FEDERAL UNIVERSITY OF AGRICULTURE
ABEOKUTA NIGERIA

63RD INAUGURAL LECTURE

UNLOCKING THE PRODUCTION POTENTIALS OF SOME ANNUAL OILSEED CROPS IN NIGERIA

by

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INAUGURAL LECTURE

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Protocols

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Distinguished members of the University Senate;
Distinguished Academic and Professional Colleagues in FUNAAB and from other Tertiary Institutions;
Members of my immediate and extended families;
Distinguished Ladies and Gentlemen;
Gentlemen and Ladies of the Press;
Great FUNAABITES!!!

PREAMBLE

I am grateful to God for this unique opportunity to present the 63rd Inaugural Lecture of the Federal University of Agriculture, Abeokuta (FUNAAB). My lecture is the 12th Inaugural Lecture from the College of Plant Science and Crop Production, and the third Inaugural Lecture from the Department of Plant Physiology and Crop Production (PPCP), COLPLANT. The first and second

Inaugural Lectures from PPCP were presented by Profs. P.O Adetiloye (45th) and late K. A Okeleye (54th) respectively. This Inaugural Lecture is the first from the Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR). The Institute is saddled with the responsibility of anchoring the research component of the tripodal mandate (teaching, research and extension) of the University.

1.0 INTRODUCTION

Oilseeds are crops which bear oil in their seeds. The use of vegetable oils of plant origin by man dates back to the Bronze Age (3300-1200 BC) in the Middle East, Africa and Central Asia (Anon, 2020). The use of oil has its deep roots in Jewish history and has been used severally for anointing Priests, healing, unity and empowering for vocation (Gillespie, 2019). The list of common oil-bearing plants in Nigeria includes cashew (*Anacardium ocidentale* L.), oil palm (*Elaeis guineensis* L.), corn (*Zea mays* L.), cottonseed (*Gosyppium* spp L.) groundnut (*Arachis hypogea* L.) sunflower (*Helianthus annuss* L.), sesame seeds (*Sesamum indicum* L.), rapeseeds (*Brassica napus* L.), mustard seeds (*Brassica carinata* L.), castor seed (*Ricinus cumunis* L.), linseed (*Linum usitatissimum* L.), etc. Nigeria's national consumption requirement (NCR) of edible vegetable oil stood at 2.3 million tonnes per annum in 2014 whereas local production was 1.8 million tonnes leaving 600,000 tonnes shortage which is normally met through imports (Nzeka, 2014). In 2018, Nigerians consumed about 3 million tonnes of fats and oils with palm oil accounting for approximately 45% of total consumption (PwC, 2019). The two leading providers of edible vegetable oil in Nigeria are palm oil/palm kernel oil and soybean oil contributing approximately 70 percent and 25 percent of the country's National Consumption Requirement (NCR) respectively. The remaining 5 percent is met by other oilseeds.

Nigeria was number five (5) among the top palm oil producing nations in the world in 2019 with Indonesia and Malaysia producing 57 and 27% of the total world production, respectively (See Annexe 1). However, consumers prefer oils from annual oil bearing crops because their oils are heart-friendly since they contain unsaturated fatty acids and are liquid always unlike the oils of animal fat (lard), palm kernel, and coconut oil that contain saturated fatty acids and are solid at room temperature (Singh, 2007). The Federal Government of Nigeria removed the import ban on bulk crude vegetable oil in 2008. However, the ban on importation of all types of vegetable oil in packs still subsists (Nzeka, 2014). Despite the ban on importation of vegetable oils by the Federal Government of Nigeria, the country still imported 112,480 tonnes of oil palm in the first quarter of 2019 (Adesoji, 2019). As at March 2019, based on the report from the Central Bank of Nigeria, Nigeria spent the sum of $500 million on oil palm importation annually (Adesoji, 2019). In 2017, Nigeria spent a total of $1.46 billion on the importation of 11 vegetable oils with palm oil, soybeans and sunflower occupying the first three positions in terms of cost of import (Table 1).

In an attempt to make vegetable oils readily available to the citizenry of Nigeria, many vegetable oil processing companies are operating in different locations in Nigeria (See Annexe 2). However, if we must meet the demand of local vegetable consumption, concerted efforts must be geared towards increasing the production of the major oil-bearing crops in Nigeria. Apart from oil palm and probably soybeans, other oilseed crops are normally regarded as 'minor oilseeds' in the tropics because farmers usually grow them after harvesting the main crops (cereals) from the field leaving them to utilize residual nutrients and moisture and no fertilizer is usually applied on them. The belief was that at least the farmers would get something from the minor oilseed during the last two to three months of the late cropping season in the year. However, most of these so called minor oilseeds have gradually transformed into major oilseed crop status. Out of the annual oilseed crops, only sesame is among the agricultural products that go on export from Nigeria (Table 2). Nigeria generated about N61 billion from sesame seeds during the first half of 2019. Production of other oilseed crops does not even meet the local demand for human and industrial uses. According to FAOSTAT (2019), an overview of the production of some annual oilseeds (soybean, sesame, groundnut, cottonseed and melon) in 2018 revealed that a total of 4,973,128 tonnes of oil seeds was produced in Nigeria with groundnut accounting for over half of them (Fig. 1).

The prevailing weather conditions across the six geopolitical zones of Nigeria are favourable for the production of different oilseed crops. However, the traditional growing regions for oilseeds are located in the savanna belts of Nigeria (Fig. 1). The major oilseeds producing geopolitical zones are North east, North west and North central of the country.

Agronomy is a Greek word '*agros*' meaning field and '*nomos*' meaning management. Therefore, Agronomy is a branch of Agricultural Science which deals with the principles and practices of crop production and field management. An agronomist therefore, is a scientist who studies the way and means of production of food for man and feed for his animals (Pearson, 1967). The scope of agronomy is therefore, very broad cutting across crop production and protection, plant breeding and genetics, soil and water management etc. Consequently, the future of the hungry human race largely depends on the output of agronomists.

Land has been described as a critical natural resource in Africa which constitutes a rich and dynamic mosaic of resources with vast opportunities to improve human livelihoods (ADR, 2007).

Based on data compiled by the United Nations (2017) and FAOSTAT (2018), Nigeria's population has been projected to reach 973 million and 1082 million in 2100 under medium and worst cases respectively while the land remains 91 million hectares and out of which about 40 million hectares are currently utilized as cropland. At present with an estimated population of 193.5 million people, it translates to 2100 m^2 of land available per person.

Table 1. Nigeria's vegetable oil import in 2017

Oilseed crop	Quantity (tonnes)	Value of import ('000 $)
Oil palm	5,926	1,459,500
Soybeans	724	894
Sunflower	575	869
Olive	170	576
Rapeseed	380	534
Linseed	83	114
Maize	16	30
Groundnut	11	27
Palm kernel	9	14
Coconut (copra)	736	10
Cotton seed	33	4
Total	**8,663**	**1,462,572**

Source: http://www.fao.org/faostat/en/data/TP

Table 2. Nigeria's top 10 agricultural products in half year 2019 and Q1 2020

Products	Export (N'B) 2019	Products	Export (N'B) 2020
1. Sesame seeds	60.69	1. Sesame seeds	49.1
2. Fermented cocoa beans	31.05	2. Fermented cocoa beans	35.2
3. Cashew nuts, in shell	22.59	3. Raw cocoa	16.8
4. Raw cocoa beans	17.15	4. Cashew nuts	4.5
5. Cashew nuts, shelled	8.05	5. Cocoa butter	3.9
6. Other frozen shrimps & prawns	5.21	6. Ginger	2.7
7. Ginger	2.59	7. Frozen shrimps & prawns	1.8
8. Natural cocoa butter	2.26	8. Cotton lint	1.7
9. Agro Foods items	1.83	9. Flours & meal of oilseeds	0.9
10. Sesame oil and its fractions	0.92	10. Soya beans	0.7

Nairametrics (2019): https://nairametrics.cpm/2019/09/25/nigerias-top-10-agricultural-export-hit-n152-billion-in-half-year-2019/ (9/06/2020)

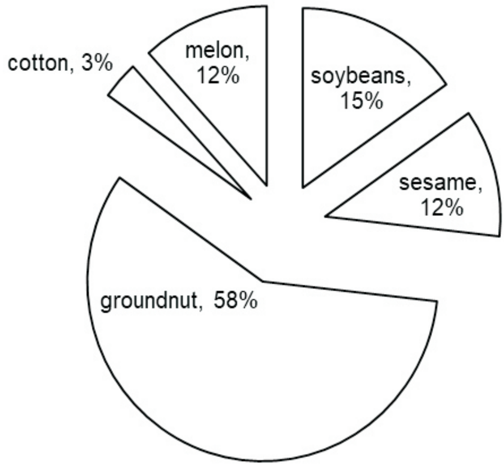

Fig. 1: Nigeria's arable oilseeds production in 2018
Source : FAOSTAT (2018)

Under medium and high fertility assumption till 2100 with a predicted population of 793 and 1082 million people, only 504 and 370 m^2 of land will be available per person respectively (Rahmann *et al.,* 2019). This shows very clearly that arable land scarcity is expected to rise significantly in Nigeria as population increases. At present, Nigeria is the most populous (>190 million) nation in Africa and the seventh largest in the world with an annual population growth rate of 2.7% (Worldometer 2020).

A few strategies to address food insecurity have been suggested by Olowe (2020). The two major factors that are often used to determine growth in agriculture are yield per hectare and land expansion (PwC, 2017). However, with the dwindling fortunes on limited arable land, there is the need to generate strategies that will result in optimal output of production practices by the country's resource constrained farmers. As an agronomist, this lecture will be based on my research findings on the production of three key annual oilseed crops (sesame, soybean and sunflower) under sole and intercropping systems, and under organic crop production system in Nigeria.

