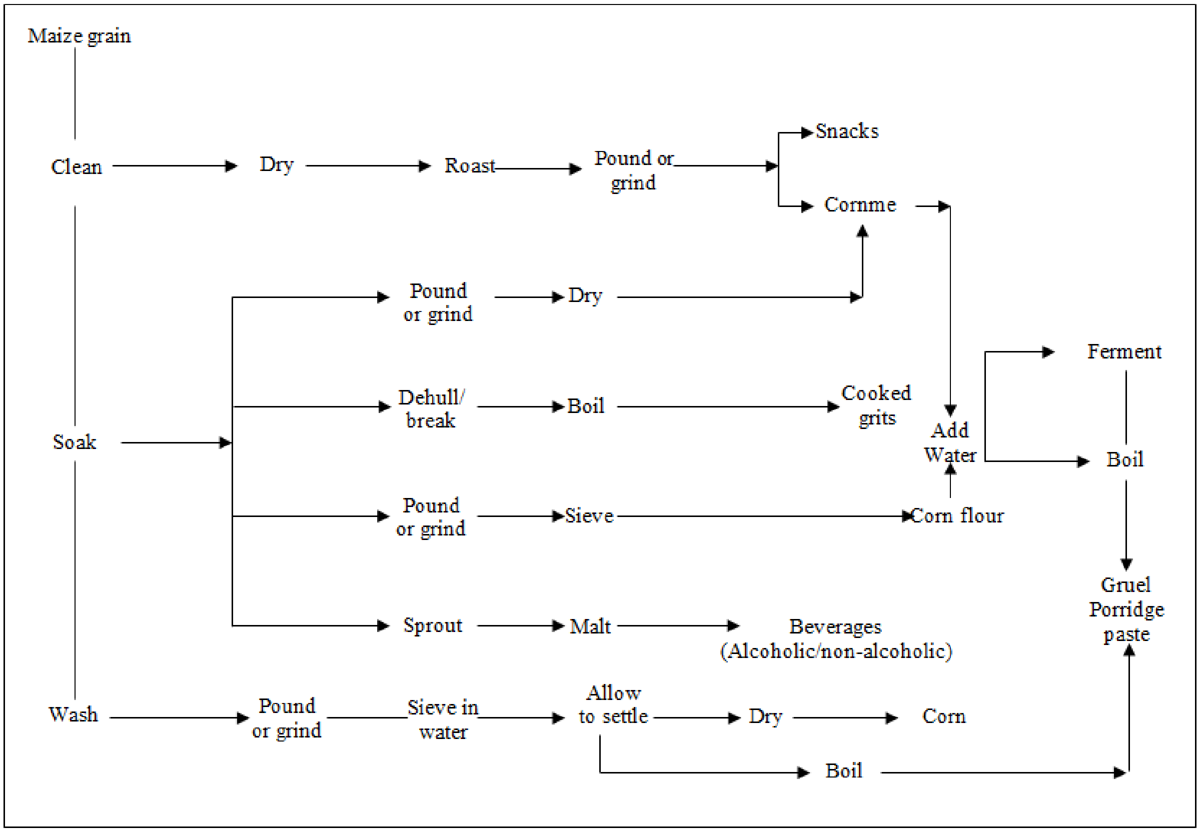

Figure 1. Utilization of dry maize grains. Source: Okoruwa, 1997.

Table 1. Annual world cereal harvest (3 year average 2002-2004).

Crop	Cultivated area ('000 ha)
Wheat	212,193
Rice	149,292
Maize	**143,355**
Barley	56,569
Sorghum	43,812
Millet	35,601
Oat	12,082
Rye	7,639

Source: FAOSTAT, 2005.

various end users at the traditional level and on industrial scale. A large proportions of products utilized in developing countries are obtained from traditional processing, while industrial processing meets the bulk of the demand in developed countries. Traditional commercial products obtained from maize are based on certain endosperm and some quality parameters, which influenced the choice and suitability of maize varieties for various uses. The properties include chemical, physical, biochemical, physico-chemical, organoleptic and rheological properties that can be influenced or altered favourably through breeding and other agronomic practices (Okoruwa, 1997).

GLOBAL MAIZE PRODUCTION TRENDS

Globally, maize ranked third after wheat and rice in terms of area harvested (Table 1) but in terms of annual production maize ranked first (Table 2). There is continuous increase in maize production all over the world and this is attributed to both increase in area of production and increase in yield per hectares. Maize grain production in the world in 1970 was about 266 million metric tons (MMT), while in year 2000, it was over 592 MMT and exceeded 844 MMT in 2010. Of the total global production, United States is far the biggest producer, contributing between 37-43% of the total world production (Table 3). In 2010 world ranking, United States was followed by China (177MMT), Brazil (56MMT), Mexico (23MMT) and Argentina (21MMT) (FAOSTAT, 2012). Maize production in United States and other developed countries of the world is highly mechanized on large scale production, where hybrids

Table 2. Annual Cereal Production (3 year average 2002-2004).

Crop	Average production ('000 metric tonnes)
Maize	**654,907**
Rice	588,947
Wheat	587,186
Barley	143,901
Sorghum	57,511
Millet	28,896
Oat	25,941
Rye	17,814

Source: FAOSTAT, 2005.

Table 3. World maize production and fraction produced in USA (metric tonnes).

Year	World production	USA	% by USA
1970	265831023	105471000	39.7
1980	396623417	168647000	42.5
1990	483343614	201832000	41.8
2000	592479279	251852000	42.5
2010	844405181	316165000	37.4

Source: FAOSTAT, 2012.

Table 4. Maize production, yield and area harvested in Africa and the World, 1986-2006.

Production (m tons)	1986[a]	1996[a]	2006[a]
World	472.3	564.1	736.1
Africa	31.7	40.3	48.9
Africa as % of World	6.7	7.1	6.6
Yield (tons/ha)	1986	1996	2006
World	3.6	4.1	4.9
Africa	1.4	1.6	1.7
Africa as % of World	39.6	38.8	35.7
Area harvested (ha)	1986	1996	2006
World	130.8	139.1	151.6
Africa	22.2	25.6	28.2
Africa as % of World	17.0	18.4	18.6

[a]Three-year averages for 1985-87; 1995-97 and 2005-07. Source: FARA, 2009.

maize varieties are commonly grown with high inputs in terms of agrochemicals.

Africa is a minor producer of maize by world standard (Table 4), accounting for only 7% of global production, while the average annual productions were estimated at 32MMT during 1985 - 1987, which increased to 49MMT during 2005-2007. Area planted with maize in West and Central Africa increased from 3.2 million in 1961 to 8.9 million in 2005, leading to increased production from 2.4MMT in 1961 to 10.6MMT in 2005 (IITA, 2009). Until the middle of the 20th century, maize production in the Sub-Sahara Africa grew mainly through expansion in the area planted. However, shortage of the land mass has eliminated area expansion as a potential source of production growth and there is an increased attention on increasing productivity. Basic facts about maize production and trade in Africa as highlighted by FARA (2009) stated that:

1) Africa accounts for 7% (49MMT) of global maize production.
2) Maize yield in Africa (1.7 tons/ha) account for 36% of global maize yield (4.9 tons/ha) (Table 4).
3) Maize production in Africa is increasing faster (2.8% per annum) than global production (2.5% per annum); however; global yields are increasing faster (1.6% per annum) than yields in Africa (1.3% per annum).
4) Africa is a net importer of maize. Average annual net imports have more than doubled from 4.57 million tons in 1995-1997 to 10.64 million tons in 2005-2007.
5) Maize imports have risen by 76% between 1995-1997 (6.82 million tons) and 2005-2007 (12 million tons), while exports have declined by 40% from 2.25 million tons to 1.35 million tons during the same period.
6) Africa accounts for 12% of the global maize imports.
7) Africa spends more than US$2.0billion on net imports of maize in 2005-2007.

MAIZE IN NIGERIA

Increase in maize production in Nigeria has been achieved greatly by expansion in area harvested rather than increase in yield. The area harvested increased from 2.8 million hectares in 1986 to over 3 million hectares in 2000 and over 6 million hectares in 2011. Of the total world production (844M tons) in 2010, Nigeria, the largest producer in Sub-Sahara Africa produced 7.7 million tons representing 0.9% of the world production.

