WEED SUPPRESSION IN MAIZE-GROUNDNUT INTERCROPPING SYSTEMS AT BENIN CITY IN A RAINFOREST AGRO-ECOLOGY OF NIGERIA

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BENIN CITY

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A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, IN PARTIAL FULFILLMENT FOR THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE (MSc.) IN THE DEPARTMENT OF CROP SCIENCE, FACULTY OF AGRICULTURE, UNIVERSITY OF BENIN, BENIN CITY, NIGERIA

FEBRUARY, 2023

CERTIFICATION

This is to certify that the work contained in this Thesis, titled "**Weed suppression in maize-groundnut intercropping systems at Benin City in a Rainforest agro-ecology of Nigeria**" was carried out by **Idowu AGBOOLA (PG/AGR0806196)** of the Department of Crop Science, Faculty of Agriculture, University of Benin, Benin City, Nigeria.

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CERTIFICATION OF THESIS/DISSERTATION ON PLAGIARISM

We the undersigned attest and declare that the Thesis of Idowu AGBOOLA, titled "**Weed suppression in maize-groundnut intercropping systems at Benin City in a Rainforest agro-ecology of Nigeria**" has successfully passed the anti-plagiarism test and does not violate any copyright regulations.

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M. Sc. Crop Protection

February, 2023

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Date………………………..

DEDICATION

This project work is dedicated to God Almighty who is the author and finisher of my faith for His everlasting love and mercy.

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LIST OF ABBREVIATION AND ACRONYMS

°C : Degrees Celsius

ANOVA : Analysis of Variance

asl : Above Sea Level

Cm : Centimetres

Cmol : Concentration Mole

mLER : Maize Land Equivalent Ratio

gLER : Groundnut Land Equivalent Ratio

tLER : Total Land Equivalent Ratio

g : Gram

Ha : Hectare

IITA : International Institute of Tropical Agriculture

WAP : Week After Planting

NPK : Nitrogen, Phosphorus, Potassium

H_2O : Water

Kg/ha : Kilogram per hactare

L : Litre

LSD : Least Significant Difference

Max. : Maximum

Mg : Magnesium

Min. : Minimum

mm : Millimetre

% : Percent

No/m^2. : Number/Metre Square

ns : Not significant

PROC : Procedure

SAS : Statistical Analysis Software

CISC : Classical biological control

IBC : Inundative biological control

IWM : Intergrated weed management

ABSTRACT

Uncontrolled weed reduce crop productivity by interfering with crop growth and yield. The reduction of weed growth by crop interference is a viable alternative to reduce the reliance on herbicide use in weed management. One of the strategies to reduce weed infestation is to grow crops as intercrops.

A field trial was conducted during the rainy seasons of 2018 and 2019 at the Teaching and Research Farm of the Faculty of Agriculture, University of Benin, Benin City (06^0 20' 50' N, 5^0 37' 23 "E; 78 m asl) to assess weed suppression in maize-groundnut intercropping systems. The experiment was laid out in a Randomized Complete Block Design (RCBD) and replicated three times. The experiment consisted of six treatments (weed-free intercrop, weed-free sole maize, weed-free sole groundnut, weedy intercrop, weedy sole maize and weedy sole groundnut. The attributes measured for weed were weed density per m^2, weed dry weight per m^2, weed smothering efficiency, and for the crops were days to flowering, plant height, ear and pod maturity, cob and pod yields, seed weight, yield and land equivalent ratio. Results showed that weed-free intercrop suppressed weeds relative to weed-free sole maize cropping system. Maize and groundnut plants grew taller in weed-free cropping system (175 cm and 61.5 cm). Number of cobs, 1000-seed weight and grain yield (maize), and pods and 100-seed weight (groundnut), were higher in weed-free intercrop or sole cropping systems. This implies that weeds are major constraints limiting maize and groundnut production in Rainforest environment. For weed suppression, weed density of broadleaves, narrowleaves and their total (561.4 cm, 246.8 cm and 808.2 cm) were all higher in weed-free cropping systems. However, weed dry weight of broadleaves, narrowleaves and their total (78.6 cm, 250 cm, and 329.2 cm) were higher in weedy cropping systems. Weed smothering efficiencies for broadleaves, narrowleaves and their total (72.9 % 626% and 68.0 %) were

higher in weed-free intercrop. Broadleaves were better controlled in both weed-free and weedy intercrops. Land equivalent ratios were generally above one showing that it was more advantageous growing maize and groundnut together instead of the respective sole crops. Therefore, it may be recommended that farmers in the Rainforest agro-ecology should intercrop groundnut with maize and regularly control weeds.

CHAPTER ONE

INTRODUCTION

Maize (*Zea mays* L.) is an annual crop and a cereal which serves as a major food staple for majority of people in Sub-Saharan Africa (SSA) (McCann, 2007), especially in Nigeria. It is one of the important crops occupying third position next to wheat and rice in cereal production in the world (Adesoji *et al.,* 2013). It is a staple food crop in Nigeria (Remison, 2005). Apart from maize serving as staple human food, it also serves as feed for livestock and raw materials for industries. It is used as a source of carbohydrate to both human and livestock (Undie *et al.,* 2012). It is recently used in production of biofuel. It is equally well accepted for feed ingredient and maize contribute up to 30% protein, 60% energy and 90% starch in animal diets (Dado, 1999).

Groundnut (*Arachis hypogeal* L.) is an important annual legume worldwide as it ranked the 13th worldwide most important food crops and fourth important oilseed crop (Smith, 2002). It is known for its oilseed, food and animal feeds (Mangasini *et al.,* 2012). It is a legume plant that is cultivated throughout the tropical, sub-tropical and the warm temperate climatic zones (Sogut *et al.*, 2016). In nearly 100 countries, of which over 90% are developing countries on nearly 24.6 million hectares of land, with a production of 41.3 metric tons and productivity of 1676 kg/ha (Ajeigbe *et al.,* 2014). Groundnut improves soil fertility through nitrogen fixation, thereby increasing the productivity of other crops when used in rotation or in a cereal cropping system. It was estimated that on average, groundnut contributes to about 60 kg nitrogen per hectare. However, China, India, Nigeria, the USA and Myanmar are the leading groundnut producing countries in the world. Nigeria is the largest groundnut producing country in West Africa, accounting for 51% of production in the region and contributing about 10% of total global production and 39% to that of Africa (Sogut *el al.,* 2016). Nigerian groundnut production has been increasing at a growth rate of 8% per annual resulting from area expansion of 6% and increased productivity of 2%. Ndjeunga and Ibro (2010). It is an excellent source of high quality, easily digestible protein (25%), edible oil (50%) and carbohydrates (20%) (Sorrensen *et al.,* 2004, Musa *et al*., 2012).

Weeds are unwanted and undesirable plant that interferes with the utilization of land and water resources and thus adversely affect crop production (Subramanian, 1991). Weeds have been a problem to man ever since he began cultivating crops about 10,000 BC (Joshi, 2004). Its removal is useful because it competes with crops for water, soil nutrients and light, thus reducing crop yield (El Naim and Ahmed, 2010). Joshi (2004) reported that weeds can deprive the crop of 30-50% of applied nutrients and 20-40% of soil moisture. Uncontrolled weed reduce yield by about 40% in maize and 84% in upland rice, 31 – 70% in groundnut, 63-91% in Okra and 73 – 78% in cayenne pepper (Awodoyin and Ogunyemi., 2005). Akobundu and Ekeleme (2001) reported that uncontrolled *Imperata cylinderica* (L.) Raeuschel resulted in 92% reduction in maize grain yield in the drier savanna zone of south western Nigeria. Absence of weed control in crop farm may lead to crop losses of up to 100% (Nyam, 2005). Of all the constraints limiting maize production in Nigeria, weeds are the most deleterious, causing 69 – 92% reduction in grain yield (Magani, 1990).