Fig. 2: Major vegetational belts of Nigeria

2.0 SOME ANNUAL OILSEED CROPS OF NIGERIA

2.1 The sesame (*Sesamum indicum* L.) plant

Sesame (*Sesamum indicum* L.) is the oldest oilseed crop known and used by man, and is also known as benniseed, gingelly, sim sim, ajonli, sesamo and til (Weiss, 2000). Sesame is a member of the order Tubiflorae, family Pedaliaceae and it probably originated from Africa before spreading to India, China and Japan. It is a broadleaf annual plant growing 50 to 100 cm tall, with opposite leaves 4 to 14 cm long with an entire margin; they are broad lanceolate, to 5 cm (2 in) broad, at the base of the plant, narrowing to just 1 cm broad on the flowering stem (Fig. 3a&b). The flowers are tubular, 3 to 5 cm long, with a four-lobed mouth and may vary in colour with some being white, blue or purple. Sesame fruit is a capsule, normally pubescent, rectangular in section and typically grooved with a short triangular beak. The length of the fruit capsule varies from 2 to 8 cm, its width varies between 0.5 to 2 cm, and the number of loculi from 4 to 12. Sesame is grown mainly for its seed which contains 50-60% oil and 19-25% protein with antioxdants ligans such as sesamolin and sesamin, which prevent rancidity and give sesame oil long shelf life (Nagendra Prasad *et al.,* 2012). The seeds are very rich in iron, magnesium, copper, manganese, and calcium and contain vitamin B1 thiamine and E tocopherol. The nutrients are easily absorbed by the body when properly prepared as in tahini (Bedigian, 2004).

Fig. 3(a) Sesame plant parts (b) Sesame plants on IFSERAR field

2.2 The soybean (*Glycine max* (L.) Merrill) plant

Soybean is a leguminous annual plant, normally bushy, erect, usually less than 75 cm in height, much branched with well-developed tap root system, producing seeds in pods and it belongs to the family Fabaceae (Fig. 4; Fig. 5a&b). The cultigen probably has its origin in north-eastern China. The roots of soybean plant carry nodules that contain a species-specific strain of *Rhizobium japonicum* bacteria which when developed contribute to nitrogen fixation (Weiss, 2000).

Soybeans have historically been called 'Golden Bean', 'Chinese Pea', 'Churia Bean', 'Cinderalla Crop', 'Meat of the field', 'Cow of China', 'Miracle Crop', Protein Hope of the Future', 'Life Giver', 'Meat without Bones' because of its colour and high protein content. The more recent varieties of soybeans are promiscuous. Promiscuity has been described as the ability of a legume host to nodulate with a wide diversity of rhizobial strains in the soil (Mpepereki *et al.,* 2000). Soybean is grown mainly for its seed which contains 15-25% oil and 40-50% protein. According to Shahbandeh (2020), soybean is the most widely cultivated Oilseed crop in the world (337.48 million metric tonnes) followed by rapeseed (68.02 million metric tonnes) and sunflower (53.48 million metric tonnes). On health benefits, soybean is an excellent blend of protein and fibre, source of molybdenum, copper, manganese, phosphorus, iron, omega-3 fatty acids, vitamin B2, magnesium, Vitamin K and potassium. Other excellent nutrients in soybean seed include flavonoids and isoflavonoids, phenolic acids, phytoalexins, phytosterols, unique proteins and peptides, and saponins (Merrit, 2004; Lampe, 2009; Barnes, 2010).

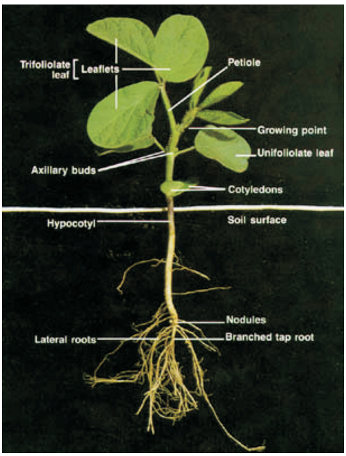

Fig. 4: The main features of a young soybean seedling


Fig. 5(a): Soybean pods


(b) Soybean plants on IFSERAR Field

2.3 The sunflower (*Helianthus annuus* L.) plant

Sunflower is an important oilseed crop that belongs to the family Asteraceae. The genus name '*Helianthus*' consists of two Greek words *'Helios'* and *'anthos'* which mean 'sun' and 'flower', respectively. It is at present the third (53.48 million metric tonnes) most widely cultivated oilseed crop in the world after soybeans (337.48 million metric tonnes) and rapeseed (68.02 million metric tonnes) as reported by Shabandeh (2020). Helianthus genus contains 65 different species (Andrew et al., 2013). Sunflower is grown mainly for its seed that contains oil (36–52%) and protein (28– 32%) as reported by Rosa et al. (2009). According to Khaleghizadeh (2011), the plant has a rough, hairy stem, broad, coarsely toothed, rough leaves and circular heads of flowers (Fig. 6). The heads consist of many individual flowers which mature into seeds on a receptacle base (Seghatoleslami et al., 2012). The seed of sunflower is rich in Vitamin E that has anti-inflammatory and cardiovascular benefits. The seeds also contain magnesium responsible for calming nerves, muscles and blood vessels. Selenium contained in the seeds improves detoxification and prevents cancer because it is incorporated at the site of many proteins, including glutathione peroxidase (Vogt *et al.,* 2003; Phillips *et al*., 2005). Sunflower is used in industry for making paints and cosmetics. A coffee type could be made with the roasted seeds. In some countries the seed cake that is left after the oil extraction is used as livestock feed.

Fig. 6. Sunflower plants on IFSERAR field

3.0 HYDROTHERMAL CONDITIONS IN FUNAAB BETWEEN 2000 AND 2019

In general, only 5% of Africa's (Abrams, 2018) and 1% of Nigeria's (Liangzhi et al., 2018) cropland are irrigated. Consequently, Nigerian agriculture is presently performing below its potential because it is mainly dependent on rain-fed cultivation. Rainfall distribution and temperature were used as proxies in this section to describe the growth conditions in the last two decades at FUNAAB. Weather data were sourced from the Department of Water Resources Management and Agricultural Meteorology, College of Environmental Resources Management (COLERM), FUNAAB. Weather data were also sourced from Ogun Oshun River Basin Development Authority (ORBDA) to complement FUNAAB data. Table 3 contains data on annual rainfall distribution from 2000 to 2019 and the long term (LTM) rainfall distribution over 35 years (1985-2019) at FUNAAB. The first half (2000-2005) of the first decade recorded lower rainfall distribution relative to the long term. The second half of the first decade however, was wetter than the LTM, except 2008. In the second decade, two years (2018 and 2019) were wetter than the LTM. Traditionally, the months of July and September are the two wettest months of the year. However, this trend was only observed in 2001, 2007 and 2018 in the last two decades (Table 3). The mean annual temperature also compared favourably with the long term temperature between 2000 and 2019. Temperature ranged between 24.8 and 31.7°C and was even stable at 27.9°C in 2015, 2019 and LTM (Fig. 7). The moving average of monthly rainfall distribution during the late cropping season and the LTM is presented in Fig. 8. The total rainfall values ranged between 641.7mm (2015) and 1212.4 mm (2010) as against 833.4mm for the LTM during the late cropping season. These values compared favourably with values recommended as being adequate for good crop yield of sesame (500-650 mm), soybean and sunflower (500-750 mm) by Weiss (2000). In a study we conducted on hydrothermal variability effect on sunflower seed yield in the humid tropics between 2001 and 2008, it was concluded that despite the global increase in climatic variability a good yield of sunflower is still possible in the humid tropical region (Olowe *et al.,* 2014). The observed variation in weather parameters in the last couple of decades could easily be attributed to climate change which is a complex biophysical process affecting many enterprises such as agriculture, water resources, energy, health, housing and urban development (IPCC, 2007).

Table 3. Monthly rainfall distribution between 2000 and 2019 at the Federal University of Agriculture, Abeokuta (UNAABA), Alabata, Abeokuta, Nigeria

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	**Total**
	3.4	0	110.8	31.1	74.2	140.4	257.1	267.1	204.5	48.4			0
2000	3.4	0	110.8	31.1	74.2	140.1	257.1	267.1	204.5	48.4	0	0	**1136.7**
2001	0	0	49.3	89.3	172.3	155.2	2	57.4	199.3	45.5	17.4	0	**869.7**
2002	0	2.7	389.1	136.9	134.9	137.5	325.5	110.1	148.3	297	54.5	0	**1736.5**
2004	15.3	20.4	75.2	83.2	233.7	145.2	130.8	73.8	172	163.1	0	0	**1112.7**
2005	0	42.5	22.6	104.1	135.7	259.5	122.3	68.5	198.4	38.3	0	17	**1093.7**
2006	4.5	62	62.1	180.3	77.75	261.85	92.8	61.8	250.7	56.8	43.4	0	**1154**
2007	0	0	69.5	71.4	231.2	163.5	300.7	777.6	212.1	103.5	16.4	0	**1945.9**
2008	0	0	0	87	130.2	168	299.2	192.7	126.5	120.1	0	16.2	**1139.9**
2009	0	0	96	101	124	140	160	162.1	151.6	180.1	64.6	10.4	**1189.8**
2010	4.4	41.2	58.9	112.7	169.6	98.3	322.9	266.6	257.6	172.3	94.7	0	**1599.2**
2011	0	139.8	23.9	74.5	73.7	84.5	349.5	88.7	204.1	288.1	3.6	0	**1330.4**
2012	0	67.2	67.7	80.1	115.3	225.1	155.4	36.3	181.4	184.7	149.6	1.3	**1264.1**
2013	39.8	23.5	78.1	82.4	128.2	53.7	202.6	35.2	136	94.4	15.6	16.5	**906**
2014	8.2	15.5	149.1	87.2	113.8	116.5	90.7	92.7	160.8	205.9	17.6	0	**1058**
2015	0	51.3	66.8	69	60.4	164.9	65.6	29.4	165.1	159.1	20	0	**851.6**
2016	32	0	150.3	68.2	226.2	150.5	65.2	63.6	229	155.4	5.9	0	**1146.3**
2017	15.9	0	34.3	112.8	146	111	156.1	90.5	50	92.2	45.6	0	**854.4**
2018	14.6	14.2	88.1	99.3	152.2	172.9	222.9	161.8	270	173.4	36	0	**1405.4**
2019	9	79	59.6	157.6	150.4	264.5	108.7	65.8	96.3	310	112.3	0	**1413.2**
LTM	6.3	27.5	72.5	100.6	132.1	172.7	191.5	112.3	183.3	131.9	22	8	**1160.8**

Source: Department of Water Resources Management and Agro-metereology, FUNAAB.