Based on production potentials, Nigeria has been divided into four groups namely low, medium, medium to high and high maize production potential (ATA, 2011) (Figure 2). The average yield of maize in Nigeria as in other Sub-Sahara Africa countries is generally low 1.68 tons/hectare, which is very low compared to average yield in United States 9.3 tons/hectare over the same period (Table 5).

Maize production constraints in Nigeria

In view of the importance of maize in Nigeria, efforts are continuously made to increase maize yield per unit area of land and to extend areas where it can be grown,

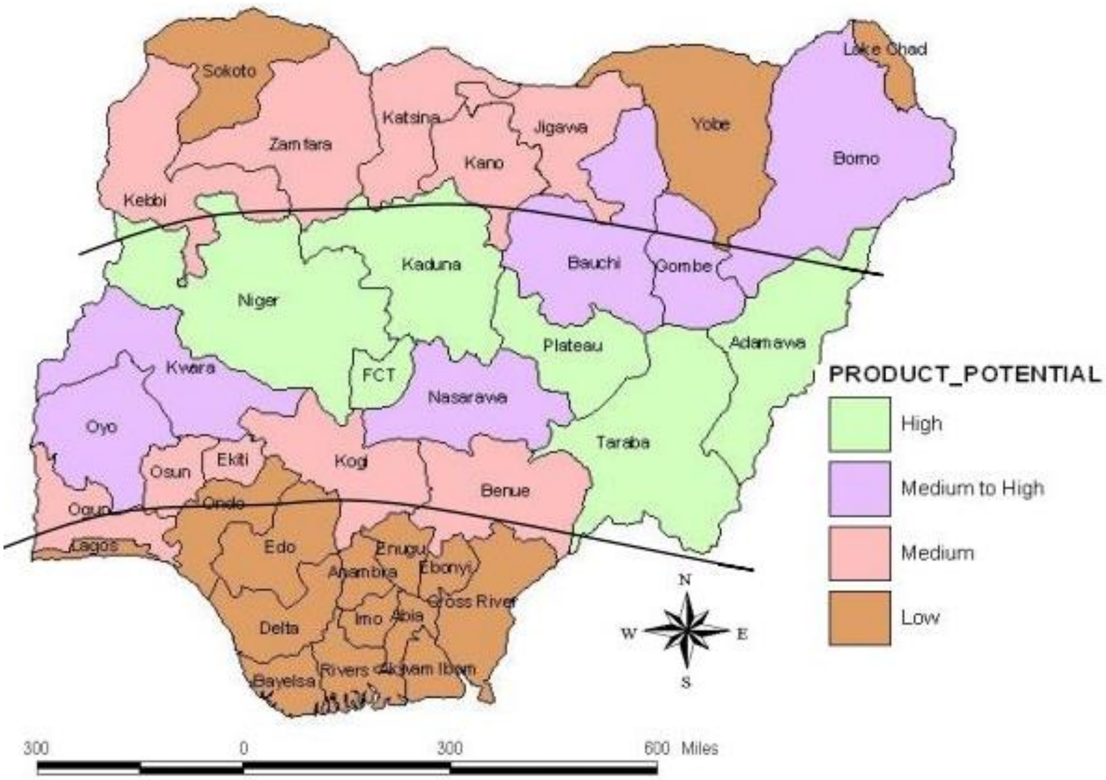

Figure 2. Maize production map of Nigeria. Source: ATA, 2011.

Table 5. Maize production in Nigeria and USA.

Year	Area harvested ('000ha)		Total production ('000t)		Yield (t/ha)	
	Nigeria	USA	Nigeria	USA	Nigeria	USA
1986	2,800,000	27,885,000	3550000	208,943,000	1.268	7.493
1987	3,408,000	24,080,000	4612000	181,142,000	1.353	7.523
1988	3,212,000	23,573,000	5268000	125,914,000	1.640	5.311
1999	3,423,000	28,525,000	5476000	239,549,000	1.600	8.398
2000	3,159,000	29,315,700	4107000	251,852,000	1.300	8.591
2001	3,283,000	27,829,700	4596000	241,375,000	1.400	8.673
2002	3,282,000	28,057,200	4898000	227,765,000	1.490	8.118
2003	3,469,000	28,710,300	5203000	256,227,000	1.500	8.925
2004	3,479,000	29,797,700	5567000	299,874,000	1.600	10.064
2005	3,589,000	30,399,000	5957000	282,261,000	1.660	9.285
2006	3,905,000	28,586,500	7100000	267,501,000	1.818	9.358
2007	3,944,000	35,013,800	6724000	331,175,000	1.705	9.458
2008	3,845,000	31,796,500	7525000	307,142,000	1.957	9.660
2009	3,350,560	32,168,800	7358260	332,549,000	2.196	10.338
2010	4,149,310	32,960,400	7676850	316,165,000	1.850	9.592
2011	6,008,470	33,986,300	9180270	313,918,000	1.528	9.237

Source: FAOSTAT 2013.

especially the cultivation of dry areas as improved through irrigation. Traditionally, maize has been mostly grown in forest ecology in Nigeria but large scale production has moved to the savanna zone, especially the Northern Guinea savanna, where yield potential is much higher than in the forest. The environmental condi-

Table 6. Grain yield (kg/ha) of maize genotypes grown at varying densities in South-western Nigeria.

Parameter	Density (plants/ha)			
	Ibadan		Ilora	
Maize genotype	53,333	80,000	53,333	80,000
Open-pollinated	3598.7	3913.7	3346.7	4899.0
Single cross hybrid	3542.3	5284.9	N.A.	N.A.
Double cross hybrid	3879.5	5162.3	3818.8	4889.7

N.A. = Not available; Source: Olaniyan and Lucas, 2004.

tions required for maize cultivation are therefore, superior in the savanna zone with high solar radiation, less incidence of biotic stresses and natural dryness at time of harvest (Kim et al., 1993). However, in spite of all efforts, maize yields in Nigeria, like in many other Sub-Sahara countries, is still very low compared to developed countries due to many constraints, which may be biotic, abiotic agronomic or others like low soil fertility, pests and diseases, drought, unavailability of improved germplasm, weeds, unremunerative prices, uncertain access to markets etc.

Agronomy of maize

Density of planting

Density of planting has significant effect on the yield of crop and specifically on maize. Studies on the impact of plant density on maize had shown that yield response to plant density varied substantially with management practices, maize genotypes, location, year and soil fertility level (Carolene and Russell, 1987).

Application of optimum plant density in maize production helps the proper utilization of solar radiation, which influences leaf area, interception and utilization of solar radiation and consequently maize dry matter accu-mulation and yield (Pepper, 1987). Generally, the dry matter per unit area of land of hybrid maize increased significantly with plant density and the highest density of planting produced the highest dry matter yield per unit area (Olaniyan and Lucas, 2001). However, in temperate regions, the relationship between total dry matter and density of planting in maize is asymptotic (Adelana and Milbourn, 1972).

Yield increases with increase in plant density up to a maximum for a maize genotype grown under a set of particular environmental and management conditions and decline when plant density is increased further. In other words, the relationship between grain yield and density in maize is parabolic (Cardwell, 1982).

Decline in grain yield per plant when plant density increased can be attributed predominantly to a decline in kernel number and kernel weight. Maize yield is low with low plant density because of little plasticity in leaf area per plant (Cox, 1996) and if plant density is too high, the reduction in the availability of resources per plant in the period surrounding silking generates a marked fall in yield per plant that is not offset by the increase in the plants number (Vega et al., 2001).