Intercropping is the cultivation of two or more crops at the same time on the same field (Sagar *et al.,* Wolfe, 2000). Intercropping can lead to a better control of weeds, pest and diseases by providing more competitive effect against weeds either in time or space than sole cropping (Olorunmaiye, 2010; Zuofa *et al.,* 1992). Weed population was reduced in Eggplant-groundnut intercropping (Sirkrishnah *et al.,* 2008). Increased leaf cover in intercropping systems help to reduce weed populations once the crops are established (Beets, 1990). Makinde *et al.* (2009) found that leafy greens can be intercropped with maize to control weeds in the tropic and increase productivity. Intercropping maize and legumes considerably reduced weed density (Badmus, 2005). Maize-pumpkin and maize-bean intercropping reduced weed biomass by 50-66% when established at a density of 12,300 and 222,000 plant ha $^{-1}$ for beans (Mashingaidze, 2004). Intercropping system helps in weed suppression practice in annual crops production (Banik *et al.,* 2006). The reduction of weed growth by crop interference is a viable alternative to reduce the reliance on herbicide application in weed management (Poggio, 2005).

In Nigeria, weeding takes between 21-32% out of the total period dedicated for the production of annual crops (Lucas, 1990). Different weeding methods such as hand weeding, herbicide and other methods has proved inadequate or expensive because of the ability of weeds to infest, spread and colonize native vegetation (Agahiu *et al.,* 2011; Dozier *et al.,* 1998; Chikoye *et al.,* 2002). However, weed smothering by the use of intercrop has been successful and it is cheap (Smith and Ayenigbara, 2003). Intercropping reduced weed density and biomass compared to other weeding methods (Liebman and Elizabeth, 1993). Intercropping has been used to reduce weed control cost and crop production by decreasing the dependency on chemical herbicide in weed control (Banik, *et al.,* 2006).

1.1 JUSTIFICATION

Irrespective of the potentials of maize in addressing the alarming food demand of the increasing populations in Africa as well as various uses to which it is subjected, the average production of maize in Africa is below the world average (IITA, 2007). Weed is a major problem in maize production in Nigeria. Weed reduced yield of maize by 40% and 31-70% in groundnut

(Awodoyin and Ogunyemi, 2005). Nyam (2005) reported that absence of weed control in annual crop farm may lead to crops losses of up to 100%. Weed control is by far the most labour-demanding field operation in maize production and the control is currently the cornerstone of increased production in Africa (Agahiu *et al*., 2011). There are many methods used in the management of weeds- manual, mechanical, biological and chemical methods. Manual weeding is very common and labour intensive in Nigeria. Due to recent trend in unavailability of farm labours and its high wage rate, manual weeding is being replaced by chemical weeding (Chauhan *et al.,* 2012). Chemical weed control using herbicides offers easy and low cost of herbicidal weed management in world agriculture. But its indiscriminate use by farmers in controlling weeds has led to the disruption of balance in the ecosystem resulting in the reduction of crop yield and the building of herbicide resistant weed biotypes. Using intercropping systems could help decrease the dependency on chemical herbicides (Banik *et al.,* 2006). In fact, intercropping system is a viable alternative to reduce the reliance on herbicide application in weed management (Poggio, 2005). Liebman and Elizabeth (1993) reported that intercropping reduced weed density and biomass. Chikoye, *et al.* (2002) reported that the simultaneous cropping of cover crops with staple food crops has the inherent capacity for reducing weed control cost in crop production. Increased canopy cover in intercropping systems help to reduce weed populations once the crops are established (Beets, 1990). Intercropping also has several benefits to the farmers including yield increase, soil nutrient stabilization and weed control (Ijoyah and Usma, 2013). However, the use of intercropping system to manage weed in maize and groundnut is not a common practice in the rainforest agro-ecology. More so, there is a dearth of scientific information on suppression of weeds in maize-groundnut intercrop in the region. Therefore, there is a need to determine weed suppression in maize-groundnut intercropping systems in the rainforest agro-ecology.

1.2 Objective of the Study

The aim of this study was to assess weed suppression in maize-groundnut intercropping systems.

Specific objectives were to determine:

i. Comparative advantage of weed suppression of intercropping over sole cropping system.

ii. The weed density and biomass in maize-groundnut intercropping systems.

iii. The weed smothering efficiency of maize-groundnut intercropping systems.

CHAPTER TWO

LITERATURE REVIEW

2.1 Importance of weeds in annual crops

Weeds are higher plants in agro-ecosystems, which are not sown, undesirable, out of place or generally as plants which do more harm than good (Bedry, 2007). Weeds have been a problem to man ever since he began cultivating crops about 10,000BC (Silva *et al.,* 2004b). EL Naim and Ahmed (2010) reported that weed as unwanted plant compete with crops for water, soil nutrients, light and space, thus reducing crop yield. Joshi (2004) reported that weeds can deprive the crop of 30-50% of applied nutrients and 20-40% of soil moisture.

Nyam (2005) reported that absence of weed control in annual crop farm may lead to crops losses of up to 100%. Weed infestation has become one of the most famous limitations to maize production in Nigeria. In Nigeria, weeding takes between 21 and 32 out of the total period dedicated for the production of maize therefore, uncontrolled weeds cause okra yield losses ranging from 63 to 91% (Lucas, 1990).

Alabi (1997) reported that weed infestation is a constraint in cassava production. He further stated that cassava is generally susceptible to weed infestation because of its initial slow growth after planting. IITA (1990) reported the reduction in tuber from 40% in the early branching varieties to nearly 70% in the late or non-branching varieties.

Ayeni (2000) reported that weeds constitute a major pest with which farmers in West Africa must contend. In West Africa, uncontrolled weed growth has been reported to cause 40 – 90% yield loss in cereals, 53 – 60% loss in legumes, 50 – 53% loss in oil seeds and 65 – 91% loss in root and tuber crops (Ado, 2007). Magani (1990) reported that of all the constraints limiting maize production in Nigeria, weeds are the most deleterious causing 69 – 92% reduction in grain yield. In Nigeria uncontrolled weed reduced yield by about 40% in maize and 84% in upland rice 31 – 70% in groundnut and 73 – 78% in cayenne pepper (Awodoyin and Ogunyemi, 2005). Akobundu and Ekeleme (2001) reported that uncontrolled *Imperata cylinderica (L.) Raeuschel* resulted in 92% reduction in maize grain yield in the drier savanna zone of southwestern Nigeria. Apart from reduction of crop yield, weeds contaminate and taint farm product to reduce their market value and change their use (Chianu and Akintola, 2003). After a long research, FDA (1994) reported that one of the major tasks facing Nigerian farmers in their effort to feed the nation is the absence of adequate technologies to control weeds. Magani (1990) reported that the total land area a farmer can cultivate is determined to a great extent by how much labour is available to him for weed control.