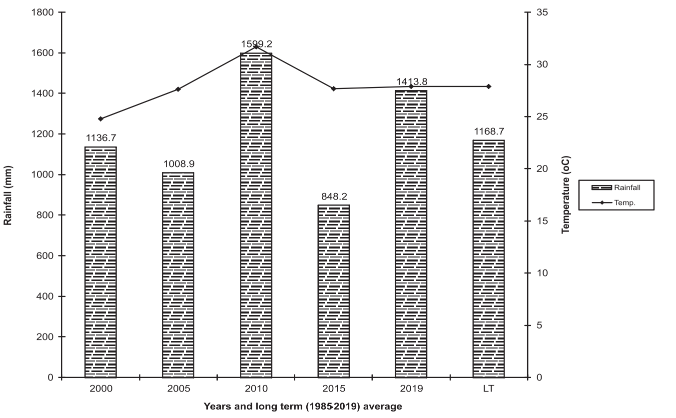

Fig. 7: Moving annual rainall distribution and mean temperature since 2000 till 2019 and long-term average (1985-2019) in Alabata, Abeokuta, Nigeria

Source: Department of Water Resources Management and Agro-metereology, FUNAAB.
LTM – Long Term Rainfall Distribution

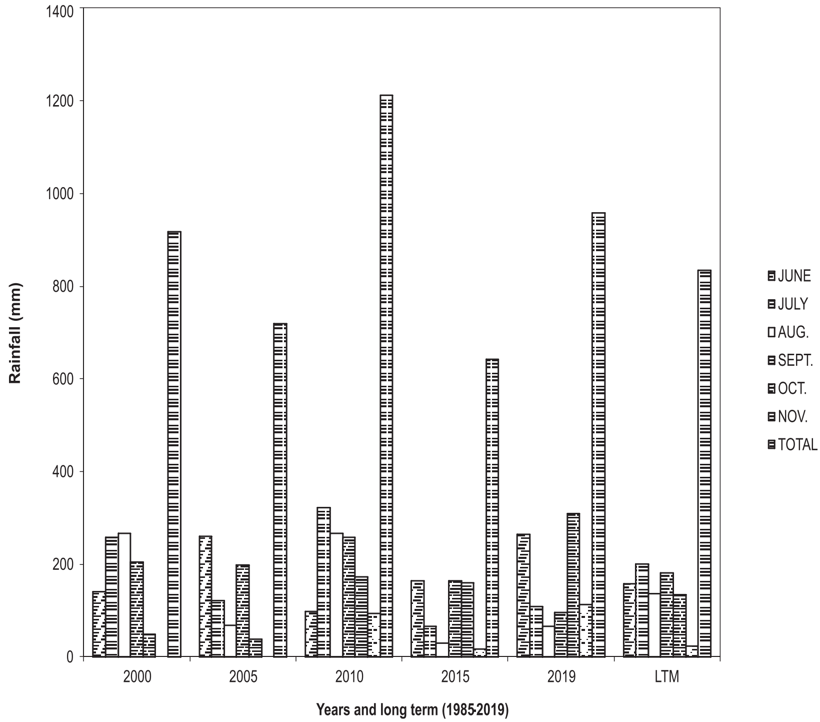

Fig. 8: Moving monthly rainfall distribution during the late cropping seasons of 2000 to 2019 and long term average (1985-2019)

Source: Department of Water Resources Management and Agro-metereology, FUNAAB and Ogun Osun River Basin Development Authority (ORBDA). LTM – Long Term Rainfall Distribution

4.0 PRODUCTION OF SOME KEY OILSEED CROPS IN NIGERIA

4.1 Sesame production between 2014 and 2018

Pioneer research efforts to improve the very low yield of sesame (300 kg/ha) commenced in 1964 at the Institute of Agricultural Research, Zaria, Nigeria with the evaluation of 142 collections of exotic sesame varieties for adaptable agronomic charactersitcs (van Rheenen, 1973). The National Cereals Research Institute

(NCRI) Badeggi was established in 1975 and is presently saddled with the national mandate for the genetic improvement, farming systems research and extension as they relate to sesame, rice, sugarcane, soybean, 'acha' and castor. Between 2014 and 2018, average sesame yield in Nigeria increased by 85.4% (Table 4). Whereas, average sesame yield in the world and Africa have remained stagnant during the period under review, similar trend was recorded for production figures in the world and Africa. However, sesame production in Nigeria increased by 243.0% between 2014 and 2018. In 2018, Nigeria produced 572,761 tonnes of sesame seed (FAOSTAT 2019). However, this output is about half of the crop's potential output which is 1 m tonnes per annum. The astronomical increase could be partly attributed to the release of promising varieties such as E-8, Yandev 55 and more reecently NCRIBEN-01M, NCRIBEN-02M, NCRIBEN-03L, NCRIBEN-04E and NCRIBEN-05E by the National Research Institutes (NCRI, Badeggi and IAR, Zaria) following two decades of research endeavours by Nigerian scientists (Olowe, 2004). At present, Nigeria is the second largest producer of sesame after Tanzania in Africa and the fourth in the world behind Myanmar, India and Tanzania (Table 5). Despite the huge production potentials of sesame in the world, the area under organic sesame production relative to the total area of cultivation is about 1.12% as at 2018 (FAOSTATA, 2019; (Willer and Lernerd, 2019). The implication is that more efforts should be directed towards organic sesame production worldwide. Information on sesame producing areas in Nigeria and top ten agricultural exports are presented in Annexes 3 and 4, respectively.

Table 4. Sesame World, Africa and Nigeria production and yield between 2014 and 2018

Year	Parameters	World	Africa	Nigeria
2014	Yield (kg/ha)	575.4	533.5	573.0
	Production (tonnes)	6,270,708	3,559,624	166,962
2015	Yield (kg/ha)	576.5	575.0	528.1
	Production (tonnes)	5,702,809	3,016,606	171,900
2016	Yield (kg/ha)	546.0	542.0	937.5
	Production (tonnes)	5,631,443	3,195,680	450,000
2017	Yield (kg/ha)	554.1	546.4	1,100.0
	Production (tonnes)	5,531,948	3,146,249	550,000
2018	Yield (kg/ha)	512.3	473.5	1,062.5
	Production (tonnes)	6,015,573	3,574,703	572,761

Adopted from FAOSTAT (2015 -2019)

Table 5. Top ten sesame seed producing countries in the world in 2019

Countries	Metric tonnes	5-years CAGR, %
1. Myanmar	785,038	-0.4
2. India	755,346	-1.8
3. Tanzania	663,935	-9.8
4. Nigeria	588,334	+6.2
5. China	392,414	-9.1
6. Ethiopia	296,001	+0.5
7. Burkina Faso	244.086	-5.4
8. South Sudan	206,163	+3.3
9. Chad	177,870	-2.8
10. Uganda	143,234	-0.2

Source: https://www.nationmaster.com/nmx/ranking/sesame-seed-production (9/06/2020)
CAGR – Compound Annual Growth Rate

4.2 Soybean production between 2014 and 2018

The first joint research projects on soybeans at the national level started in 1981 following a planning meeting by soybean scientists from the Institute of Agricultural Research & Training, Ibadan (IAR&T); Institute for Agricultural Research (IAR), Zaria. National Cereals Research Institute (NCRI), Badeggi; and International Institute of Tropical Agriculture (IITA), Ibadan (Oyekan, 1985). Presently, the National Cereals Research Institute, Baddegi has the national mandate for soybean improvement and production. Data on soybean production in the world, Africa and Nigeria during the last five years are presented in Table 6. At present, soybean is one of the most widely cultivated oilseed crops in the world with 348.7 million tonnes in 94 countries from 124.9 million ha and an average yield of 2,791.4 kg/ha (world), 1,379 kg/ha (Africa) and 973.3 kg/ha (Nigeria) based on FAOSTAT (2018). The United States of America, Brazil and Argentina are the first three largest producers, accounting for about 90% of the world's production with Nigeria ranking 15th and second in Africa after South Africa (14th in the world) as documented by FAOSTAT (2018). It is worthy of note that despite the prevailing favorable weather conditions in the tropics, no African country is listed among the ten top soybean producing countries in the world in 2018 (Table 7). Soybean is central to Nigeria's agriculture sector because it is used for human food and animal feed, and a gap of 150,000 tonnes of soybean was identified between demand and production in the Agriculture Promotion Policy (2016-2020) of the government (FMARD, 2016). Soybean yield in Nigeria has remained stagnant in the last five years but production increased by 20.0% between 2014 and 2019. The increase could be attributed to area of production expansion. Average soybean yield is still below 1 t/ha because the crop is being produced largely on smallholder farms that are less than 1ha in size and operations not mechanized. According to Nzeka (2014), Nigeria's installed annual soybean crushing capacity is 600,000 tonnes and the soybean crushers operating at 60% which is resulting in their inability to meet the ever-growing demand for soybean oil and meal by consumers. Although the volume of organically produced soybean is less than 0.1% of total world production, the demand for organic soybean has been increasing gradually in the last decade due to increase in soybean products being consumed by human beings and organic soybean meal for livestock feeds (Hartman *et al*., 2016).The responsibility is now in the domain of the agronomists to develop practicable strategies to boost the production of soybean seeds that can be used by the processors.