Maize as a sole crop is grown at population densities ranging from 18,000 to 55,000 plants/ha in Nigeria and the general recommendation is inter-row spacing of 75 and 25 cm as intra-row spacing to give 53,333 plants/ha. This recommendation is likely to be based on earlier studies where optimum density of 53,000-66,000 plants/ha gave optimum grain yield (Lucas, 1981). However, using high yielding FARZ 27 genotype, optimum yield at population density of 88,000 plant/ha was reported (Lucas, 1986). The density of 80,000 plants/ha was found optimal for hybrid maize varieties grown in Kaduna that is, Northern Guinea savanna zone of Nigeria and 53,333 plants/ha for Ikenne and Mokwa representing the forest and southern Guinea savanna zones respectively (Akintoye et al., 1997). Results of studies carried out in Ibadan and Ilora representing the Southwestern part of Nigeria, confirmed 80,000 plant/ha as the optimum density as against recommended density of 53,333 plants/ha for the areas (Table 6). Hybrid maize planted at the higher density produced 23 and 27% higher yields at Ibadan and Ilora respectively.

Efforts to push the density of planting to 100,000 plants/ha with high nitrogen level reduced grain yield by 15% (Olaniyan and Lucas, 2002). Maize grain yield is associated with the number of kernels per area, numbers of ear per plant and number of kernels per ear (Sangoi and Salvador, 1998). Echarte et al. (2000) found grain yield response to plant density to be positively and strongly related to number of kernel/m^2 and negatively and weakly related to weight/kernel.

Maize improvement in Nigeria

Maize researchers' efforts in Nigeria have no doubt improved maize production. The collaborative efforts of research institutes in Nigeria and advance maize breeding research programmes has led to many achievements including: (i) Development of agronomic package for maize production for different farming systems. (ii) Development and release of many maize genotypes based on the needs, requirements, prevailing pest and diseases in different agro ecological zones. (iii) Development of new varieties that yield up to twice the yield of the traditional varieties. (iv) Release of different maturing varieties: extra early, early, intermediate and late maturing which enable expansion of maize production to different areas, including areas with short rainy season. (v) Improvement in nutrient composition: quality protein maize were developed which provides better quality protein than normal maize in terms of

Table 7. Some improved open pollinated maize varieties in Nigeria.

Name of variety	Original source	Developing institution	Outstanding characteristics	Year of release	Year of Registration
Western yellow-1	Mixed germplasm from Caribbean and Mexico	I.A.R. &T Ibadan	High carotene content good for ogi. Also good for poultry feeds	1971	1991
096-EP6	Nigeria	FDAR Ibadan	High carotene content, good for pap and poultry feeds	1975	1991
TZPB	IITA, Ibadan	IITA, Ibadan	Big cobs, high yielding rust blight resistant	1975	1991
TZB	IITA, Ibadan	IITA, Ibadan	High yielding, good for pap	1975	1991
TZSR-W/Y	CIMMYT/ IITA, Ibadan	IITA, Ibadan	High yielding and widely adapted streak resistant	1981	1991
DMR-LSR (W&Y)	IITA, Ibadan	IITA, Ibadan	Resistant to downy mildew, sturdy and vigorous plants	1984	1991
KEWESOKE	I.A.R. and T Ibadan	I.A.R. and T Ibadan	Good for mixed cropping	1980	1991
TZESR – W	I.A.R. and T/IITA, Ibadan	I.A.R. and T/IITA Ibadan	Resistant to downy mildew, rust and blight	1982	1991
TZESR – Y	I.A.R.andT/IITA, Ibadan	I.A.R. and T/IITA Ibadan	Resistant to streak rust and blight	1982	1991
95 TZEE – W1 SAMMAZ 12	IITA, Ibadan	IITA, Ibadan, IAR, Samaru, Zaria	Extra earliness, high yield potential, and suitable in area with ≥ 600 mm rainfall distribution with 80days	2001	2001
95 TZEE–Y1 SAMMAZ 13	IITA, Ibadan	IITA, Ibadan, IAR, Samaru, Zaria	Extra earliness, high yield potential, and suitable in area with ≥ 600 mm rainfall distribution with 80days	2001	2001
PH 2 (OBA-FEMI)	Premier Seed Nig. Ltd. Zaria	Premier Seed Nig. Ltd. Zaria	Short plant type, high yield potential, resistant to lodging, good for mechanized harvesting	2001	2001

Table 7. Contd.

PH 5 (OBA - 99)	Premier Seed Nig. Ltd. Zaria	Premier Seed Nig. Ltd. Zaria	High yielding potential, quality protein maize	2001	2001
PH 6 (OBA - 98)	Premier Seed Nig. Ltd. Zaria	Premier Seed Nig. Ltd. Zaria	High yielding potential, quality protein maize	2001	2001
OBATANPA SAMMAZ 14	CRI, Kumasi Ghana	IAR, Samaru	High lysine and tryptophan contain, medium maturing, good seed quality, high yield, tolerance to Striga.	2005	2005
IWDC2SynF2 SAMMAZ 15	IITA, Ibadan	IITA, Ibadan, IAR, Samaru, Zaria	Medium maturing, good seed quality, high yield potential, tolerance to Striga hermonthica	2008	2008
TZLComp 1SynW-1	IITA, Ibadan	IITA, Ibadan, IAR, Samaru, Zaria	Late maturing, good seed quality, high yield, resistance to Striga hermonthica	2008	2008

lysine, tryptophan and micronutrients to combat diseases caused by macro and micronutrient deficiencies (Ado et al., 2007; IITA, 2009).

A list of some of the improved varieties of maize (open pollinated and hybrids) developed in Nigeria are presented in Tables 7 and 8.

Pests and diseases of maize

Maize in Nigeria is attacked by an array of diseases that can cause significant damages. These include the downey mildew, rust, leaf blight, stalk and ear rots, leaf spots and maize streak virus (IITA, 2009). However, Striga is one of the most dangerous weeds in maize production especially in savanna area of Nigeria. Yield losses from Striga range from 10 to 100% depending on time of parasite infection (Lagoke et al., 1991). Studies on time and rate of application of nitrogen were carried out at Mokwa, Southern Guinea savanna zone of Nigeria using four hybrid cultivars (Kim and Adetimirin, 1997). Timing and nitrogen application rates significantly affected Striga emergence, host plant damage scores, agronomic traits and grain yield. Nitrogen application at two weeks after planting (WAP) (compared with 0, 4 and 6 WAP) at 60kg/ha gave the best result in terms of maize performance and reduction of Striga emergence. The tolerant cultivar produced 188% higher grain yield than susceptible cultivars across all treatments. Grain yield of tolerant cultivar at 60kgN/ha was 88% higher than that of susceptible cultivar at 120kgN/ha. In a similar study, Striga infestation reduced grain yield of two susceptible hybrids by 49% and of two tolerant hybrids by 24%. The two tolerant hybrids produced on average 87% higher grain yield than the two susceptible hybrids under low N rates (0-60 kg/ha) and 51% higher yields under high N (90-150 kg/ha) (Kim et al., 1997). Efforts are continuously made to reduce or control these diseases; however, the efforts were complicated by several factors that are making it difficult to achieve an impact in a relatively short time, due to the following reasons:

i. Important diseases change with time
ii. Some diseases are specific to particular ecologies, whereas others are present in all ecologies iii. Difficulty in infecting maize with some of the diseases for effective screening of the germplasm for resistance for example downey mildew.
iv. Difficulty of artificially inoculating maize plants to screen for resistance; therefore, plant breeders could not study the genetics of resistance of

Table 8. Some improved hybrid maize varieties in Nigeria.

Name of variety /original	Original source	Developing institution	Outstanding characteristics	Years of release	Yeas of regist.
8321-18	IITA	IITA	Resistant to streak, Striga/ weevil, semi-flint grain, high yield – 6.5t/ha	1984	1991
8321-21	-do-	-do-	High yield 6.0 ton/ha, resistant to streak, rust and blight dent grain texture	1984	1991
8522-3	-do-	-do-	-do-	1984	1991
8322- 13	-do-	-do-	High yield 6.5t/ha, resistant to streak, downy mildew, and drought, dent grain type.	1984	1991
8341-5	-do-	-do-	-do-	1984	1991
8425-8	-do-	-do-	-do-	1985	1991
8428-19	-do-	-do-	High yield 6.0 ton/ha, resistant to streak, Striga, semi-dent	19885	1991
8434-11	-do-	-do-	High yielding, resistant to streak and storage weevil semi flint grain, high yielding 5t/ha.	1985	1991
8505-2	-do-	-do-	High yield 6.0ton/ha, resistant to streak and Striga, semi-dent grain	1986	1991
8505-3	-do-	-do-	Same as above but semi flint grain	1986	1991
8505-4	-do-	-do-	High yield 6.0ton/ha, tolerant to streak and Striga, semi-flint grain texture.	1986	1991
8505-5	-do-	-do-	-do-	1986	1991
8505-13	-do-	-do-	-do-	1986	1991
8341-5	-do-	-do-	High yielding, resistant to streak and weevil, flint grain texture	1984	1991

Source: National Centre for Genetic Resources.

some of the diseases (Fakorede, 2001).