According to Lavabre (1991) weeds to some extent affect all crops but how serious this is depends on the species and circumstances. He explained that average crop losses due to weeds are estimated at 25% but may be as high as 50% or over 80% with certain food crops. Adigun and Lagoke (2003), Badmus (2005), Giwa (2007) and Adebomi (2008) reported that hoe-weeding in intercrop and sole groundnut improved the performance of groundnut pod yield.

2.2 Weed management methods in annual crops

Akobundu (1996) reported that weed control refers to those actions that seek to restrict the spread of weeds and destroy or reduce their population in a given location. There are many tactics to manage weeds such as manual, mechanical, biological and chemical methods. Due to recent trend in unavailability of farm labours and its high wage rate, manual weeding is being replaced by chemical weeding using herbicides which is very easy with low cost means of herbicidal weed management in world agriculture (Chauhan *et al.,* 2012). Manual weed control is popular among farmers and is one of the most back breaking activity in Nigeria (Chui *et al.,* 1997). Cultural weed control can be an important integrated weed management option in suppressing weeds in annual crops. Orluchukwu and Udensi (2013) reported that the complementary effect of companion crops is believed to reduced weed pressure. Lithourgidis *et al.* (2011) reported that an ideal spatial pattern should be used with minimum influence on companion crop yield while it's able to suppress weeds. The peasant farmers rely strongly on the traditional hand weeding for control but it takes between 21 – 32% out of the total period dedicated for the production of maize (Lucas, 1990). The popular weed control method used is more than 80% of the resource poor farmers produces bulk of the food eaten in developing nation is hand weeding (Orluchukwu and Udensi, 2013). Several Scientists such as Agahiu *et al.* (2011), Dozier *et al*. (1998) and Chikoye *et al.* (2002) reported that hand weeding is the oldest method of weed control. These Scientists noted that this method has consistently proved inadequate and expensive.

Sanyal *et al.* (2008) and Ronald *et al.* (2011) reported that integrated weed management (IWM) is a process that combines both direct and indirect strategies for the control of weeds. Direct control strategies include biological, chemical, cultural and/or physical measures for the control of weeds. Method of direct control involve agronomic practices, which may include the choice of cultivar, crop rotation, sowing period and nutrient management among other factors and are designated to promote the competitive ability of crop. Harker and O' Donovan (2013) reported that the importance of IWM was recognized nearly 80 years ago but currently received increasing attention due to the rapid development of weed biotypes that are resistant to herbicides. Ekpo *et al.* (2010) found that the combination of herbicide and the use of melon as intercrop satisfactorily controlled weeds and resulted in lowest reduction in maize yield compared to that obtained with two hoe weedings. In IWM, the selection of the species to be intercropped with maize and the choice of other methods to be used for weed control are important (Yeganehpoor *et al.,* 2013). In many intercropping systems, only one weeding is required to produce optimum yields instead of three or more in sole crops (Ekpo *et al.,* 2010). Hart (1975) concluded that the success of an intercropping system in suppressing weed growth depends on soil fertility and climate as well. The work showed that suppression of weed is often higher with low fertility than with high fertility soil and the same was valid for low and high rainfall areas. Agahiu *et al.* (2011) reported that herbicides are likely to become increasingly important as a means of weed control in cassava, okra, maize and groundnut especially where labour is in short supply or expensive and where farm size is large. The use of herbicides may lead to increased farmer holding with associated increase in productivity. Ayeni (2000) reported that hand weeding and slashing will continue to be expensive as well as the drudgery associated with it especially, where farmers cannot afford alternative means like herbicides. He further stated that intercropping melon and okra without herbicide will have limited weed control benefit, because both crops are short seasons and once harvested exposes the cassava to weed competition. Kruidholf *et al.* (2008) found that weed suppression is positively correlated to early light interception by the living mulch and is sustained by the strong negative correlation between cumulative light interception and weed biomass. Similarly, Badmus (2005) reported that weed suppression was linked to light interception by the much cover for most weed species.

Allelopathy is another mechanism by which living mulches may suppress weeds (Fujita *et al.* 1992). Chemeda (1996) reported that biological control of weeds using pathogens can be considered from two broad approaches including classical biological control (CLBC) and Inundative Biological Control (IBC). Sanjay *et al*. (2012) reported that weed control efficiency at harvest of maize was significantly influenced by weed management, where all the weed management treatments resulted in increase of weed control efficiency over the weedy check. The highest weed control efficiency was observed under Alachlor 1.5 kg/ha + hand weeding at 40 DAS (83%) which was followed by alachlor 2.0 kg/ha (59%) and hand weeding at 30 DAS (59-53%).

2.3 Effects of intercropping systems on weed in annual crops

Beets (1990) reported that the increased diversity of the physical structure of plant in an intercropping system produces many benefit. Increased leaf cover in intercropping systems help to reduce weed populations once the crops are established (Beets, 1990). Intercropping also has several benefits to the farmers including yield increase, soil nutrient stabilization and weed control (Ijoyah and Usman, 2013). Banik *et al.* (2006) reported that intercropping systems is perfectly used for weed suppression. The reduction of weed growth by intercropping systems is a viable alternative to reduce the reliance on herbicide application in weed management (Poggio, 2005). Eskandari (2011) reported that wheat-bean intercropping system suppress weeds better than sole. Banik *et al.* (2006) conducted wheat-chickpea intercropping study and observed that intercrops suppressed weed in addition to increase total productivity per unit area and land used efficiency improvement. Yih (1982), Sheaffer *et al.* *(*2002), Midya *et al*. (2005) reported that intercrops may demonstrate advantages on weed control over sole crops both by producing greater crop yield and less weed growth through usurping resources from weeds.

Agengnehu, *et al.* (2008) reported that weed biomass was lower in intercropping compare to sole cropping. Less weed biomass and density under intercropping system could be due to high inter-specific competition between intercrop crops which increased competitive ability of crops towards weeds (Banik *et al.,* 2006). Orluchukwu and Udensi (2013) reported that using herbicides to control weed in an intercropping system on small farm holdings has not been found workable or popular.

Liebman and Elizabeth (1993) reported that intercropping (spatial diversification) reduced weed density and biomass performance. Chikoye *et al.* (2002) reported that the simultaneous cropping of cover crops with staple food crops has the inherent capacity for reducing weed control cost and crop production. Intercropping can be used for decreasing the dependency on chemical herbicides in weed control (Banik *et al.,* 2006).

Liebman and Dyck (1993) studied an intercrop system where a main crop was inter-sown with a 'smother' crop species and concluded that weed biomass in the intercrop was lower in 47 cases and higher in 4 cases than in the main crop grown alone. Ofosu-Anim and Limbani (2007) reported that intercropping okra with cucumber resulted in reduced weed infestation, especially of broadleaf weed in Ghana while Katsaruware and Manyanhaire (2009) in Zimbabwe reported that weed density and biomass were significantly lower when maize was intercropped with cowpeas than sole cowpeas.

Takim and Fadayomi (2010) reported that maize-cowpea intercrop and sole cowpea can reduce weed establishment and biomass production. They further stated that crop canopy formed under the maize-cowpea and sole cowpea cropping system must have been responsible for the reduced weed density and biomass. Nwagwu *et al.* (2000) reported that intercropping system influenced the quantity and quality of light required for germination of weed seeds, while Kruidholf *et al.* (2008) stated that competitiveness under different cropping systems is strongly correlated to early light interception. Ijoyah and Dzer (2012) reported that intercropping system ensures efficient suppression of weeds thereby encouraging higher net returns. Intercropping may often result in reduced weed density and growth compared to sole crops (Liebman and Dysck, 1993).