Table 6. Soybeans World, Africa and Nigeria producti on and yield between 2014 and 2018

Year	Parameters	World	Africa	Nigeria
2014	Yield (kg/ha)	2,603.00	1,307.60	985.50
	Production (tonnes)	306,207,046	2,334,736	623,815
2015	Yield (kg/ha)	2,675.70	1,220.90	965.80
	Production (tonnes)	323,195,697	2,480,611	588,523
2016	Yield (kg/ha)	2,753.50	1,175.30	957.60
	Production (tonnes)	335,508,753	2,285,291	614,632
2017	Yield (kg/ha)	2,854.20	1,379.40	973.30
	Production (tonnes)	352,643,548	3,125,814	730,000
2018	Yield (kg/ha)	2,791.40	1,360.00	971.00
	Production (tonnes)	348,712,311	3,556,163	758,033

Adopted from FAOSTAT (2015 -2019)

Table 7. Top ten soybean seed producing countries in the world in 2018

Country	Soybean production (tonnes)
1. United States of America	123,664,230
2. Brazil	117,887,672
3. Argentina	37,787,927
4. China	14,193,621
5. India	13,786,000
6. Paraguay	11,045,971
7. Canada	7,266,600
8. Ukraine	4,460,770
9. Russia	4,026,850
10. Bolivia	2,942,131

Source: https://en.m.wikipedia.org/wiki/List_of_countries_by_soybean_production#Production_by_country

4.3 Sunflower production between 2014 and 2018

In Nigeria, though it was first cultivated in 1965 its production is yet to gain popularity among most of the farmers (Ogunremi, 2000). Institute for Agricultural Research (IAR), Samaru, Zaria has the national mandate for the improvement and production of sunflower in Nigeria. Data on sunflower grain yield and production between 2014 and 2018 are presented in Table 8. Between 2014 and 2018, yield and production statistics of sunflower increased by 15.5 and 22.0% (world) and declined by 21.0 and 35.4% in Africa, respectively (FAOSTAT 2019). Despite the >1,000 kg/ha average yield of sunflower in the world (1,948.20 kg/ha) and Africa (1,137.30 kg/ha) as at 2018, the potential productivity of sunflower can still be improved using appropriate agronomic practices. The huge slump from 3,685,173 tonnes in 2014 to 2,382,013 tonnes in 2018 in Africa should be a source of concern for agronomist despite the ability of the crop to grow in diverse agroecological zones. In fact, no African country is listed among the top ten producing countries in the world (Table 9). The global low productivity of sunflower have been partly attributed to insufficient supply of nutrients, non-adoption of appropriate crop rotation scheme, poor weed management practices, cultivation under rainfed conditions with sub optimal crop stand, imbalanced nutrition, declining soil fertility attributable to mono-cropping of cereals, crop residue removal and limited fertilizer availability and continuous use of inorganic fertilizers that result in deterioration of soil health and productivity (Gebremedhin *et al.*, 2015; Krishnaprabu, 2018). The total sunflower production figure in Nigeria was 57,000 MT in 2019 as against projected 150,000 tonnes (Personal communication). This calls for involvement of all the facets of the value chain of sunflower to drive the initiative to increase production, processing and utilization. Sunflower oil is rich in Vitamin E and it commands higher premium price than soybean and sesame oils in the world market. Unfortunately, the total land area under organic sunflower in the world is about 0.06% of total land dedicated to sunflower production (Willer and Lernoud, 2019). This is against the backdrop that organic crops and crop-based foods contain up to 60% higher key antioxidants than conventionally grown crops (Branski et al., 2014).

Table 8. Sunflower World and Africa yield and production between 2014 and 2018

Year	Parameters	World	Africa
2014	Yield (kg/ha)	1,686.10	1,440.50
	Production (tonnes)	42,584,145	3,685,173
2015	Yield (kg/ha)	1,741.0	1,401.8
	Production (tonnes)	44,313,302	4,079,275
2016	Yield (kg/ha)	1,803.80	1,000.20
	Production (tonnes)	47,515,480	2,228,057
2017	Yield (kg/ha)	1,803.90	1,123.00
	Production (tonnes)	47,863,077	2,376,285
2018	Yield (kg/ha)	1,948.20	1,137.30
	Production (tonnes)	51,954,777	2,382,013

Adopted from FAOSTAT (2015 -2019)

Table 9. Top ten sunflower seed producing countries in the world in 2019

Country	Production, tonnes	CAGR, %
1. Ukraine	15.0	+9.0
2. Russia	12.7	+23.0
3. EU	9.6	-6.0
4. Argentina	3.8	+7.0
5. China	3.3	+4.0
6. Turkey	1.8	+16.0
7. USA	1.0	-1.0
8. Kazakhstan	0.8	-2.0
9. Moldava	0.8	-2.0
10. Serbia	0.7	+26.0

Source: https://latifundist.com/en/rating/uzhe-razlili-maslo-rejting-proizvoditelej-podsolnechnika (09/06/2020)
CAGR – Compound Average Growth Rate

5.0 MIXTURE PRODUCTIVITY INVOLVING OILSEED CROPS

Intercropping, growing of two or more crops at the same time on a single field, is an ancient practice still widely used in the developing countries of the world. Other forms of intercropping in tropical agriculture include mixed intercropping, relay intercropping and alternate strip intercropping where animal traction or tractors are used (Okigbo and Greenland, 1976). Advantages of intercropping copiously documented in recent literature include increased crop productivity (Reta Sanchez et al., 2010), better utilization of environmental resources (Chandra, 2011), reduction of pests, diseases and weeds incidence (Chu et al., 2004; Stephen, 2009; Boudreau, 2013), enhanced yield and productivity (Adekunle et al., 2014), compatibility of component species (Olowe and Adeyemo, 2009; Olowe and Adebimpe, 2009) and improvement and maintenance of soil fertility (Li et al., 2007) amongst others. Legumes are usually included in cropping systems because of the ability to fix atmospheric N in soil and improve the soil fertility and thereby reduce the competition for limited soil nutrients within the soil (Meena et al., 2015). Furthermore, legumes also have the ability to absorb nutrients from deep soil layers due to their robust tap root system (Jat et al., 2012).

Several indices such as land equivalent ratio, LER (McGilchrist, 1965; Willey and Rao, 1980), area time equivalency ratio, ATER (Hiebsch and McCollum, 1987), relative crowding effect, RCE (De Wit 1960); competitive ratio, CR (Willey and Rao, 1980; aggressivity, A (McGilchrist, 1965); Land Equivalent Coefficient, LEC (Adetiloye et al., 1983); actual yield loss, AYL (Banik, 1996); intercropping advantage, IA (Banik et al., 2000); MAI (Ghosh, 2004); yield equivalent, (YE) of dominant crop (Prasad and Srivastava, 1991) and monetary equivalent ratio, MER

(Adetiloye and Adekunle, 1989) have been developed and used where applicable (Bhatti et al., 2006; Wahla et al., 2009; Olowe and Adeyemo, 2009; Haruna et al., 2013) to describe competitive behavior and performance of component crops in intercropping in terms of land use efficiency and economic advantage. However, most of the studies were conducted on short season arable crops and their number rarely exceeded two in the mixtures.

6.0 MY RESEARCH FOCUS AND CONTRIBUTIONS TO KNOWLEDGE

My main research activities have focused on the agronomy of arable crops with emphasis on tropical oilseeds (sesame, soybeans and sunflower), legumes (cowpeas and groundnut) and some other arable crops like maize and cassava, and their mixtures. I started my research career at the National Cereals Research Institute, Badeggi under the Oilseeds Research Programme in 1990 as a Senior Research Fellow. To be precise, I met soybean, sunflower and sesame in 1980 in Russia when I was a graduate student at the Faculty of Tropical and Sub-tropical Agriculture, University of Agriculture, Krasnodar, Russia. My MSc. and PhD Research topics were on soybean irrigation and rhizobium inoculation in Russia, and response of soybeans to varying row spacing in south West Nigeria, respectively. I was also involved with oilseeds during my National Youth Service year at the Institute of Agricultural Research and Training, Ibadan (IAR&T) under Industrial Crops Research Programme (kenaf, cotton, sesame, cotton and sugarcane) in 1983/84. However, I got actively involved in oilseed crops research after my PhD (Plant Science) in 1990 when I was employed as a Senior Research Officer at the Oilseeds Research Programme of the National Cereals Research Institute, Badeggi that has the national mandate for sesame, soybean and castor beans among others.

6.1 Agronomy of sesame

The first major challenge identified in sesame production was getting the optimum output from a unit land area. Consequently, alternate planting patterns were evaluated to substitute for the two major sesame sowing methods practiced by resource-constrained farmers which were the Igbirra method (planting on widely spaced large ridges) and the Tiv method (seed broadcast on flat land or low and fairly wide ridges) in Nigeria until 1994. Out of nine planting patterns evaluated, row spacing of 60 x 5-10 cm were adjudged appropriate and practicable for sowing sesame on the flat in the southern Guinea Savannah region of Nigeria (Olowe and Busari, 1994). This recommendation had since been adopted by sesame farmers in Niger State, Nigeria. The corresponding plant populations were 167,000 and 333,333 plants per hectare for 60 x 10 cm and 60 x 5 cm, respectively. The forest-savannah transition zone is outside the traditional growing area of most tropical grain crops. For this zone, sowing sesame between early – mid July has been recommended for sustainable cultivation of sesame (Olowe, 2007). Sesame recorded comparable grain yield at both sowing dates in 1998 and 1999 (Table 10).

A trial carried out in 1991 and 1992 on response to fertilizer application of sesame revealed that a combination of 60 kgN/ha and 30 kg P_2O_5 applied after first weeding at three weeks after sowing (WAS) was adequate for optimum productivity of sesame in the southern guinea savannah region (Olowe and Busari, 2000). Data on mean grain yield values are presented in Table 11.