The most debilitating pests in maize production include stem borers, termites, storage insects, beetle and host of others. Various species of stem borer rank as the most devastating, causing maize pest loss of 20 - 40% during cultivation and 30 - 90% post-harvest storage (IITA, 2009). As a result of significant yield loss due to pest and diseases, extensive research has been done along this area. Many national maize programs with the aim of developing maize resistant varieties to prevailing diseases in different agro ecological zones of the country had been organized. On account of these national programs, germplasms both of pollinated and hybrids resistant to prevailing diseases have been developed. Several agronomic practices have also been investigated to minimize the effect of many of these pests and diseases.

Although many insects, pests and diseases can be controlled with chemicals, these chemicals, often times, are not available, are dangerous and often expensive for small-holders who lack access to credit facilities. Moreover, chemicals are increasingly viewed as environmentally hazardous, threat to human life and safety, such that their use are been discouraged by many policy makers. A variety of chemical and cultural practices can help control many of the diseases; however, using resistant germplasms, which is the least harmful to the environment, is the most effective method for controlling them.

Low soil fertility and maize

Low soil fertility ranks among the most serious constraints of maize productions which are brought mainly by reduction in the fallow period because of ever increasing population pressures. Nigeria as in many other tropical climates is characterized by high rainfall and insolation, the attendant problem of nutrient leaching and low level of soil organic matter which has made nitrogen the most nutrient limiting maize production in Nigeria (Azeez et al., 2006). Increase of fertility level has played a key role in the increase of maize yields and the dominant plant nutrient causing this increase has been nitrogen.

One important characteristic of maize is its high nutrient requirement especially N, P and K. On the average, maize grain contains up to 2% N and 2.6% for all above ground parts. 20 kg of nitrogen is removed from the soil for every ton of maize grain harvested (Fakorede, 2001). Farmers understand the importance of nitrogen in maize production and employ different strategies to minimize the adverse effects of low soil fertility such as using low population density, applying mineral fertilizer or animal manure, leaving the land fallow and switching to less demanding crops (Carsky et al., 1998). However, even with all these efforts farmers are not able to supply adequate quantity of fertilizer and most often do not apply fertilizer mostly due to high cost or unavailability. Therefore, maize yield is generally low.

Fertilizer requirements of maize

Increase in fertility level has played a key role in the increase of maize yields in Nigeria, and the dominant plant nutrient responsible for this increase has been nitrogen, which is a major nutrient needed in large quantity for high yields in maize production. Many field experiments have shown responses in grain yield of maize to application of nitrogen fertilizer. But the magnitude of response to applied nitrogen varies across experiments due to confounding influences of soil nitrogen supply from non-fertilizer sources, weather variation, variety and cropping practices. Consequently, recommendations of nitrogen management are site and season specific.

Nitrogen is a component of protein and nucleic acids but when it is sub-optimal, growth is reduced (Haque et al., 2001). Nitrogen is also a characteristic constituent element of protein and also integral components of many other compounds essential for plant growth processes including chlorophyll and many enzymatic processes. Nitrogen plays a significant role in protein synthesis and thus strongly influences grain production and grain protein content (Gallais and Hirel, 2004). Its supply also affects both leaf area development and leaf senescence, and consequently crop radiation interception (Lemcoff and Loomis, 1986). Meanwhile, photosynthetic activity of the leaf canopy, and thus radiation use efficiency, varies with leaf nitrogen (expressed as the amount of nitrogen per unit leaf area (Muchow and Sinclair, 1994).

During reproductive development, nitrogen is mobilized from the leaves and stem to the grain (Ta and Weiland, 1992) with consequent reduction on leaf photosynthetic capacity and the consequences for grain yield depend on the relative contribution of crop nitrogen uptake and mobilization of leaf nitrogen to grains as moderated by the grain concentration. Common nitrogen recommendation for old NS series in Nigeria is 75 kgN/ha (Jones, 1973). Lucas (1986) recommended 150 kgN/ha for FARZ series based on profitability, although the yield of maize at 75 kgN/ha was not significantly different from the yield at 150 kgN/ha, while Akintoye et al. (1999) reported responses up to 70, 140 and 210 kg N/ha for maize grown in Ikenne, Mokwa and Kaduna respectively, using different maize genotypes.

With regard to dry matter distribution in maize as influenced by nitrogen, studies on nitrogen levels at Ilora, Southwestern Nigeria using three genotypes of maize (open pollinated, single cross and double cross hybrids) indicated that at final harvest, among all genotypes and fertilizer levels, the least dry matter was partitioned to tassels while the highest was found in stem and grains. The proportion of dry matter partitioned to grains are 27% for single and double cross and 25% for open pollinated while the proportion partitioned to grain was similar (30%) for 75,100, 150 and 200 kgN/ha (Olaniyan,1999) (Figures 3 to 7).

The biggest problem to fertilizer use in Nigeria is the cost because the government has reduced drastically the subsidy on fertilizer. In view of this a bag of nitrogenous fertilizer costing only ₦3.00 a bag (50 kg) to the farmer in 1980s, ₦ 1,500 in 1990s is now N6,000. Fertilizer is relatively expensive in Nigeria than countries in Asia or South America, probably because fertilizer imports have to be financed with foreign exchange which is often in short supply. Another obstacle to fertilizer use in Nigeria is the unavailability at the time when the farmer needs it or in the formulations they desire. Many factors contribute to fertilizer supply problem. Planning and administering a national fertilizer program require skills that are not always available in the government agency that oversee input supply, and the private sector also may experience problems in distribution of fertilizer (Shepherd, 1989).

Furthermore, deep-seated corruption in Nigeria is a major obstacle to fertilizer supply. For instance, medical practitioners, engineers, politicians and others who have no business in farming are the major players in fertilizer and other inputs distribution of fertilizer; thereby, benefiting from government support towards fertilizer supply, while the farmers who are supposed to be major beneficiaries are relegated to the background.

Data from sites throughout Africa suggested that modest doses of fertilizer, especially nitrogen in maize often generate significant yield increases. Whether or not crop responses are sufficient to justify the increased cost of purchasing and applying fertilizer depends on a number of factors, including the price of fertilizer, the price of maize grain and cost of additional inputs required.

Applying chemical fertilizer is a major strategy for maintaining soil fertility. Other technology such as crop rotation, crop residue management, use of live mulches, use of organic fertilizer (compost, animal manure, organo-mineral fertilizer) and other techniques have been researched into. Moreover, nitrogen use efficient genotypes have been researched and developed. Research into many of these soil fertility technologies has shown that they could be viable, and trials on various farmers need to test whether they are economically viable and sustainable from the farmers' point of view.