Intercrops that are effective at suppressing weeds capture a greater share of available resources than sole crops and can be more effective in pre-empting resources by weed and suppressing weeds growth (Susan and Mini, 2005). Intercrop treatments such as wheat-canola and wheat-canola-pea tended to provide greater weed suppression compared with each component crop grown alone, indicating some kind of synergism among crops within intercrops with regard to weed suppression (Szumigalski and van Acker, 2008). Saucke and Ackermann (2006) reported that intercropping peas with false flax in additive arrangements had a greater suppressive effect on weed coverage of about 63% and 52%. Bilalis *et al.* (2010) reported that intercropping maize with legumes considerably reduced weed density and weed dry matter in the intercrops, compared with maize pure stand. This was ascribed to decrease in the available light for weeds in the maize-legume intercrops. Similarly, Midega *et al.* (2010) reported that finger millet (*Eleusine caracana*) intercropped with Greenleaf desmodium (*Desmodium intortum*) reduced *Striga hermonthica* counts in the intercrops than in the sole crops. Sanginga and Woomer (2009) reported that intercropping systems more efficiently used the growth factors to suppresses weed and favour soil-physical conditions, particularly intercropping cereal and legume crops which also maintain and improve soil fertility.

Maereka *et al.* (2009) reported a reduction in weed pressure in maize-pumpkin intercrop because of reduced resource consumption by weeds. Henrik *et al.* (2003) reported that intercrop reduced weed density and biomass compared to sole cropping probably due to smothering of weeds by denying them light. Iqbal *et al.* (2007) reported that soyabean-sesame and sorghum-cotton significantly decreased weed density and biomass due to radiation interception. Weed biomass in intercrop system was lower than sole maize crop, this observation was similar to findings by

Eskandasri and Ghanbari (2010) who reported a reduced dry weed biomass in intercrop systems compared to sole crop.

Baumann *et al.* (2001) reported that intercropping plays a significant role in integrated weed management and improvement of soil fertility. They further stated that intercropping increased light interception by the weakly competitive component therefore, shorten the critical period for weed control and reduce growth and fecundity of late-emerging weeds. Musambasi *et al.* (2002) reported that intercropping field beans *(Phaseolus vulgaris),* groundnuts and cowpea reduced the number of weed seeds, especially striga and suppressed germination and growth of other weeds. Intercropping also helps in the suppression of at least the secondary growth of weeds that occur after the intercrops have fully covered the ground. Eskandari and Ghanbari (2010) reported that intercropping serve as better option for an integrated weed management systems in many crops as it also suppress secondary growth of weed that occur after canopy development. Reduction of weed growth by crop interference has been referred to as one determinant of yield advantage of intercropping, being a viable alternative to reduce the reliance of weed management on herbicide use (Agengnehu *et al.,* 2008; Banik, *et al.,* 2006). There are two possible reasons for the reduction of weeds biomass in intercropping systems; some intercrop species release allopathic compounds which limit the occurrence of weeds while the other is by providing shade. (Olufemi *et al.,* 2001). Celette *et al.* (2005) reported that weed suppression in intercropping are through more efficient use of environmental resource by component crops.

Chen *et al.* (2004) and Song *et al. (*2007) reported that legume intercropping system is advocated because of its beneficial effect on yield increase of maize and weeds control thereby improve the farmers income and soil fertility. Giwa (2007) and Adebomi (2008) reported reduced weed infestation in similar mixtures compared with sole maize crop. Liebman and Elizabeth (1993) reported that weed population density and biomass production may be markedly reduced using crop intercropping system. Eskandari and Kazemi (2011); Tripathy *et al.* (2008), Chikoye *et al.* (2006); Hugar and Palled (2008) and Agahiu *et al.* (2011) on the efficacy of intercrop in reducing weed incidence. Similarly, the low weed biomass recorded in intercrop pattern agrees with the report on reduced weed dry weight in intercropping system (Eskandari and Ghanbari 2010).

Omovbude *et al.* (2017) reported that egusi melon was more effective in weed suppression than water melon and pumpkin in the intercropping systems. Adhikary *et al.* (1991) reported that cereal-legume intercropping is an important agronomic practice, in which the efficiency of the system as a whole is usually better than that of each component independently. Shading by the crop canopy has been recognized as the main factor promoting weed suppression in intercrops (Baumann *et al.,* 2001). Intercropping maize and legumes considerably reduced the weed density compared with the sole crop maize by decrease in available light for weeds compared to sole crops. Evidence of better weed control was reasonably clear where intercropping provides a more competitive effect against weeds either in time or space than monocropping (Srikrishnah *et al.* 2008). Nielson *et al.* (2003) reported that lesser weed biomass production and weed density under intercropping systems was due to higher inter-specific competition combined with complementarity between intercrop species that improve the crop stand competitive ability towards weeds.

Sharma and Banik (2013) reported that the effect of intercropping maize with legumes on weed dynamics and community structure suppress weeds growth and population more than their respective sole crops, but weed diversity and evenness were higher in intercropping systems.

Odedina *et al.* (2014) reported that intercropping reduced okra yield and increased yield of cowpea.

2.4 Land equivalent ratios

Land equivalent ratio is the relative land area required as sole crops to produce the yield achieved in intercropping (Mead and Willey, 1980). It yield values could also be thought of as relative yields. Midya *et al.* (2005) reported that greater intercrop yield advantage from total intercropping system of land equivalent ratio values were higher than one indicates that is advantage of mixtures over sole stands in regard to the use of agro-environmental resources for plant growth. Similar results were reported for different proportion of plant in mixtures by Agengnehu *et al.* (2006a). Hauggaard-Nielsen *et al.* (2009); Mucheru-Muna *et al.* (2010) and Hauggaard-Nielsen and Jensen (2001) reported that the intercrop plant growth resources were use on average of 20% without nitrogen application and 5-10% more efficient with nitrogen application. Adhikary *et al.* (1991; 2005); Adhikary and Sarkar (2000) and Dariush *et al.* (2006) reported that land equivalent ratio produces yield advantage per unit area in an intercropping system over sole cropping. An intercrop experiment showing land equivalent ratio values more than one depicting yield advantage in intercropping over sole cropping (Lithourgidis *et al.,* 2006). Maize + pea, maize + chilli (1.21) and maize + groundnut (1.16) intercropping systems gave higher land equivalent ratio about (1.52, 1.21 and1.16) compared to when they were planted separately. Rahimy *et al.* (2003) reported that land equivalent ratio in intercrop of maize-soyabean was higher than sole cropping. Koucheki *et al.* (2009) and Sajj and Safar (2014) reported that an intercrop of wheat and lentil gave higher land equivalent ratio. Sajj and Safar (2014) reported that sorghum and mung-bean intercropping gave the LER indicating yield advantage over sole cropping. Akter *et al.* (2004) weed control on the amount of land equivalent ratio was significant in a test on sesame intercropping with green mung-bean and black mung-peanut including sun-flower compared to sole cropping. Sarkar and Kundu (2001) reported that chickpea-barley intercropping systems yielded maximum land equivalent ratio of (1.25) indicates advantage than sole cropping. Getachew *et al.* (2006) reported that intercropping of barely and bean land equivalent ratio was higher compared with sole cropping. The intercropping of chickpea and barley LER was higher compared to sole crop, the reason for this was attributed to biological nitrogen fixation (BNF) by root of pea plant (Launay *et al.,* 2009). A LER greater than 1.0 has also been reported with maize-soybean (Addo-Quaye *et al*., 2011, Solanki *et al.,* 2011), Maize-cowpea (Dahmardeh *et al*., 2010; Hugar and Palled, 2008) and maize-common beans (Yilmaz *et al*., 2008; Odhiambo and Ariga, 2001). Davis *et al.* (1993) reported that light is the most important factor determining LER of maize and soybean intercrop due to the fact that LER declines when legume become severely shaded.