Table 10. Mean grain yield of sesame sown at different periods in the forest-savannah transition zone, 1998 and 1999

Sowing date	Grain yield (kg/ha)	
	1998	1999
Early July	355.07	645.60
Mid July	425.07	175.55
Mid August	117.92	177.50
SE± (18 df)	22.66	75.83

Source: Olowe, 2007

Table 11. Effects of nitrogen and phosphorus application on sesame gran yield in the southern guinea savannah, 1991 and 1992

Treatment	Grain yield (kg/ha)	
	Badeggi, 1992	Mokwa, 1991
N0P0	147.70	132.69
N30P30	206.60	114.40
N60P30	289.40	260.93
N90P30	160.20	175.51
SE± (22 df)	32.083	32.633

Source: Olowe and Busari, 2000

Following my relocation from National Cereals Research Institute, Badeggi to FUNAAB in May, 1993, I introduced fourteen sesame varieties and accessions into the forest-savannah transition zone. Our first trial was carried out to describe the growth characteristics of these accessions and evaluate their grain yield in the new location (Olowe et al., 2003a, Olowe, 2004). Ten out of the fourteen entries recorded average grain yield that ranged between 523.84 and 899.46 kg/ha and were higher than 457.0 and 383.0 kg/ha the then average Nigerian and world values, respectively. However, the top five yielders are listed in Table 12.

Number and weight of capsules per plant, weight of seeds per plant and plant height were identified as yield attributes contributing strongly to sesame grain yield (Olowe, 2004). Sesame yield loss has been estimated to be up to 50% at harvest and about 99% of sesame is harvested manually in the world (Langham and Schwarz, 2006). Consequently, one of our studies recommended harvesting sesame plants at physiological maturity, staking to dry and threshing at 3 and 4 weeks after harvest, WAH (Olowe and Adeniregun, 2011). The sesame thus treated also produced 1000 seed weight >3.0g which readily meets the world premium standard (Table 13).

Our study carried out in 2001 on yield response of sesame to defoliation induced at reproductive stage (45 DAS) showed that significant yield loss would be recorded if up to 66% and 99% of leaves were defoliated on sesame plant (Olowe et al., 2004). We also evaluated the yield and yield attributes of seven sesame varieties over three years (2004, 2005 and 2006). However, the oil content of the varieties was only determined in 2006 and was comparatively high ranging between 40.0% and 50.0% (Table 14).

Table 12. Mean grain yield of five top sesame yielders in 1999 and 2000

Accessions	Grain yield (kg/ha)		
	1999	2000	Mean yield
530-3	733.49a	1065.41ab	899.46a
530-6-1	628.57ab	1157.60ab	893.07a
PB Til	436.37bcd	1347.17a	891.77a
Type4	569.10abc	1054.59ab	811.86ab
E-8	450.50bcd	1049.30ab	749.90abc

Means along the same column with a common letter are not significantly different from each other based on Duncan's Multiple Range Test at 5% probability level
Source: Olowe, 2004

Table 13: Grain yield and 1000 seed weight of sesame var. E-8 subjected to different post harvest procedure

Treatment	Description	Grain yield (kg/ha)	1000 seed weight (g)
T1 (Control)	Plants threshed once at 1 WAH	261.0	2.8
T2	Plants threshed twice at 1 and 2 WAH	311.0	2.7
T3	Plants threshed twice at 2 and 3 WAH	499.7	3.1
T4	Plants threshed twice at 3 and 4 WAH	861.3	3.3
T5	Plants threshed twice at 4 and 5 WAH	511.0	3.6
LSD (5%)		181.42	0.14

WAH – Weeks After Harvest
Source: Olowe and Adeniregun, 2011

Table 14 : Mean seed yield, 1000 seed weight, oil content and harvest index of seven sesame varieties, 2006

Variety	1000 Seed Weight (g)	Harvest index (%)	Oil content (%)	Seed yield (t/ha)
E-8	3.4	20,7	50.0	0.77
PBTil	3.0	25.2	45.0	1.05
NCRIBEN-01M	3.3	26.4	45.0	0.85
NCRIBEN-02M	3.0	26.4	45.0	0.92
NCRIBEN-03L	2.6	30.0	40.0	1.23
Yandev 55	2.5	29.1	40.0	1.11
Ex-Sudan	3.0	27.6	50.0	1.21
Lsd (5%)	0.31	0.43	2.38	ns

Source: Olowe and Adeniregun, 2010

6.2 Agronomy of soybeans

My pioneer research activities on soybeans commenced with the description of the growth and development of different varieties of soybeans that exhibited the three growth habits (indeterminate, determinate and semi-determinate) under varying row spacing in the forest ecology (Olowe and Alofe, 1991a and 1991b). The results of the studies indicated that when soybeans is planted at the appropriate time in the forest ecology, the crop is capable of producing comparable grain yield relative to its grain yield in the traditional growing region of Nigeria (Middle Belt) and the determinate types with shorter plant height will be better adapted to the narrow (45 cm) - medium (60 cm) inter row spacing (Olowe and Alofe, 1992). An inter row spacing of 60 cm was recommended for soybean cultivation under sole and intercropping with other compatible arable crops (Table 15).

In 2014, three earlier released soybean varieties and thirteen promising and advanced breeding soybean lines were evaluated for response to organic fertilizer application in terms of seed yield and quality. All the entries exhibited tremendous potential in the forest-savannah transition zone by recording seed yield greater than 1 t/ha (Onyenali and Olowe, 2015). Consequently, two of the varieties (TGx 1448-2E and TGx 1440-1E) were added to TGx 1740-2F for the 2015 and 2016 trials. The use of organic soil amendments is very important in tropical agriculture because of their relatively cheaper cost and ready availability when compared with the inorganic fertilizers. Consequently, three locally produced organic fertilizers namely Aleshinloye Grade B (abattoir waste-based), Organo Farm (brewery waste-based) and Gateway (animal dung-and wood ash-based) fertilizers were evaluated using three soybean varieties: TGx 1448-2E (late maturing), TGx 1440-1E (late maturing) and TGx 17402F (early maturing) during the late cropping seasons of 2015 and 2016. We observed that application of organic fertilizers significantly ($P < 0.05$: F test) increased aboveground plant weight, number of branches and pods per plant, weight of seeds per plant, seed yield, and quality in both years relative to the control treatment, except oil content and seed yield in 2016 (Table 16). We therefore, recommended that the three organic fertilizers can be used for soybean cultivation since soybeans grown on treated plots produced seed yield above 1/ton in both contrasting years of experimentation.

Table 15. Effects of row spacing on height to lowest pod, harvest index and grain yield of soybeans at Ile Ife, 1985-1987

Treatment	Height to lowest pod (cm)	Harvest index (%)	Grain yield (t/ha)
Inter row (cm)			
90	15.59	41.27	1.26
75	15.74	38.67	1.78
60	16.34	41.51	1.93
45	17.26	37.97	1.85
LSD (5%)	1.24	2.45	0.23

Source: Olowe and Alofe, 1991a

Table 16. Effect of organic fertilizer application on soybean seed yield and quality in 2015 and 2016

Treatment	2015			2016		
	Protein Content (%)	Oil Content (%)	Seed yield (kg/ha)	Protein content (%)	Oil content (%)	Seed yield (kg/ha)
Control	35.1	16.5	997.90	37.9	16.9	1444.45
Aleshinloye	36.9	17.6	1595.68	36.2	17.3	1577.78
Organo Farm	37.2	17.0	1446.57	35.6	17.1	1794.43
Gateway	37.4	17.6	1318.67	36.8	17.4	1683.33
LSD 5%	0.22	0.02	281.65	0.19	0.28	ns

Source: Onyenali *et al.,* 2020.

6.3 Agronomy of sunflower

Since sunflower is a relatively new crop in the forest-savannah transition zone of south west Nigeria, the nutrient requirement was one of the major research questions addressed in the last two decades. In a trial conducted in 1999 and 2000, four levels on nitrogen (0, 30, 60 and 90 kgN/ha) and three levels of phosphorus (0, 30 and 60 kg P_2O_5) were evaluated in a 4 × 3 factorial experiment in three replicates. Application of $N_{60}P_{30}$ appeared adequate for sunflower production in the forest-savannah transition zone of South West Nigeria (Olowe et al., 2005a). The split and whole application of these rates on the agronomic performance of local (Funtua) and two exotic (Record and Issanka) was evaluated in 2001 and 2002 (Olowe et al., 2005b) and on four recently released sunflower varieties (SAMSUN 1, SAMSUN 2, SAMSUN 3 and SAMSUN 4) by Akpojotor et al. (2019). On the average, single application of both nutrients at 21 days after sowing (DAS) appropriate for optimum productivity of sunflower in terms of seed quality (protein and oil content) and seed yield in the forest-savannah transition zone (Table 17)

Sunflower demonstrated linear response to increase in plant population from 37,500 to 55,000 to 111,000 plants per hectare. This is a desirable trait because it will enable the crop to fit into different traditional cropping systems in the tropics and also compensate for variation in population density by producing higher number of achene per head and head weight at sub optimal/intermediate population density (Olowe, 2005a). Data on these traits are presented in Table 18.

Cultural practices like sowing date and fertilizer application and some environmental factors (temperature and rainfall) play major roles in plant growth and development. Therefore, the optimum planting date for sunflower was determined in the forest-savannah transition zone of Nigeria was determined during the early and late cropping seasons of 2012. It was concluded that sunflower could be sown in the forest–savannah transition zone in early July or second to third week in August (Oshundiya et al., 2014).

Formation of multiple heads instead of a single head on a plant is an undesirable phenomenon in commercial sunflower grown for seed since it results in uneven ripening of the head, varying seed (achene) size and more difficulty in harvesting with equipment developed for single heads (Weiss, 2000). Therefore, we carried out studies to assess the effects of sowing seeds from plants with multiple heads and seeds from single-headed plants on seed yield, head characteristics and oil content of a local adapted variety (Funtua) and two exotic varieties (Record and Isaanka) of sunflower under rain-fed conditions with a view to improving stability and sunflower productivity in the forest-savannah transition zone. The performance of the three test varieties irrespective of their seed source was satisfactory because their seed yield values compared well with African and world averages. Thus, the fear of farmers that small seeds usually predominant on multiple heads can rarely produce the same crop as large seeds on single heads has finally been allayed (Olowe et al., 2013). Data on seed yield and oil content of sunflower are presented in Table 19.