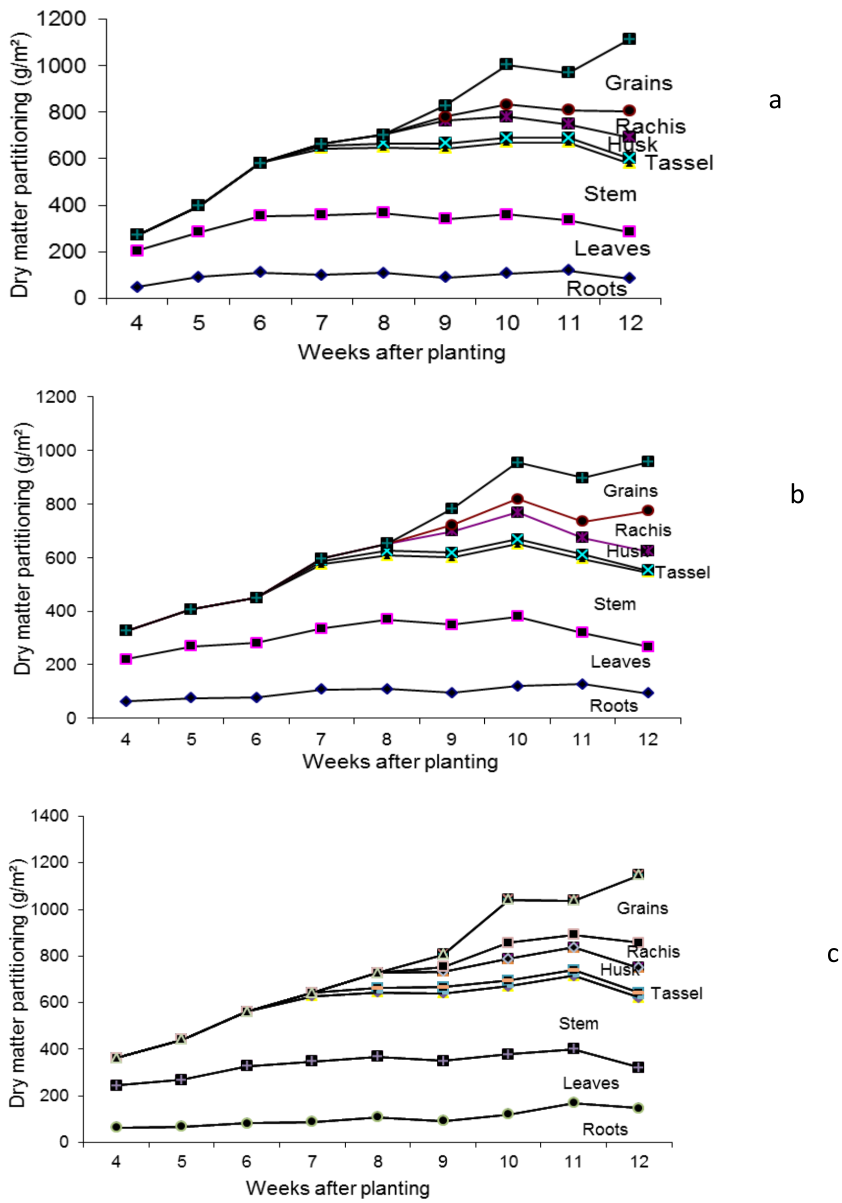

Figure 3. Dry matter partitioning in (a) Open pollinated (b) Single cross (c) Double cross maize genotypes grown at 80,000 plants/ha at zero N level.

Weed infestation and maize

Maize require minimum weed invasion to exhibit its yield potential. Heavy weed interference results in competition for essential resources and, consequently, yields loss. Weeds seriously limit maize productivity in farms in Nigeria. Indeed, it is estimated that weed control takes 50 to 60% of the total cost of maize production (Fakorede, 2001). Weeding takes between 21 to 32% of the total time devoted to maize production in Nigeria. Maize is susceptible to competitions from many annual weeds in the first six to eight weeks after planting and the extent of weed infestation varies from one ecology to the other. It has been reported that weeding during a critical period of 10 to 30 days after crop emergence greatly enhances grain production, while uncontrolled weed growth during this period could reduce maize yield by 40 to 60% (Olaniyan and Lucas, 2004).

One of the most dangerous weeds in maize production is Striga, which is also known as *witch weed*. It is indigenous parasitic weeds that attack maize crop, especially in the savanna areas of Nigeria. Striga is becoming a detrimental pest of maize as a result of the intensification and expansion of maize in the savanna, where Striga is endemic. Apart from savanna region, the weed has been reported in other parts of Nigeria,

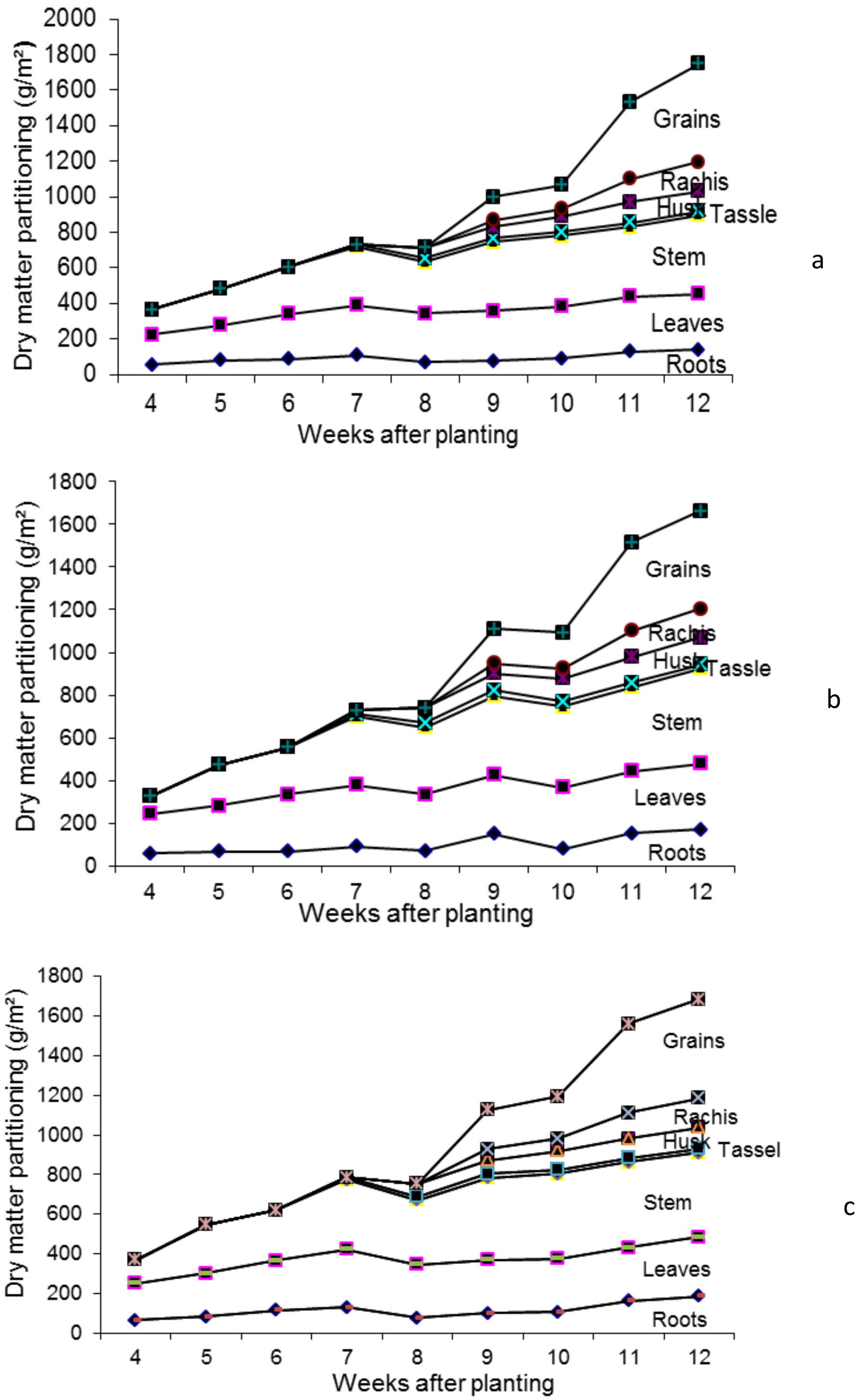

Figure 4. Dry matter partitioning in (a) Open pollinated (b) Single cross (c) Double cross maize genotypes grown at 80,000 plants/ha with 75kg N/ha.

including the derived savanna of southern Nigeria. The species observed in the southern part of Nigeria are *Striga asiatica, Striga aspera, Striga gesnerioides* and *Striga forbesii*. However, *Striga hermonthica* which is prevalent in the Northern part of Nigeria is the most damaging and widespread among Striga species. Yield losses from Striga range from 10 – 100% depending on time of parasite infection (Lagoke et al., 1991). Although major technologies exist to control Striga weeds but since most of the effective control practices require expensive