Amanullah *et al.* (2016) reported that intercropping of maize and common bean with compost application had higher LER compared with sole cropping. Ayisi *et al.* (1997) reported significant row arrangement effect on the productivity of canola-soybean. They comfimed that narrow strips of one to four meters width gave land equivalent ratios significantly greater than unit (1.02 to 1.65). Nguimgo *et al.* (2003) obtained land equivalent ratios of more than unity in either maize-groundnut or maize-cowpea intercropping when no nitrogen was applied. Odhiambo and Ariga (2001) obtained LER of 1.6 in maize-bean intercrop, while Marer *et al.* (2007) obtained LER of 1.52 in maize-pigeon pea mixture. Midya *et al,* (2005) reported that partial LER of cowpea was greater than that of okra in okra-cowpea mixtures. Khan *et al.* (1992) reported that maize and soybean recorded a high LER of 1.40 as a result of sowing them rows, while a low LER of 0.95 involving the same crops was noted but on alternate rows. Fininsa (1997) reported that LER for intercrop was far above that of sole crop with maximal relative yield advantage of 28%. Ijoyah *et al.* (2012) reported that a land equivalent ratio (LER) of 1.25 can be interpreted as 25% greater yield for intercropping or as a 25% greater area requirement for the sole cropping system. Ijoyah and Usman, (2013) reported that land equivalent ratio (LER) value were all above 1.00, indicates yield advantage, as well as the suitability and compatibility of okra in all the reviewed intercropping system trials.

Njoku and Muoneke (2008) found that intercropping system resulted in yield advantages of total land equivalent ratio of 1.76 showing higher productivity of 76%. The higher partial LER of cassava at almost all cowpea densities indicated that cassava was more competitive than cowpea and that cassava utilized the N fixed by cowpea for better growth and yield.

Chipomho *et al.* (2015) reported that despite high grain yield of sole crops compared to intercrop companion crops, the overall performance showed higher productivity LER >1.0 in intercrop compared to sole crop. Addo-Quaye *et al.* (2011) found that LER was greater than unity, implying that it will be more productive to intercrop maize-soybean than grow them in sole. Abera *et al.* (2005) observed that the LER values ranged from 1.15 to 1.42 indicates more productivity and land use efficiency of maize + climbing bean (*Phaseolus vulgaris*) intercropping in terms of food production per unit area. Ullah *et al.* (2007) reported that soybean + maize in 90 cm space double row strips gave maximum maize grain equivalent yield and maximum land equivalent ratio.

He further explained that, LER of greater than one recorded with the intercropping patterns shows that resource consumption or land, utilization efficiency for intercropping pattern was more advantageous than sole cropping. Poodineh *et al.* (2014) reported that LER greater than one indicated that more advantages in intercrop than sole cropping systems. Gorge and Jeruto (2010) reported that an intercrop between maize, cowpea and soya bean productivity increased land equivalent ratio by 22 to 32%. Omovbude *et al.* (2017) reported that land equivalent ratio was generally above one indicating that the crops perform better in intercrop than in sole crop.

2.5 Weed smothering efficiency

Weed smothering efficiency was calculated using weed dry biomass in intercropping plots in comparison to sole maize at 60 DAS (Shah *et al.,* 2011). Vijay *et al.* (2014) reported that sole cowpea had the highest weed smothering efficiency of 88% followed by the intercropped plot one maize- cowpea (85%). Yilmaz *et al.* (2008) reported that lettuce-tomato intercropping best utilized environmental resources and had better weed smothering efficiency. Singh *et al.* (2005) and Shah *et al.* (2011) reported that weed smothering efficiency of intercropping was highest with the mixed intercropping pattern at 6 weeks after planting. Fatokun *et al.* (2002) reported that yield advantages demonstrated with okra-cowpea intercrops were ascribable to the soil N economy often associated with inclusion of legume in the mixture and ability of the cowpea varieties to establish rapidly to achieved high LAI in smothering weeds and modify environmental factors by reducing their adverse effects in crop mixtures.

Orluchukwu and Udensi (2013) reported that weed smothering efficiency in okra intercropping with maize and pepper achieved acceptable weed suppression benefits than sole cropping pattern. They further explained that crop combinations practiced were able to exploit and harnessed soil nutrients and played vital role in promoting the efficiency of intercropping pattern in smothering weeds.

Omovbude *et al. (*2017) reported that egusi melon had the best weed smothering efficiency compared to other crops in the trial. Saad *et al.* (2016) reported that weed smothering efficiency was greater in intercropping cauliflower-lettuce compared to sole cauliflower and lettuce. Ashish and Yadav (2013) reported that the lower uptake of nutrients by different weeds under intercropping systems may be attributed to hang up of weed growth and reduced crop weed competition due to smothering effect of intercrops on weeds which led to lower dry matter production, consequently resulting in lower uptake of nutrient by weeds. Shah *et al.* (2011) reported that weed smothering efficiency (%) calculated at 20 and 45 DAS and at harvest clearly indicated that intercropping of maize with soybean have higher weed smothering efficiency than the maize with green-gram. This was only due to the fact that the lower availability of space and light leads to lower down the density of weeds and ultimately recorded lower weeds dry weight in intercropping and also suppressed the weed species by more canopy cover. However, weed smothering by using intercropping systems has been successful in many experiments (Smith and Ayenigbara, 2003). Mohamed *et al*. (2006) reported that among all intercrops, cowpea registered higher weed smothering efficiency as compared to maize which was due to fact that cowpea ensured better coverage of soil surface from the beginning and diminished light penetration to the soil reducing the weed growth and ensuring better weed smothering efficiency. Zuofa *et al.* (1992) reported that a reduction in weed dry weight in cassava intercropped with smother crops at 3 to 6 weeks after planting resulted in increased crop yield from 9% to 20%. Abe, 2006, Nwonkwo, (2010) and Atilola 2007, all reported that combination of groundnut with maize contributed to the sustainability of mix cropping systems and a significant reduction in weeds population density due to the weed smothering effect of the cover crop as well as moisture conservation effect. Sole maize had potentials of smothering weeds in weed-free intercrop than weedy intercrop. This could be due to the removal of weeds in the intercropping systems.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental Site

The experiment was conducted in the early cropping season (May-August) of 2018 and 2019, at the Teaching and Research Farm of the Faculty of Agriculture, University of Benin, Benin City, (06^0 20' 50' N, 5^0 37' 23 "E; 78 m asl), in the Tropical Rainforest of Nigeria. The soils are underlain by sands, clayey sands and discontinuous clay sequences of Benin formation of Niger Delta Basin classified as Ultisols (Olatunji *et al*., 2014, Umweni *et al*., 2014). Rainfall is of high intensity and bimodal, beginning in March/April and ending in October/November with a dry little spell in August usually referred to as "August Break". About 2025 mm of precipitation falls annually in Benin City with an average annual temperature of 26.1 °C (Climate-Data.org., 2018). Prior to the commencement of the trial, soil samples were collected randomly from the entire plots at 15-20 cm depth using soil auger. The soil samples were bulked and a composite sample obtained, air dried, grounded and sieved with the use of 1 mm sieve. The labeled sample was sent to the Analytical Services Laboratory of the Faculty of Agriculture, University of Benin, Benin City, for analysis of the physical and chemical properties. Before the establishment of the trial, the land was covered by heavy vegetation, mostly made up of *Panicum maximum* (Jacq.). The second year trial was repeated on the same piece of land used for the first year trial and was left to fallow before the onset of the second year trial in 2019.