Table 17. Sunflower seed yield and quality as influenced by fertilizer regime in 2014 and 2015

Treatment	2014			2015		
	Protein Content (%)	Oil content (%)	Seed yield (kg/ha)	Protein content (%)	Oil content (%)	Seed yield (kg/ha)
Control	15.3	27.2	1246.9	18.0	26.6	361.9
Split	21.1	27.8	1650.4	18.3	27.8	704.9
Single	16.7	28.4	1994.2	19.7	28.3	597.0
LSD (5%)	0.08	0.33	425.94	0.21	0.17	126.67

Source: Akpojotor et al., 2019

Table 18. Effects of plant population density on seed yield and some yield attributes of sunflower in 2002 and 2003

Treatment	2002			2003		
	Head wt. (g)	Achene number per head	Seed yield (t/ha)	Head wt. (g)	Achene number per head	Seed yield (t/ha)
Population/ha						
111,000	77.2	679.0	3.0	47.8	330	2.8
57,500	90.5	709.0	2.2	47.7	370	1.6
37,500	91.9	619.0	1.8	62.3	485	1.4
LSD (5%)	ns	ns	0.39	8.98	49.68	0.19

Source: Olowe, 2005a

Table 19. Seed yield and oil content of three sunflower varieties grown from seeds of single and multiple headed plants

Variety	Seed source	Seed yield (kg/ha)		Percent oil content (%)
		2004	2005	2004
Record	Single	1201.0	1252.0	42.9
	Multiple	833.0	860.0	42.6
Issanka	Singe	1388.0	1202.0	48.3
	Multiple	1221.0	1036.0	49.4
Funtua	Single	1392.0	1019.0	45.7
	Multiple	1956.0	1499.0	44.5
SED(4d.f)		67.81	63.48	0.67
SED(10d.f)		98.88	91.10	1.14

Source: Olowe et al., 2013

6.4. Agronomic performance of sesame, soybeans and sunflower in mixtures

Having established the production potentials of these oilseeds under sole cropping in the forest-savannah transition zone which is outside their traditional growing areas, the next stage of our studies was to explore their potential in association with crops already established and adapted to the zone and also in mixtures involving other oilseeds. Reduction of the population density of soybeans and sesame from 100% to 75% and 50% was evaluated in association with maize in the late cropping season of 1998 and 1999 (Olowe et al., 2003b). The results revealed that on average, maize + soybeans (100%) and maize + sesame at 75% recorded the highest values of LER, grain yield and maize equivalent yield in both years (Table 20).

Field trials were conducted during 2002 and 2003 to determine the productivity and compatibility of the cropping systems obtained from intercropping varieties of sesame (E8, PBTil and 530-6-1) and sunflower (Funtua, Record and Isaanka) in the humid forest–savannah transition zone (Olowe, 2005b; Olowe and Adeyemo, 2009) and the mixtures were found to be remunerative (Olowe, 2006). Based on competitive ratio values, E8 demonstrated the greatest ability to compensate for intercrop competition with taller sunflower varieties. It was concluded that growers can successfully cultivate the other two sesame varieties (530-6-1 and PBTil) along with E-8 under intercropping with sunflower in the humid forest–savannah transition zone (Table 21).

Three sunflower varieties (a local adapted var. Funtua and two exotic varieties Isaanka and Record from Argentina) and five improved, high-yielding soybean varieties: TGx 1448-2E (late), TGx 1440-1E (late), TGx 1019-2EB (medium), TGx 1740-2F (early) and TGx 1485-1D (early maturing) were evaluated during the late cropping season (July– Nov.) of 2001 and 2002 to determine the grain yields, and other yield attributes of sunflower and soybeans and their productivity under monocropping and intercropping. All yield attributes of both crops exhibited significant positive relationship with grain yields, except height to the lowest pod of soyabean. TGx 14482E and TGx 1440-1E intercropped with Isaanka and Record recorded average grain yield of 1043 and 1081 kg ha^{-1} and land equivalent ratios (LER) of 1.47 and 1.58, respectively. It was recommended that intercropped combination of TGx 1448-2E/Isaanka and TGx 1440-1E/Record be used to improve yields of vegetable oilseeds (Table 22).

Table 20. Mixture productivity of maize/soybean/sesame intercropping in 1998 and 1999

Cropping System	1998			1999		
	GY (kg/ha)	MYE (kg/ha)	LER	GY (kg/ha)	MYE (kg/ha)	LER
Maize sole	2892.6	2892.6	1.00	2953.44	2953.44	1.00
Soybean sole	2011.8	3017.7	1.00	1632.85	1632.85	1.00
Sesame sole	243.9	396.4	1.00	56.77	92.27	1.00
Maize +	3398.3	4714.6	1.60	1905.40	4680.09	1.13
Soybean (100%)	754.6			1849.79		
Maize +	2843.7	2690.9	2.0	1285.17	1347.03	1.12
Sesame (75%)	883.5			39.09		
LSD 5%	1660.64	864.61	0.27	1146.55	1195.28	0.22

GY – Grain yield, MYE – Maize yield equivalent, LER – Land Equivalent Ratio
Source: Olowe *et al.,* 2003b

Table 21. Land Equivalent Ratio (LER) and Competitive Ratio (CR) of sesame/sunflower intercropping in 2002 and 2003

Intercropping System	2002			2003		
	LER	CR		LER	CR	
		Sesame	sunflower		sesame	sunflower
Sesame/sunflower						
E-8/Sunflower	1.37	0.56	0.40	1.13	1.53	0.18
530-6-1/Sunflower	1.46	0.43	0.55	1.32	0.79	0.31
PBTil/Sunflower	1.22	0.48	0.43	1.35	0.69	0.37
F ratio	2.73[b]	0.90[a]	1.11[a]	2.86[a]	18.36[b]	3.68[a]
SE± (16d.f.)	0.042	0.226	0.246	0.044	0.034	0.046

[a] - Significant at 1% probability level, [b] - Significant at 5% probability level
Source: Olowe and Adeyemo, 2009

Table 22. Effect of intercropping on Land Equivalent Ratio and Grain yield of soybeans and sunflower varieties (mean of 2001 and 2002)

Intercrop	LER	Soybean grain yield (kg/ha)
TGx 1448-2E/Isaanka	1.47	1043.0
TGx 1448-2E/Record	1.04	565.0
Tgx1448-2E/Funtua	1.13	630.0
TGx 1440-1E/Isaanka	0.95	665.0
TGx 1440-1E/Record	1.58	1081.0
TGx 1440-1E/Funtua	1.15	537.0
LSD 5%	0.05	335.40

Source: Olowe and Adebimpe, 2009

The agronomic and economic potentials of intercropping soybeans and cowpea with sunflower at three growth stages (simultaneously (SS) at planting, tenth true leaf stage, V10 and eighteenth true leaf stage, V18 was evaluated in 2002 and 2003 late cropping seasons in FUNAAB. The overall output of the various intercropping systems was higher during the more favourable weather conditions of 2002 than 2003. Agronomic advantage (LER > 1.00) ranged from 1.04 to 1.40 and 1.05 to 1.24 in 2002 and 2003 respectively.

The highest Monetary Equivalent Ratio (MER) values of 1.12 (sunflower/cowpea SS0 and 1.04 (sunflower/soybean V10) corresponded with the highest sunflower yield equivalent of 1,349.2 and 1,421.6 kg/ha in 2002 and 2003 respectively (Table 23). On the average, the results confirmed the potential of increased overall productivity of intercropping systems provided the productivity of the dominated legumes could be enhanced (Olowe et al., 2006)

We also evaluated the performance of sesame (var. PBTil) and sunflower (var. Isaanka) intercropped with cassava (var. TMS 30572 and TME 1) in a cassava-based cropping system with a view to studying the phenology of the component crops and establishing mixture productivity in terms of biological efficiency (land equivalent ratio [LER] and area time equivalent ratio [ATER]), intercrop compatibility land equivalent coefficient (LEC) and economic efficiency (monetary advantage index [MAI] and cassava yield equivalent [CYE]) of the systems under humid tropical conditions during the early and late cropping seasons of 2003/2004. The results revealed that the six intercropping systems recorded significantly ($P < 0.05$) higher biological efficiency (LER > 1.00 in both plantings and ATER > 1.00 in the late planting) than their respective monocrops and relatively high intercrop compatibility (LEC > 0.037 and 0.25). Based on MAI and CYE, TME 1/Ses/Sun, TMS 30572/Ses/Sun and TMS 30572/Sun were the three most economically efficient cropping systems, especially in the late and more preferred planting season and are hereby recommended to prospective growers for cultivation, economic empowerment, and reduction of household food insecurity (Table 24).

Generally, sesame and sunflower grow slowly during the first month after emergence. Formation of sunflower capitulum (head) commences when the second or third pair of true leaves appear on the main stem. Consequent upon the full appearance of the capitulum, rapid growth continues for 3–4 weeks and later diminishes at the peak of anthesis. For sesame, rapid growth lasts longer starting from the time of bud formation till ripening of the first capsule (Ustimenko-Bakumovsky, 1980).