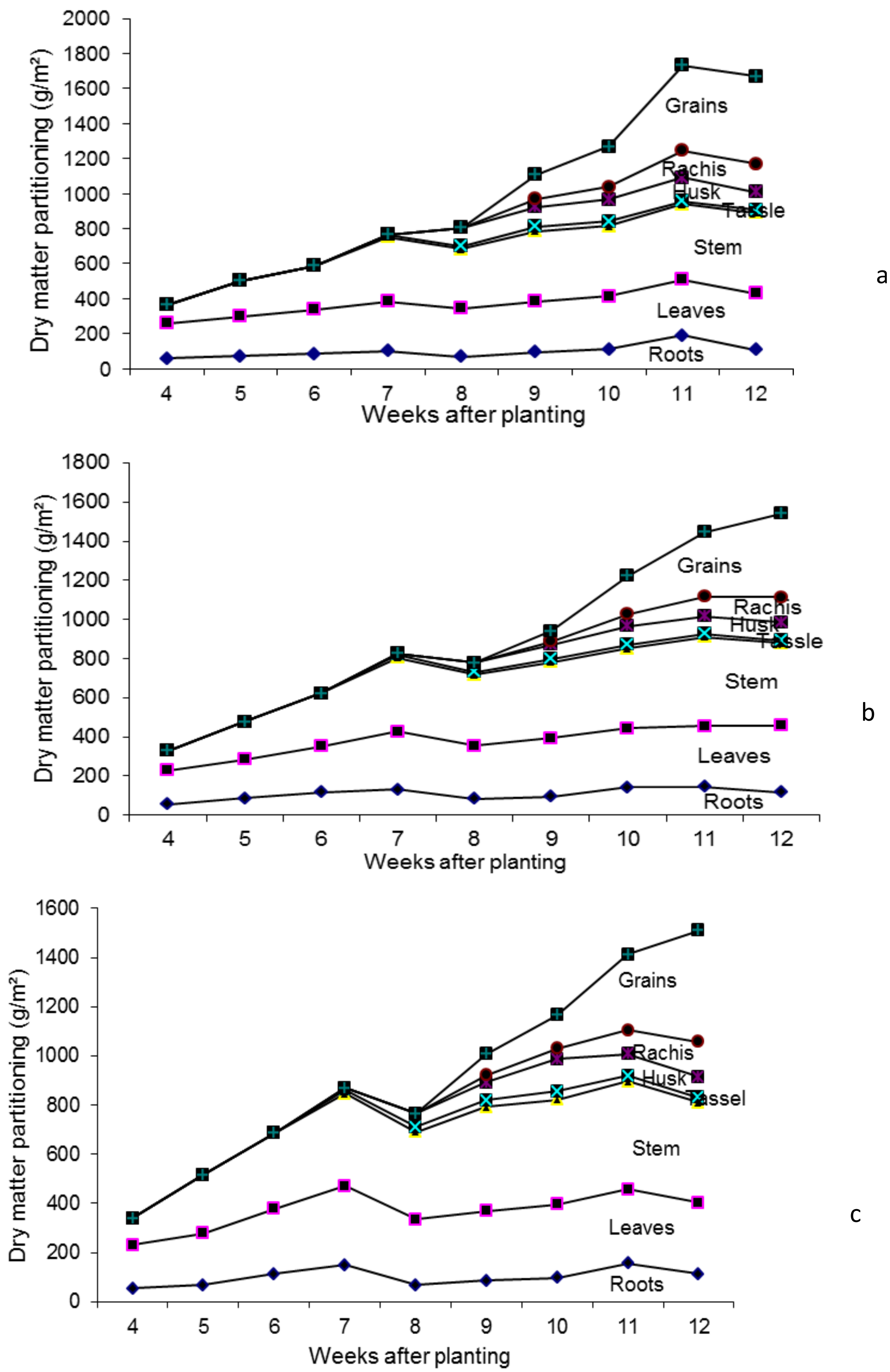

Figure 5. Dry matter partitioning in (a) Open pollinated (b) Single cross (c) Double cross maize genotypes grown at 80,000 plants/ha with 100kg N/ha.

inputs or special equipment, they are not suitable for small scale farmers who constitute the large family population in Nigeria (Ogborn, 1987). However, it has been recommended that the most practical approach of controlling Striga species is the use of cultivars that are resistant to or tolerant to the weed infestation.

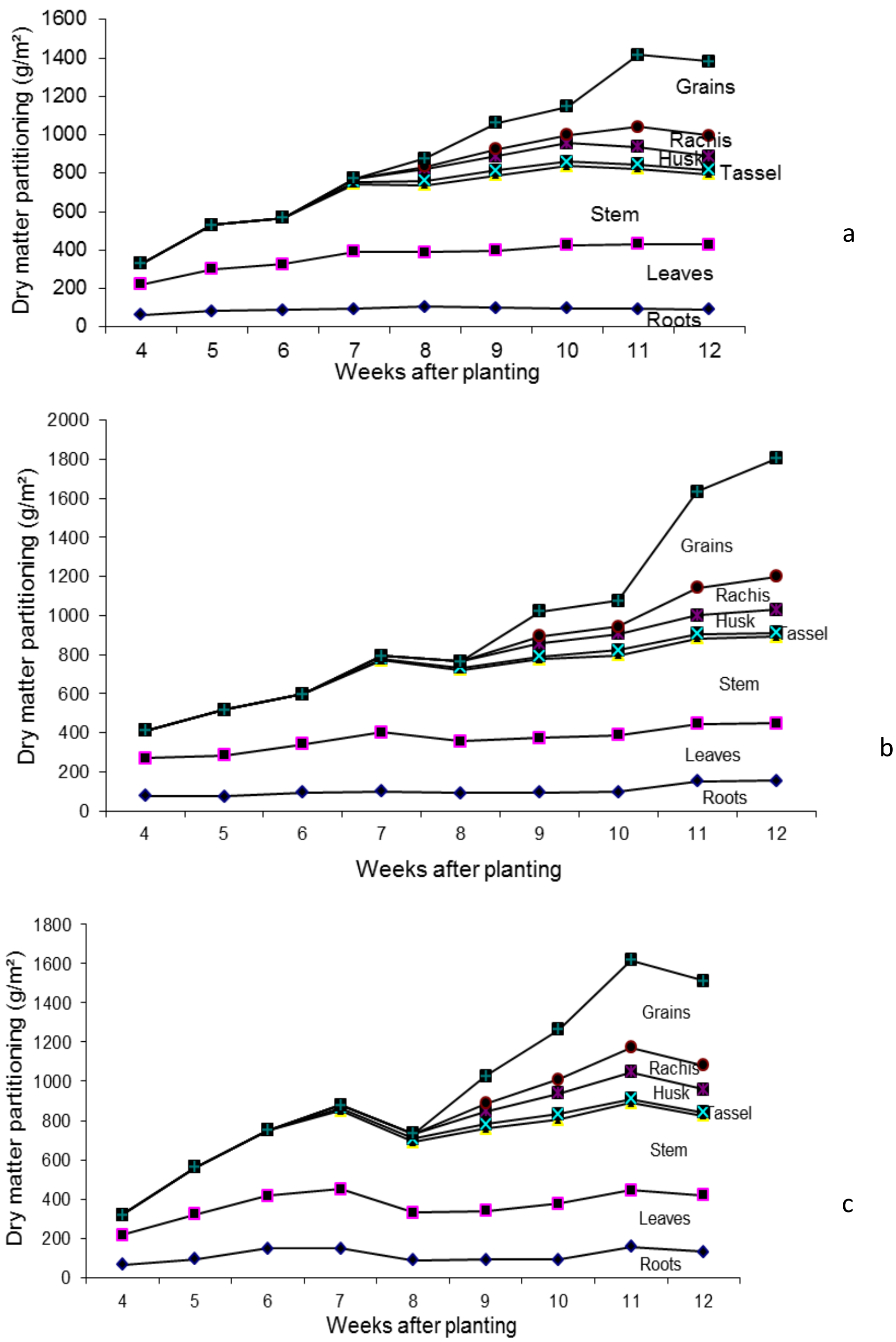

Figure 6. Dry matter partitioning in (a) Open pollinated (b) Single cross (c) Double cross maize genotypes grown at 80,000 plants/ha with 150 kg N/ha.