3.2 Plant materials

Extra early maturing maize variety (BR 9928 DMR-LSR-Y) obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria and a local groundnut namely 'Auchi local' obtained from New Benin market, Benin City, Edo state, Nigeria, was evaluated in the study.

3.3 Experimental design and treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) and replicated three times. The experiment consisted of six treatments (weed-free intercrop, weed-free sole maize, weed-free sole groundnut, weedy intercrop, weedy sole maize and weedy sole groundnut. A treatment plot measured 3 m x 5 m containing 4 rows. Plant spacing was 75 cm x 50 cm for maize and 75 cm x 10 cm for groundnut. Treatment plots and replications were separated by 50 cm apart.

3.4 Land preparation

The land was manually cleared and the debris was packed without burning.

3.5 Sowing

Sowing of crops was done on 11 May, 2018 and 13 May, 2019 when the rain had stabilized and the soil was sufficiently moist. Maize and groundnut seeds were treated with Apron plus at a rate of 4 kg of seeds to a sachet of 10 g of Apron plus before sowing. Three seeds were sown at a depth of 2-5 cm. Sole maize was planted at a spacing of 75 x 50 cm with two seedlings per stand after thinning at two weeks after sowing. Sole groundnut was sown at a spacing of 75 x 10 cm with one seedling per stand after thinning at two weeks after planting. The plant spacing and number of plants per stand in sole crops were maintained for both crops in the intercrop. Groundnut was planted in the furrow between two maize rows. Both crops were planted the same day.

3.6 Fertilizer application

At sowing, 60 kg N, 60 kg P_2O_5 and 60 kg K_2O ha^{-1} respectively, in form of NPK 15:15:15 was applied to each plot at the rate of 112 g per plot. Urea was side-dressed at about 10 cm to the maize stand at a rate of 60 kg N ha^{-1} (64 g per plot) at 3 WAP.

3.7 Weed control

At sowing, two 1 m x 1 m quadrats were marked out diagonally for weed sampling in each plot. The plots were hoe-weeded three times at 3 WAP, 6 WAP and 9 WAP to keep the plots weed-free for the treatment plots in which weeding was required.

3.8 Data collection

3.8.1 Crop data

3.8.1.1 Flowering

Number of days to tasselling and silking was recorded for maize, and number of days to 50% flowering in groundnut. This was achieved by counting the number of plants in a net plot with flowers, tassels or silk daily till half of the number of plants in a plot had tassels, silks or flowers. For maize, plant height was measured from ground level to the node where the last top leaf (flag leaf) attached itself to the stem just before the tassel using a measuring rule. For groundnut, plant height from ground level to the highest point of growth was measured at full flowering. For each crop, measurement was done on five randomly selected plants in a net plot and average was recorded per treatment.

3.8.1.2 Ear and pod maturity of maize and groundnut

These were determined by recording the number of days to maturity (95% of cob sheath turning brown in maize, 95% of leaf turning brown in groundnut) at 9 WAP.

3.8.1.3 Cob and pod yields of maize and groundnut

Number and weight of cob or pod per the net plot was recorded and calculated as cobs or pods per plant.

3.8.1.4 Seed weight of maize and groundnut

A 1000-seed weight for maize and 100-seed weight for groundnut were obtained by counting and weighing in each plots.

3.8.1.5 Grain Yield of maize and groundnut

Harvested ears from net plot were de-husked and air-dried for one week. Grains were threshed from the dried cobs, weighed using electronic balance (Dickey-John; Model: R21PE30, Serial number: RS-232-C and USB) and recorded.

3.8.1.6 Stover yield

Stover or folder yield was determined by air-drying the leaves and stems of crops to a constant weight, weighed and expressed in kg/ ha^{-1}.

3.8.1.7 Land equivalent ratio

The LER was calculated as:

LER = (Yim/Ysm)+(Yig/Ysg) (Mead and Willey, 1980)

where, Yim and Ysm are the yields of maize in intercrop and sole crop, and Yig and Ysg are the yields of groundnut in intercrop and sole crop, respectively. A ratio > 1, implies yield advantage, a ratio < 1, implies yield disadvantage and a ratio = 1, implies no differences in yield.

3.8.2 Weed data

3.8.2.1 Weed density per m^2

For the weed-free plots, weed density was assessed from the two quadrats measuring 1 m x 1 m in a plot at each time of weeding. At each measurement, weeds were separated into broadleaves kand narrow leaves. Weed counts for the three times of measurement at 3 WAP, 6 WAP and 9 WAP, were expressed as number of emerged weed seedlings per m^2. For the weedy plots, measurement was done in the two quadrats only at the time of harvest of the crops.

3.8.2.2 Weed dry weight per m^2

On the same plots and quadrats and for the same weeds counted for density measurement, dry weight was recorded after air-drying to a constant weighed and expressed in g/m^2

3.8.2.3 Weed smothering efficiency

Weed smothering efficiency of the different intercropping systems was determined based on weed control efficiency according to Subramanian *et al*., (1991) as follows:

$$WSE\ (\%) = \frac{WDWT in \text{ sole } crop - WDWT in\ intercrop}{WDWT in \text{ sole crop}} \times \frac{100}{1}$$

Where, WSE = weed smothering efficiency; WDWT = weed dry weight.

3.9 Statistical analysis

Data obtained for the two-year trial were subjected to analysis of variance (ANOVA) using the PROC GLM procedure of SAS for Windows Release 9.2 (SAS Institute, 2011, SAS Institute Inc., Cary, NC, USA.). Means were separated using LSD test at 5% level of probability.

CHAPTER FOUR

RESULTS

4.1 Soil characteristics, rainfall and temperature of the experimental site

The physical and chemical properties of the experimental site are presented in Table 1. The soil of the experimental site in both years was sandy and acidic with a pH ranging from 4.65 to 4.90.The nitrogen content of the soil was low (0. 9 g/kg). Total organic content ranged from 17.2 g/kg to 17.9 g/kg for both years. Available phosphorous (P) were moderate in both years of experiment (12.1 and 12.3 mg/kg). Nevertheless, the calcium (0.57 cmol/kg/g), magnesium (0.16 cmol/kg/g), potassium (0.17 cmol/kg/g) and sodium (0.1 cmol/kg/g) average contents of the soil for both year were low. The soil textural class was sandy soil.

Rainfall and temperature data during the experimental period are shown in Table 2. The total amount of rainfall was 1144.8 mm in 2018 and 3724.0 mm in 2019. Maximum temperature averaged 33°C in 2018 and 32°C in 2019 where as minimum temperature averaged 23 °C in 2018 and 24°C in 2019.

4.2 Maize performance

4.2.1 Plant height, days to tasselling, days to silking and days to maturity

Year, cropping system and year × cropping system interaction influenced plant height (Table 3). Plants grew taller in 2018 than in 2019. Weed-free intercrop had maize plants similar in height with those under weedy intercrop. Weed-free sole maize grew taller than weedy sole maize. The significant Y × C interaction showed that plants under weedy intercrop grew taller in 2018 while taller plants were associated with weed-free sole maize in 2019.