Table 23 . Grain yield, Land Equivalent Ratio (LER), Monetary Equivalent Ratio and Sunflower Equivalent Yield of sunflower/soybean/cowpea intercrops in 2002 and 2003

Intercropping System	Grain yield (kg/ha)		LER		MER		SYE	
	2002	2003	2002	2003	2002	2003	2002	2003
Sole sunflower	1212.0	1369.0	1.00	1.00	1.00	1.00	1212.0	1369.0
Sole soybeans	398.0	973.0	1.00	1.00	0.26	0.57	318.4	778.4
Sole cowpea	934.0	410.0	1.00	1.00	0.93	0.36	1120.8	492.0
Sun + soybean SS	753+312	818+124	1.40	0.73	0.83	0.67	1002.6	917.2
Sun + soybean V10	922+227	1560+27	1.33	1.05	0.91	1.04	1103.6	1421.6
Sun + soybean V18	1075+132	893+18	1.22	0.67	0.97	0.67	1180.6	907.4
Sun + cowpea SS	880+391	618+324	1.15	1.24	1.12	0.73	1349.2	1006.8
Sun + cowpea V10	1116+111	923+17	1.04	0.71	1.03	0.69	1249.2	952.4
Sun + cowpea V18	1270+ 54	1071+ 6	1.11	0.80	1.10	0.09	1334.8	1078.2
LSD 5%	624.55	405.42	0.11	0.15	0.198	0.22	239.91	281.14

Source: Olowe et al., 2006

Table 24. Land equivalent ratio (LER), monetary advantage index (MAI), and Cassava yield equivalent (CYE) of cassava/sesame/sunflower intercropping in 2003/2004

Cropping System	LER		MAI (€)		CYE (ton/ha)	
	Early	Late	Early	Late	Early	Late
TME 1/Ses	1.45	1.38	483.53	576.65	21.29	28.62
TME 1/Sun	1.07	1.34	205.83	1,064.43	42.99	57.33
TME 1 /Ses/Sun	1.52	1.77	979.92	1,958.05	39.13	61.49
TMS 30572/Ses	1.19	1.49	199.62	730.55	17.08	30.35
TMS 30572/Sun	1.15	1.41	501.69	1,354.60	52.56	63.66
TMS 30572/Ses/Sun	1.27	1.74	558.25	1,938.69	35.87	62.29
SED ± (14 d.f.)	0.072	0.096	-	-	5.078	6.352
SED ± (10 d.f.)	-	-	116.892	240.590	-	-

Average procurement price per ton of Cassava – €73.17; €; Sunflower – €1,707.31; Sesame €1,073.17(€1 = N205). SED, standard error of the difference; Ses, sesame; Sun, sunflower; N, Naira.
Source: Adekunle et al., 2014

Sesame and sunflower are moderately drought tolerant because their deep tap root system can extract water from depth not attainable by roots of other crops (Myers and Minor, 1993; Oplinger et al., 1990). Furthermore, the desirable agronomic characteristics such as erect growth habit, harvestable head, relative resistance to lodging and limited ground cover present sunflower as an excellent intercrop (Robinson, 1984). Therefore, in our very recent study on mixture productivity of sesame/sunflower intercrop, mixtures that involved both sesame varieties and interplanted sunflower latest 10 DAS plus fertilizer application, exhibited high land equivalent ratio (LER) > 1.00 (biological efficiency), high land equivalent coefficient (LEC) > 0.25 (intercrop compatibility) and high economic efficiency in terms of monetary advantage index (MAI) and sesame yield equivalent (SYE). Weight of sesame capsules per plant increased significantly (*P*<0.05) following the application of organic fertilizer in both years. Similarly, aboveground plant weight of sesame was significantly (*P*<0.05) enhanced irrespective of the date of introducing sunflower into sesame in both years (Fig. 9 a&b). Sesame grain yield (543.4 - 636.5 kg/ha) during the wetter late season of 2019 compared favourably with the African and world mean values of 473.5 kg/ha and 601.5 kg/ha respectively. Organic fertilizer application significantly (*P*<0.05) enhanced sesame grain yield in both years. Delayed introduction of sunflower into sesame till 20 DAS resulted in significantly (*P*<0.05) smaller head weight, achene weight per head and depressed grain yield of sunflower in both years (Fig. 10a&b). Therefore, the mixtures of both sesame varieties with sunflower introduced simultaneously and at 10 DAS with organic fertilizer applied, have been recommended for cultivation under humid tropical conditions (Somefun et al., 2020).

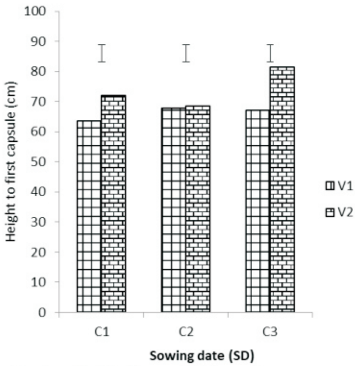

Fig . 9a : V × SD effect on height to first capsule of sesame in 2018. Capped vertical lines represent lsd (P=0.05)

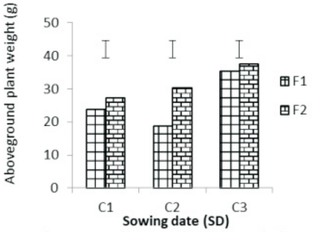

Fig. 9b : F × SD effect on aboveground plant weight of sesame at harvest in 2018.

FI – No fertilizer, F2 – Organic fertilizer, SD – Sowing date
C1 – Sown simultaneously, C2 – Sown 10 DAS, C3 – Sown 20 DAS
V1 – E-8, V2 – Cameroun white, Capped vertical lines represent l.s.d. (*P* = 0.05)
Source: Somefun et al., 2020

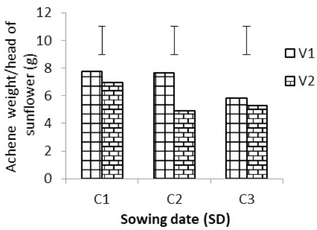

Fig. 10a: V × SD effect on ahene weight/hea of sunflower in 2018

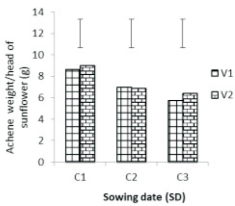

Fig. 10b: V × SD effect on achene weight per head of sunflower in 2019

C1 – Sown simultaneously, C2 – Sown 10 DAS, C3 – Sown 20 DAS
V1 – E-8, V2 – Cameroun white, FI – No fertilizer, F2 – Organic fertilizer
SD – Sowing date, DAS – days after sowing. Capped vertical lines represent l.s.d. (*P* = 0.05)
Source: Somefun et al., 2020

6.6 Oilseeds in crop rotation

Crop rotation is undoubtedly an age-long agricultural practice with recognized yield advantages, well distributed economic risks, workload, improved nitrogen management, reduced land and water pollution, long term improvement of soil quality and productivity, reduced pest, weed and disease infestation, climate change mitigation and high yield (Slavikova, 2018). Consequently, we conducted a five-year study from 2008 to 2012 to evaluate the agronomic performance of four crops (soybean, sunflower, sesame and maize) under continuous, rotational and conventional cropping systems (Table 25). On the average, the agronomic performance of sunflower and soybeans that received organic fertilizer under rotational cropping system demonstrated the potential for the crops as viable component crops in organic crop rotation system. Our findings confirmed the huge potential of crop rotation in the management of soil fertility under organic production systems in the tropics because the grain yield values (623.0 – 2758.3 kg ha-1) recorded compared favorably with the African (1,379 kg ha^{-1}) and world (2,854 kg ha^{-1}) averages (FAO, 2018) as reported by Olowe and Adejuyigbe (2020). It was concluded that for maintenance of sustainable organic crop rotation system, soybean should be included in the scheme as a legume in the humid tropics (Table 26). We have commenced another five year (2018 – 2022) study that involves sesame, soybean, sunflower and cotton under continuous, continuous plus organic fertilizer, rotational with organic fertilizer, rotational without organic fertilizer and conventional system.

Table 25. Crop rotation scheme involving soybean, sesame, sunflower and maize (2008 – 2012)

2008	2009	2010	2011	2012
Sunflower	Sesame	Maize	Soybean	Sunflower
Sesame	Soybean	Sunflower	Maize	Sesame
Maize	Sunflower	Soybean	Sesame	Maize
Soybean	Maize	Sesame	Sunflower	Soybean

Source: Olowe and Adejuyigbe, 2020

Table 26. Effect of cropping systems on seed yield (kg/ha) of sunflower during the late cropping season (July – Nov.) in 2008 – 2012

Cropping systems	2008	2009	2010	2011	2012	Mean
Continuous	-	778.0	1000.0	584.7	981.1	835.9
Rotational	540.8	1262.0	1150.0	1348.5	1428.2	906.0
Conventional	664.9	1642.6	750.0	808.9	1324.0	1038.0
LSD 5%	ns	366.75	ns	579.8	75.23	145.0

Source: Olowe and Adejuyigbe, 2020

6.7 Organic agriculture

As earlier stated, organic agriculture is still at two levels namely: non-certified and certified in Africa as a whole (Parrott et al., 2006) and in Nigeria specifically. The widely adopted definition of organic agriculture is given by the International Federation of Organic Agriculture Movements (March 2005; ttps://www.ifoam.bio/en/organiclandmarks/definition-organic-agriculture), as a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved. This production system is rapidly and steadily evolving in Nigeria because of the increasing awareness of food safety and health implications of the food being consumed.

Year 2005 was a turning point in my career following the establishment of the premier organic agriculture movement in Nigeria tagged Organic Agriculture Project in Tertiary Institutions in Nigeria (OAPTIN). The Association is now formally registered with the Corporate Affairs Commission as Organic Agriculture Professionals in Tertiary Institutions in Nigeria and the national secretariat is located in the Federal University of Agriculture, Abeokuta (FUNAAB), Nigeria. The then Vice Chancellor (Late Prof. I. F. Adu), and Prof. I.O.O Aiyelaagbe (pioneer National Coordinating Scientist of OAPTIN) facilitated the establishment of OAPTIN in FUNAAB. Sequel to the successful establishment of OAPTIN in 2005, my research focus changed markedly towards developing agronomic practices for the production of oilseeds under organic production systems in the forest savanna transitory zone.

6.7.1 Development of Organic 3.0 is innovation with research

In 2010, a global discussion on Organic 3.0 was initiated to address the problems global agri-food systems were facing in a bid to meeting food demand by the world population. I had the opportunity of attending the International Society of Organic

Agricultural Research (ISOFAR) Symposium 'Organic 3.0 is Innovation with Research', held September 20–22, 2015, in conjunction with the first ISOFAR International Organic Expo, in Goesan County, Republic of Korea and many active scientists in the field of organic agriculture participated. According to Nglli and Rahmann (2013), the system of organic agriculture started in the early twentieth century and has since gone through two major stages, including Organic 1.0 and Organic 2.0. The Korea symposium addressed the development of Organic 3.0. Organic 1.0 can be defined as the period of organic pioneers, developing the vision of organic agriculture (OA). Organic 2.0 is the period of growth and marketing of organic, and Organic 3.0 is poised to address future challenges and aims at entering organic agriculture on the global stage (Rahmann et al., 2017).