Weeding requirements of maize

Weed control in most agricultural system in Nigeria involves the use of hoes and cutlasses which are quite tedious, time consuming and often ineffective. Recommendation is usually hand weeding 14 to 21 days, and 57 days after planting, while third weeding may be necessary, depending on the varieties and severity of weeds. Weed may also be controlled by various other methods, including tillage practices, planting of weed - free seeds, cultivation using animal or mechanical power, cultural methods such as the use of cover crops, planting

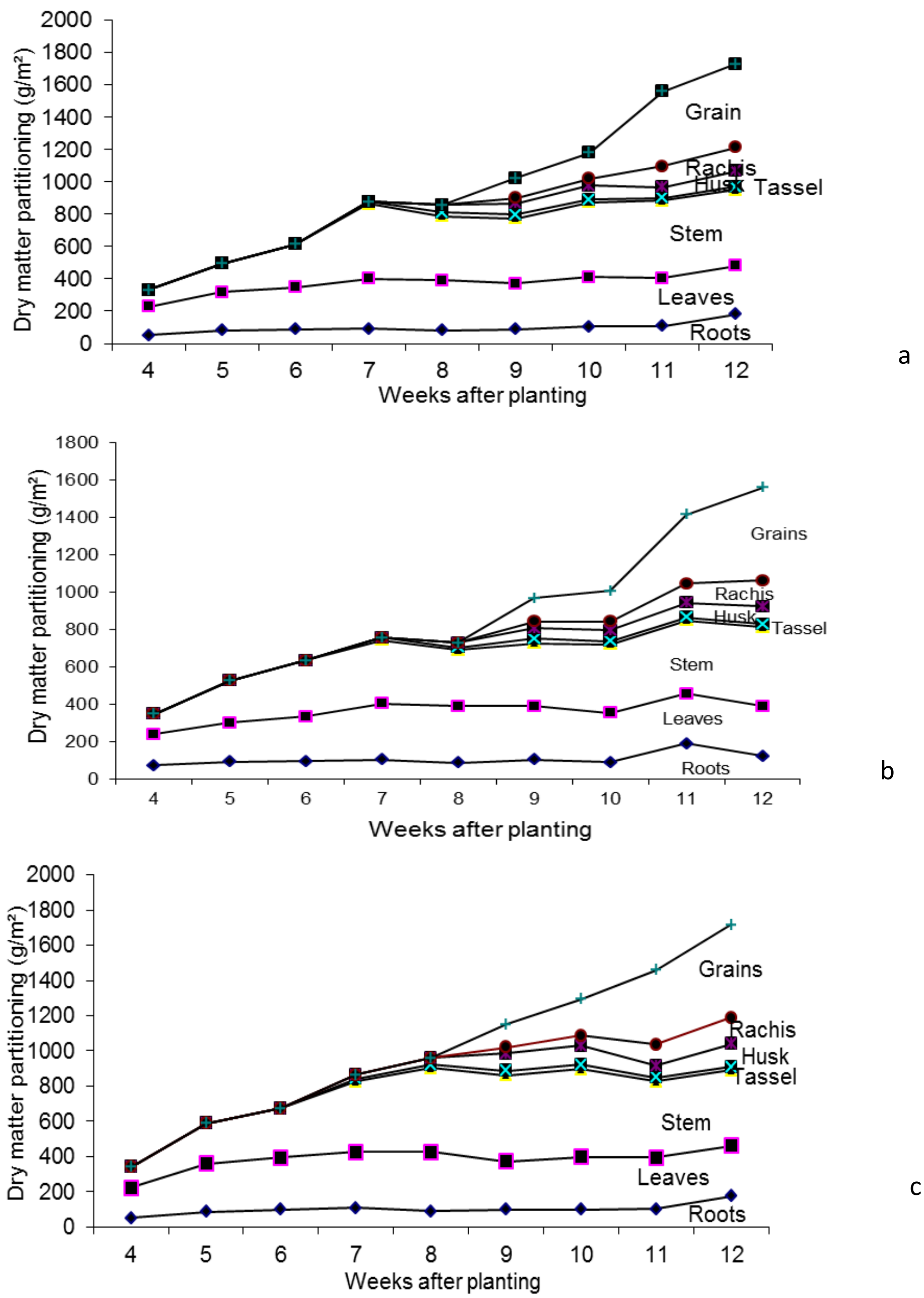

Figure 7. Dry matter partitioning in (a) open pollinated, (b) single cross, (c) double cross maize genotypes grown at 80,000 plants/ha with 200 kg N/ha.

immediately after land clearing and use of herbicides. Maize is affected by many weed species but weeds such as *Cyperus rotundus, Rottboellia Cochinchinensis* and *Imperata cylindrical* are quite problematic because they are very competitive and difficult to control when routine crop husbandry practices are employed. Others such as *Euphorbia heterophylla* occur in large number (high density) and grow as rapidly relative to crop that the young maize are shaded out. Other weeds common in maize plots included *Talinum triangulare, Amaranthus spinosus, Chromolaena odorata, Agerantum conyzoides* (Akobundu and Agyakwa, 1987).

Weeding takes between 21 to 32% of the total time devoted to maize production in Nigeria (Table 9) (Lucas, 2007). Moreover, different herbicides are recommended and for maize and maize based crop mixtures, however,

Table 9. Mean man-hours used for different cultural operations by maize farmers in Nigeria.

Operation	% time used
Land Preparation (including slashing and burning	24.6
Planting	5.1
Weeding	25.6
Fertilizer application	7.7
Harvesting	18.5
Shelling and storage	18.5
Total	100

Source: Lucas, 2007.

unavailability, cost and knowledge of handling and environmental effects are drawbacks to its use.

Drought and maize

Maize grown in Nigeria and many other countries in Sub-Sahara Africa are usually rain-fed. Rainfall, and to a lesser extent, temperature are the most important climatic factors that determine crops' growth and timing of agronomic practices in different ecological zones of Nigeria. Although, agricultural drought occurs when the levels of precipitation are sufficiently low to cause serious decrease in crop yield through its effects on the physiological process whereas, maize is essentially sensitive to moisture stress around the time of tasselling and cob formation. It also needs optimum moisture condition at the time of planting. Drought may occur at any stage of maize growth but when it coincides with flowering and grain filling periods yield loss could be between 40 to 90% (Menkir and Akintunde, 2001). Drought stress at flowering disrupts the synchrony between pollen shed and silking, which is the major cause of yield reduction (Banziger et al., 1999).

In spite of great potential of Nigeria in maize production, frequent occurrence of drought occasioned by erratic rainfall distribution and/or cessation of rain during the growing season is the greatest hindrance to increased production, and this is more serious in the northern parts of Nigeria. In order to reduce yield loss due to drought, drought resistant varieties are being developed and the Nigerian Meteorological Agency (NIMET) are taking responsibilities for weather forecast into periods of planting for different cropping zones.

MAIZE IN THE FARMING SYSTEM

Small scale farmers in Nigeria as well as other Sub-Sahara African countries prefer intercropping to sole cropping because they found the latter to be costly, risky and characterised by inadequate production of wide range of food crops needed by an average household. Maize is often intercropped with legumes, cassava, melon etc.

Cereal legume intercropping is often employed as a basis for enhancing resource use and the sustainability of tropical smallholder farming systems (Tsubo et al., 2005) In Africa, maize does well when intercropped with beans or other legumes. Productivity of mixture of maize and legumes often exceeds that of sole crops due to synergistic effects that favour the growth and yield components of both crops (Agegnehu et al., 2010). The productivity of intercropping system of maize and soybean in guinea savanna agro ecosystem of Nigeria indicated yield advantage of 2-63% as depicted by the LER of 1.02 to 1.63, indicating efficient utilization of land resources by growing intercropping maize with soybean (Muoneke et al., 2007).