Table 1: Physical and chemical properties of soil used for the experiment

Year	2018	2019
Parameter	Values	
(pH)	4.9	4.65
Total Organic Carbon (g/kg)	17.9	17.2
Total Nitrogen (g/kg)	0.9	0.9
Available P (mg/Kg)	12.1	12.3
Sand (g/Kg)	886	888
Silt (g/Kg)	58	54
Clay (g/Kg)	56	58
Calcium (cmol/Kg/g	0.58	0.56
Magnesium (cmol/Kg)	0.16	0.16
Potassium (cmol/Kg)	0.18	0.16
Sodium (cmol/Kg)	0.1	0.1
Hydrogen (cmol/Kg	1.65	1.42
Aluminum (cmol/Kg)	1	1
Soil Texture	Sand	Sand

Table 2: Rainfall and temperatures at Benin City, Nigeria for 2018 and 2019

	2018			2019		
Months	Rainfall (mm)	Maximum temperature ^0C	Minimum temperature ^0C	Rainfall (mm)	Maximum temperature ^0C	Minimum temperature ^0C
January	1.0	37	22	40.2	37	24
February	36.3	36	25	118.9	36	26
Total						
Average						
March	74.4	33	25	95.6	34	26
April	77.8	34	25	119.4	35	26
May	89.0	33	24	378.5	32	25
June	158.3	30	23	503.3	28	23
July	226.5	29	23	615.4	27	23
August	138.8	28	22	508	27	23
September	195.6	29	23	621.5	27	23
October	91.2	32	23	511.6	28	23
November	53.4	35	24	193.2	32	24
December	2.7	37	22	18.4	37	24
Total	1144.8			3724		
Average		33	23		32	24

Source: World weather online (2018)

Year and cropping system influenced days to tasselling, days to silking and days to maturity (Table 3). Performance was better in 2019 compared to 2018. Days to tasseling were similar for weed-free intercrop maize and weed-free sole maize. This trend was similar for weedy intercrop maize and weedy sole maize. Weedy intercrop increased the number of days to tasselling. Similarly, weedy sole crop increased the number of days to tasseling. Days to silking were similar for weed-free intercrop and weed-free sole maize. However, weedy sole maize took more number of days for silk extrusion than with weedy intercrop. Weedy intercrop reduced the number of days to silking.

There were no significant differences between weed-free intercrop and weed-free sole maize for days to maturity (Table 3). There were also no significant differences between weedy intercrop and weedy sole maize for days to maturity. However, the later permitted more days to reach maturity than the former.

4.2.2 Number of cobs and 1000-seed weight

There were no significant differences between years for number of cobs m^2 (Table 4). Significant differences were found among cropping systems for this trait. Weed-free intercrop maize produced higher number of cobs relative to other cropping systems. Differences did not occur between weed-free sole maize and weedy intercrop. Year × cropping system interaction was significant which showed change in ranks among the cropping systems for both years. Weed-free intercrop maize had higher number of cobs in 2018. It maintained this rank in 2019 but performance was also high in weed-free sole maize. Similarly, whereas weedy intercrop maize differed from weedy sole maize for number of cobs in 2018, both had similar number of cobs in 2019.

Table 3. Plant height, days to tasselling, days to silking and days to maturity of maize intercropped with groundnut

	Plant height			Days to tasselling			Days to silking			Days to maturity		
Cropping system (C)	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean
	(cm plant $^{-1}$)			(no.)								
Weed-free intercrop	176.8b	168.0a	172.4ab	51.4a	59.8a	55.6c	55.5a	65.3a	60.4b	68.1a	81.3a	74.7b
Weed-free sole maize	174.9b	176.6a	175.7a	53.5a	61.3a	57.4bc	57.5a	67.0a	62.3ab	70.5a	79.0a	74.8b
Weedy intercrop	194.8a	149.3b	172.1ab	52.4a	63.8a	58.1ab	56.3a	66.3a	61.3b	84.1a	88.8a	86.4a
Weedy sole maize	174.8b	149.7b	162.2b	53.5a	66.8a	60.1a	57.5a	71.8a	64.3a	81.0a	88.8a	84.9a
Mean	180.3a	160.9b		52.7b	62.9a		56.7b	67.56a		75.9b	84.4a	
$LSD_{0.05}$ Y	8.86			1.64			1.98			4.56		
$LSD_{0.05}$ C	12.53			2.32			2.79			6.44		
$LSD_{0.05}$ Y × C	17.72			ns†			ns			ns		

Means in the same column with different letters indicate significant difference ($LSD_{0.05}$)

†ns, not significant

Significant differences were found between years and among cropping systems for 1000-seed weight (Table 4). There was lack of year × cropping system interaction for this trait. 1000-seed weight was higher in 2018 relative to 2019. There were no significant differences between weed-free intercrop maize and weed-free sole maize for 1000-seed weight. There were also no significant differences between weedy intercrop maize and weedy sole maize for 1000-seed weight. Weed-free intercrop maize however, had superior performance compared to weedy intercrop maize and weedy sole maize.

4.2.3 Grain yield and stover yield

Year, cropping system and their interaction influenced both grain yield and stover yield (Table 5). Grain yield was higher in 2018 than in 2019. For grain yield, weed-free intercrop maize had the highest yield while weedy sole maize had the lowest. Weed-free sole maize and weedy intercrop maize had similar grain yield. The significant year × cropping system interaction showed that weed-free intercrop maize and weedy intercrop maize produced the highest grain yield in 2018 while in 2019, highest yields were recorded for weed-free-intercrop maize and weed-free sole maize. Grain yield was lowest in weedy sole maize in both years.

Stover yield was higher in 2019 compared to 2018. There were no significant differences between weed-free intercrop maize and weed-free sole maize for this trait. There were also no significant differences between weedy intercrop and weedy sole maize for the trait. However, the former produced higher stover yield than the later. Intercrop maize, whether weed-free or weedy produced higher stover yield than the sole maize, whether weed-free or weedy in 2018. But in 2019, weed-free intercrop maize and weed-free sole maize had the highest stover yield. Weedy intercrop maize had the least stover yield.

Table 4. Number of cobs and 1000-seed weight of maize intercropped with groundnut

Cropping system (C)	Number of cobs 2018	Number of cobs 2019	Number of cobs Mean	1000-seed weight 2018	1000-seed weight 2019	1000-seed weight Mean
	(no./m^2)			(g)		
Weed-free intercrop	8.8a	8.5a	8.6a	236.2a	195.5	215.9a
Weed-free sole maize	5.3b	7.5a	6.4b	232.7b	176.5	204.6ab
Weedy intercrop	6.5b	5.5b	6.0b	227.2b	144	185.6bc
Weedy sole maize	3.1c	4.5b	3.5c	203c	162.1	182.5c
Mean	5.9a	6.5a		224.8a	169.5b	
$LSD_{0.05}$Y	ns†			15.29		
$LS_{0.05}$ C	1.11			21.62		
$LSD_{0.05}$ Y × C	1.58			ns		

Means in the same column with different letters indicate significant difference ($LSD_{0.05}$)