6.7.2 Organic agriculture research

I have been actively involved in the development of organic agriculture research locally, nationally and internationally since 2005. I had the opportunity of being elected as a World Board Member of the International Society of Organic Agriculture Research at Istanbul, Turkey in 2014 and had since served two terms 2014 – 2017 and 2017 – 2021. I am also an Associate Editor of the world's foremost scientific journal on organic agriculture called Organic Agriculture and published by Springer. I was part of the team that articulated the new aims and scope of the journal in readiness for the future (Rahmann et al., 2018). Our pioneer contribution to the journal was on Skills Gap Analysis of the faculty in the Higher Educational Institutions (HEIs) in west Africa under European Union (EU) funded project in 2010 -2012 with Contract number 197625 (Aiyelaagbe et al., 2016). It was a collaborative project that involved six Higher Education Institutions (HEIs) namely University of Cape Coast, Ghana, Kwame Nkrumah University of Science and Technology, Kumasi Ghana, Njala University, Sierra Leone, Universite d'Abomey-Calavi, Republique du Benin, University of Agriculture, Abeokuta, Nigeria and Coventry University, UK. The project was aimed at increasing the level of expertise in all aspects of Organic Agriculture in the West African sub-region. The study concluded that the pool of well-qualified academic staff in HEIs in Anglophone West Africa had competencies skewed towards crop and livestock production areas of specialization and identified skills gaps in the areas of plant and animal health, trade, and some aspects (fish pathology and breeding) of aquaculture. In the last one decade, I have had the opportunity to facilitate workshops on the development of curricula in organic agriculture for HEIs in Nigeria under the auspices of some EU-funded projects and EOA-I led by the African Union Commission. Our recent publications (Olowe and Adebimpe, 2009; Olowe et al., 2009; Adekunle et al., 2014; Oshundiya et al., 2014; Onyenali et al., 2020; Olowe and Adejuyigbe, 2020) on the development of appropriate agronomic practices for some oilseed crops have been highlighted in this lecture. In preparation towards the aborted 2020 Organic World Congress, we did a synthesis of the last four editions (2nd, 3rd, 4th and

5th) of ISOFAR Scientific Conferences (Olowe and Somefun, 2020). We concluded that the lull of research activities in organic aquaculture, policy issues, and health, safety of organic products, standards, and certification should be redressed in the nearest future. They are the pointers to the future frontiers of knowledge in organic agriculture. Arising from a workshop on LandLess Food Production held in Marrakech, Morocco (November 14-16, 2019), I wrote a paper on “How to feed about 800 million Nigerians in 2100”. It was concluded that with the markedly reducing available land per person, and in order to adequately feed the teeming population of Nigeria, there is the need to innovate by exploring technology-related systems suitable for producing healthy food components such as starch, oils, and nutrients that can be used to manufacture fertilizers required to boost food production and measures capable of reducing wastage of perishable foods (Olowe, 2020). Our on-going studies are geared towards foliar nutrition of some of the oilseed crops using locally produced liquid organic fertilizers.

7. CONCLUSION

Based on our findings on oilseed crop research in the last two to three decades, we have been able to demonstrate that soybeans, sesame and sunflower have huge agro-climatic production potential which have substantial market demand, especially in Europe and Asia and yet to be adequately harnessed in the forest savanna transition ecology which is outside the savanna traditional growing region for the crops. The oilseeds produce very comparable and high quality grain yields when cultivated during the late cropping season. We have developed appropriate agronomic practices such as optimum sowing date (Early to Mid July) and spacing (60 x 5 - 10cm) for sesame and soybeans, fertilizer regime (single application of 60 kgN/ha, 56kg P_2O_5 and 60kg K_2O/ha) and spacing (60 x 30cm) for sunflower. We have also generated information on the efficacy of various locally produced and available organic amendments for enhancement of soil fertility and productivity of the crops in sole or compatible mixtures under organic production systems for soybeans, sesame and sunflower in this region. If the country must meet her National Consumption Requirement (NCR) in vegetable oil (3 million tonnes) and the deficit of over 600,000 tonnes, then the current production levels of these minor oilseeds with huge production potential must be increased in order to drive the growth of the vegetable oil sector going forward.

7.0 RECOMMENDATIONS

1. There is the urgent need to bridge the big gap between researchers and farmers if the developed technologies must get to the end-users. I recommend inclusion of farmers from the very beginning when a research topic is being conceived and planned for execution because the small to medium scale farmers produce about 90% of the food we consume in tropical Africa.
2. All the National Agricultural Research Institutes (NARIs)

should be adequately funded to have a full complement of the value chains of their mandate crops. More funds should be allocated.

3. There is the need for massive investment in oil extraction and value addition technology in order to encourage production of the oilseeds with export potential.

4. Synergy between the NARIs and the Colleges/Faculties of Agriculture in the specialized and conventional universities should be strengthened.

5. Gainful employment of agriculture graduates by government and private bodies across the value chain will help drive the much-anticipated revolution in agriculture.

6. If the well-articulated policies in agriculture must have any meaningful impact on the productivity of the agriculture sector of the economy, then the focus must shift a little from production to enhancing value addition across the facets of the value chain for all commodities.

7. The various agencies saddled with the responsibilities to implement food and agricultural policies should be well-empowered and motivated.

8. There should be a very strong synergy between policies, programmes, projects and frameworks at regional and national levels to enable all these strategies to work.

9. The society must reduce gender inequality and recognize the contribution of women (>80.0%) to agricultural food production.

10. Mechanization of the basic agronomic practices such as

planting, tilling and harvesting of the oilseed crops should be pursued vigorously in order to reduce drudgery and improve technical competence of the workforce.

11. Update on market information should be made available to farmers to guide them in making choices with respect to the crop to direct their energy and resources because these oil-bearing plants offer a range of opportunities for them.

12. Training of the local farmers that produce about 80% of the oilseeds consumed in Nigeria is strongly advocated because these people are still using outdated manual harvesting techniques.

13. There is the need to invest massively in order to increase the total cropland under irrigation (presently 1%) and thereby transform the Nigerian economy from rain fed to grower led. Irrigation can provide the boost that the Nigerian economy needs to make the leap from rain-fed to grower-led.

14. Since organic agriculture is now recognized as the fastest growing sector of agriculture globally, Nigeria should take advantage of this opportunity by facilitating the mainstreaming of organic agriculture into the curricula of education at various relevant levels in the country.

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Annexe 1: Amount of palm oil produced in selected countries in 2019

Country	Production (tonnes)	Share of global production, %
Indonesia	42.50	58
Malaysia	19.00	26
Thailand	2.80	4
Colombia	1.53	2
Nigeria	1.02	1
Guatemala	0.85	1
Honduras	0.58	1
Papau New Guinea	0.55	1

Source: https://www.forbes.com/sites/niallmccharty/2020/10/02/

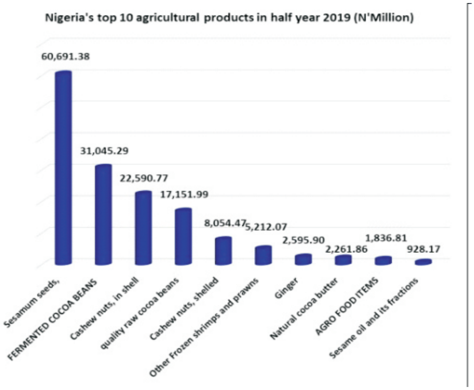
Annexe 2: List of vegetable oil companies in Nigeria

sn	Name of company	Location	Remarks
1	Devon King's Cooking oil 01 271 7153, 01 271 7154	45/47 Town Planning Way, Ilupeju Industrial Estate, Lagos, Nigeria	Produces vegetable oil and red oil
2	Kemas Innovative Global Ltd. 07067555605, 08035486815, 08051728611	Plot LL80B Sunnyvale Estate, Dakwo District, Dakwo, Abuja, FCT	Produces groundnut oil and cake
3	Kitchen Vegetable Oil Ltd. 08152679191, 07038194501, 01 440 3770	152 Aba Owerri Road, Aba, Abia State, Nigeria	Produces edible cooking oil
4	Presco Plc	Obaretin Estate, Km 22, Benin/Sapale Road, Benin, Edo State, Nigeria	Produces vegetable oil
5	Tuns International Holdings Ltd. 08077788867, 08056668867, 08057496012	Km 9, New Ikirun Road, O shogbo, Osun State	Produces vegetable oil products
6	Rosel Vegetables Oil 08161146688	Oluyole Industrial Estate, Lagos-Ibadan-Express Road, Ibadan, Oyo State.	Produces pure vegetable oil and soya oil.

7	Vino Pure Vegetable Oil 08032031508, 08032031509	1/1i Pond Street, Housing Estate, Onitssha, Anambra State, Nigeria	Produces quality vegetable oil, refined palm kernel oil and other allied products
8	Fubison Oil 08095685467, 09065502842	8 Echendu close off ykc Junction, Woji Port Karcourt, Rivers State	Sells palm oil and palm kernel oil
9	Grand Cereals Ltd. 0700 000 0999, 073 280 314, 073 280 317, 073 280 014	Km. 17 Zawan Roundabout, Jos, Plateau State	Produces grand vegetable oil products including soya oil
10	Rivers Vegetable Oil Company Ltd. 08069495821, 08037143233	80, Trans Amadi Industrial layout, Port Harcourt, Rivers State, Nigeria.	Produces vegetable oils
11	Shamad Concept Nigeria Ltd. 08039137303, 08035254375, 08067171099	Km 3 Hadejia Road, Yankaba Kano, Kano State.	Produces cotton seed oil, soya oil, groundnut oil.

Annexe 3 : Sesame producing areas in Nigeria

Annexe 4 : Export of major agricultural products from Nigeria



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