In another study in Nigeria on the effect of maize/cassava intercropping on the micro-environment, intercropping cassava with maize was found to lead to better light interception than growing cassava alone (Lucas,2007). Unfortunately, small scale farmers could not maximize the production from their intercropping system because most of the agronomic practices introduced to the farmers are usually for sole cropping.

Growth analysis of maize

Growth is a vital function of plants and is an indication of a gradual increase in number and size of cells. Growth analysis is commonly used in ecological studies to determine success of species in various habitats, competition among species, genetic differences in yield and agricultural treatment on crop growth (Hayness et al., 1967). Growth analysis is still the most simple and precise method to evaluate the contribution of different physiological indices in plant development despite its drawback. In growth analysis two basic measurements are made from which large numbers of parameter are derived. These are measure of plant material present (dry weight) and leaf area which is the measure of the assimilatory system of plant material. Generally, maize growth analysis is carried out so ascertain the formation and accumulation of plant biomass as determined by the environment or internal factors or both (Nevado and Cross, 1990). Some important parameters of growth in maize studies are as follows:

Dry matter

Total crop dry matter is the spatial and temporal integration of all plant processes and, therefore, crop dry matter is the most relevant parameters in the study of crop canopies. Rate of dry matter accumulation varies across the life cycle of a crop and leaf area sampled at intervals ranging from days to weeks to quantify the effect of environmental influences or to analyze genotypic differences between maize cultivars.

The pattern of rate of dry matter accumulation is typically characterized by a sigmoid curve and always in three phases (i) a period of exponential growth during early development followed by (ii) period of more or less constant rate dry matter accumulation and (iii) a period of declining crop growth rate during the final phase of development when green leaf decline due to leaf senescence and leaf photosynthesis declines due to leaf aging (Echarte et al., 2008).

Rate of dry matter accumulation is the product of total incident solar radiation, the absorptance of incident solar radiation by the crop canopy and the efficiency of conversion of absorbed solar radiation into plant dry matter. Dry matter accumulation increases for maize hybrids at high than at low density due to light interception. With increase in plant population per hectare dry matter yield per plant decreases steadily, but yield per hectre increases up to a maximum and then falls (Tollenaar, 1991). Differences in dry matter accumulation arise mainly in variation in leaf area.

Crop growth rate

Crop growth rate (CGR) is defined as the increase in plant material per unit time. It is a measure of rate of dry matter production per unit area of land (Watson, 1952). CGR can be expressed in energy units as a percent of daily mean total of incident radiation or transformed into a coefficient of solar energy utilization. This coefficient indicates how economically a crop uses the solar radiation available during and interval between two harvests. CGR is generally higher in C4 plant than C3 plants (Tsubo et al., 2005). CGR patterns can be defined accurately by taking plant samples at different time intervals during the growth season. Values of CGR are normally low during early growth stages and increase with time, reaching maximum values at time of flowering.

Analysis of CGR is important for evaluating treatment differences among maize crop or maize genotypes in relation to yield. CGR of tropical maize genotypes are generally higher than the temperate genotypes, but they could not out yield the temperate genotypes. The peak CGR rate observed for most studies in Nigeria ranged between 20.7 to 46.3 g/m^2/day (Lucas 1981) and peak value for CGR in temperate region ranged from between 12.0 to 24 g/m^2/day (Iremiren and Milbourn, 1978). Higher values in the tropics have been associated to higher production of dry matter per unit leaf area when compared with values reported in temperate regions.

Leaf area index

Leaf area index (LAI) describes the size of assimilatory apparatus of the plant stand and serves as a primary value for calculating other growth characteristics. LAI is defined as the leaf area of a plant over a certain area of ground (Watson, 1952). Leaf area index is the primary factor that determines crop growth rate on crop communities. Olson and Sanders (1988) concluded that one simplest ways of increasing LAI is increased plant density.

LAI increases linearly as the plant density increases but the leaf area per plant decreases as the plant density increases. Hence dry matter produced decreases with decreasing of LAI. The differences in values reported for optimum LAI in maize in different parts of the world may be due to differences in environmental factors and leaf arrangement. These two factors have been shown to affect net assimilation rate (NAR) and consequently, CGR (Pendleton, 1968). Maize varieties with erect leaf arrangement which are better suited for light interception have higher NAR at dense canopies and therefore higher optimum LAI for CGR.

Net assimilation rate

NAR is defined as increase in plant dry weight per unit time. It provides an estimate of photosynthetic production. NAR is describes as a measure of the efficiency of the unit leaf surface whose value depends on light interception characteristics of plant (plant angle and leaf inclination); gas exchange properties of leaf, characteristics for drought resistance, water use and several other factors (Williams, 1946). Warren-Wilson (1966) reported that NAR is more dependent on intercepted light than any other environmental factor while Jolliffe et al. (1990) reported that NAR is more dependent on plant density. It was reported that NAR value decreases with crop growth due to mutual shading of leaves and reduced photosynthetic efficiency of older leaves.

NAR would decrease with increased LAI; NAR per plant would decrease with increased LAI at high than at low density but increase than in per area and this trend decrease will continue from the beginning till the end of growth season (Brogeham, 2000). Thus, increasing plant density accelerated leaf senescence, increased shading of leaves, and reduced the net assimilation of an individual plant but increase NAR per unit area (Boyat et al., 1990).

Leaf area ratio

Leaf Area Ratio (LAR) is defined as ratio between leaf area and the total dry weight of the plant. It characterises the relative sizes of assimilatory apparatus as a useful measure of the growth differences that occur between experimental crops. LAR is environment specific and higher LAR was reported in the forest zone than in derived zone in an experiment conducted in two ecological zones using two varieties of maize in Nigeria (Lucas, 1981).

Harvest index

Harvest Index (HI) is an estimate of economic yield of a crop over its total dry matter represented (Donald, 1951) as:

$$HI = \frac{\text{Maximum dry matter of economic yield}}{\text{Total dry matter}} \times 100$$

In a comparison of two groups of hybrid maize, approximately 15% of the yield difference between the two groups is attributed to harvest index hence 85% of the difference is due to increased dry matter accumulation. Plant density produced an increase in total dry matter production and a decrease in harvest index and optimum plant density was a tradeoff of both effects (Tollenaar, 1989).

CONCLUSION

Maize, an efficient crop in utilizing solar energy by converting it to food, has an important role to play in providing food for the current and future needs of Nigeria and the world at large. As species, maize contains enormous genetic variation which, under good management and favorable conditions will give very good yield. In Nigeria, maize has high yield potential but yields are substantially below their potential. However, sustainable maize production is attainable in Nigeria. At present, the cost of production of 1 hectare of maize ranged between ₦ 100,000 to ₦ 120,000 while farmer's sell maize between ₦ 45,000 to ₦ 50,000 / ton. With the average maize yield, farmers are running at loss. Therefore, maize productivity should be enhanced. A wide gap between yield in researchers and farmers field needs to be addressed through efficient linkage between researcher, extension, market and input. Other factors militating against maize production should be identified and properly addressed. Storage facilities need to be improved upon, although the silo for storing grain has increased to 500,000mts capacity. However, there is need to create grain aggregation and collation centers in the rural maize growing areas for temporary storage and linkage to bigger silos or end-users.

In maize, two inputs, improved seeds and fertilizer are of overriding importance in maize intensifications system. In recent years, the private sector has become increasingly involved in the supply of improved maize seed, fertilizer and other agricultural chemicals and equipment. Development of efficient seed industries for providing and distribution of improved maize seed variety to farmers at affordable price should be prioritized in transformation agenda of government. Agriculture should be regarded as a social service as it is done in developed countries like United States and European Union. At present, the mechanisms for the distribution of subsidized fertilizer are very inefficient, and in this regard, regulatory system should be streamlined and made more transparent. The planned appropriation of ₦ 60 billion for purchase of 10 million cell phones for farmers to buy inputs and access information (people who live far from the cities and where network connection is poor) may not be appropriate.

Conflict of Interest

The authors have not declared any conflict of interest.

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