†ns, not significant

Table 5. Grain and stover yields of maize intercropped with groundnut

Cropping system (C)	Grain yield 2018	Grain yield 2019	Grain yield Mean	Stover yield 2018	Stover yield 2019	Stover yield Mean
			(kg/ha)			
Weed-free intercrop	3640.9a	1630.4a	2635.7a	4246.2a	5989.6a	5117.9a
Weed-free sole maize	2674.4b	1460.4ab	2067.4b	2993.3b	6750a	4871.7a
Weedy intercrop	3009ab	770.9b	1890.0b	5097.6a	1770.8c	3434.2b
Weedy sole maize	953.3c	775.6b	864.5c	2945.6b	3833.3b	3389.4b
Mean	2569.4a	1159.3b		3820.7b	4585.9a	
$LSD_{0.05}$ Y		358.3b			516.76	
$LSD_{0.05}$ C		507.54			730.81	
$LSD_{0.05}$ Y × C		171.78			1034	

Means in the same column with different letters indicate significant difference ($LSD_{0.05}$)

4.3 Groundnut performance

4.3.1 Plant height, days to flowering and days to maturity

Cropping system and their interaction influenced plant height of groundnut except years (Table 6). Plants grew taller in 2019 relative to 2018. With the exception of weedy intercrop, other cropping systems had similar height. Weedy intercrop groundnut however, differed only from weed-free groundnut. The significant Y × CS interaction showed that there were no significant differences among the cropping systems in 2018. But in 2019, weed-free sole groundnut had the tallest plants followed by weed-free intercrop groundnut. The weedy groundnut plants whether as intercrop or sole crop had similar heights.

Year influenced days to flowering; plants flowered shortly in 2019 compared to 2018 (Table 6). Cropping system did not influence this trait. And there was lack of significant year × cropping system interaction.

Year, cropping system and their interaction influenced days to maturity (Table 6). Groundnut took more days to reach maturity in 2018 compared to 2019. For weed-free intercrop, it took the crop lesser number of days to reach maturity compared to other cropping systems. The other cropping systems had plants that were similar in days to maturity. The significant Y × CS interaction showed that in 2018, plants took more days to reach maturity in weed-free sole crop compared to weed-free intercrop. But in 2019, both systems had plants that did not differ in height. However, in that year, in the presence of weeds, whether intercrop or sole crop, number of days to maturity was higher than in weed-free cropping systems.

Table 6. Plant height, days to flowering and days to maturity of groundnut intercropped with maize in a Rainforest agro-ecology

	Plant height			Days to flowering			Days to maturity		
Cropping system (C)	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean
	(cm)			(no.)					
Weed-free intercrop	54.7a	61.9b	57.9ab	30.7a	36.9a	33.8a	62.9b	57.0b	59.9b
Weed-free sole groundnut	53.9a	69.5a	61.5a	30.0a	34.8a	32.4a	74.0a	56.0b	65.0a
Weedy intercrop	51.4a	48.6c	53.2b	32.3a	37.4a	34.9a	70.8a	64.3a	67.5a
Weedy sole groundnut	53.6a	44.8c	57.7ab	30.5a	36.8a	33.6a	73.8a	60.8ab	67.3a
Mean	53.4a	56.2a		30.9b	36.4a		74.4a	59.5b	
$LSD_{0.05}$ Y	ns†			2.3			3.27		
$LSD_{0.05}$ C	3.98			ns			4.62		
$LSD_{0.05}$ Y × C	5.63			ns			6.54		

Means in the same column with different letters indicate significant difference ($LSD_{0.05}$)

†ns, not significant

4.3.2. Number of pods and 100-seed weight of groundnut

Significant differences were found between years and among cropping systems for number of pods m^2 (Table 7). Number of pods produced was higher in 2019 than in 2018. Weed-free intercrop groundnut and weed-free sole groundnut produced similar number of pods. Similarly, weedy intercrop groundnut and weedy sole groundnut produced similar number of pods. However, the former was higher than the later. There was lack of significant year by cropping system interaction for number of pods.

Seed weight was not influenced by year. However, significant differences were found among cropping systems for 100-seed weight (Table 7). Differences only occurred between weed-free sole groundnut and weedy intercrop groundnut with the former having higher seed weight. The significant Y × CS interaction showed that in 2018, 100-seed weight was similar within weed-free cropping systems as well as within weedy cropping systems. But the weed-free cropping systems had heavier seeds than weedy cropping systems. In 2019, this trend was reversed but the weedy intercrop groundnut had similar seed weight with weed-free intercrop and weed-free sole groundnuts.

Table 7. Number of pods and 100-seed weight of groundnut intercropped with maize

	Number of pods			100-seed weight		
Cropping system (C)	2018	2019	Mean	2018	2019	Mean
		(no./m²)			(g)	
Weed-free intercrop	157.6a	301.5a	229.5a	61.7a	54.1b	57.9ab
Weed-free sole groundnut	187.7a	318.5a	253.0a	67.3a	55.6b	61.5a
Weedy intercrop	30.5a	144.2a	87.3b	48.6b	57.9ab	53.2b
Weedy sole groundnut	20.9a	129.6a	75.2b	49.7b	65.7a	57.7ab
Mean	99.1b	223.4a		56.8a	58.3a	
$LSD_{0.05}$ Y	21.49			ns		
$LSD_{0.05}$ C	30.39			6.2		
$LSD_{0.05}$ Y × C	ns†			8.74		

Means in the same column with different letters indicate significant difference ($LSD_{0.05}$)

†ns, not significant

4.3.3 Pod yield and fodder yield

Year and cropping system influenced pod yield (Table 8). Higher number of pods was produced in 2019 than in 2018. Weed-free intercrop groundnut and weed-free sole groundnut produced similar pod yield. Similarly, weedy intercrop groundnut and weedy sole groundnut produced similar pod yield. However, the former was higher than the later. There was lack of significant year by cropping system interaction for pod yield.

Fodder yield was not influenced by year (Table 8). There were significant differences among cropping systems for fodder yield. The Y × CS interaction was significant. Fodder yield for weed-free intercrop groundnut was higher than for weed-free sole groundnut. Similarly, fodder yield for weedy intercrop groundnut was higher than for weedy sole groundnut. Weed-free and weedy intercrops had similar fodder yield. This trend was similar for weed-free and weedy sole groundnut.

4.3.4 Land equivalent ratio

Partial and total LERs for maize-groundnut intercropping systems in weed-free intercrop and weedy intercrop are given in (Table 9). Values for mLER were all higher than 1 (1.27 and 2.19) but it was lower than 1 (0.94) for gLER in weed-free intercrop and higher than 1 (1.05) in weedy intercrop. Regardless of the cropping system, tLER values were all greater than 1 (2.22) for weed-free and (3.24) for weedy intercrop.

Table 8. Pod and fodder yields of groundnut intercropped with maize

	Pod yield			Fodder yield		
Cropping system (C)	2018	2019	Mean	2018	2019	Mean
			(kg/ha)			
Weed-free intercrop	1491.7a	2897.1a	2194.4a	256.9a	225.5a	241.2a
Weed-free sole groundnut	2031.1a	2619.3a	2325.2a	224.4b	185.3b	204.9bc
Weedy intercrop	409.7a	1490.2a	949.9b	202.4b	241.3a	221.8ab
Weedy sole groundnut	480.0a	1323.5a	901.8b	165.6c	218.8a	192.8c
Mean	1103.1b	2082.5a		212.3	217.7	
$LSD_{0.05}$ Y	318.7			ns		
$LSD_{0.05}$ C	450.6			22.39		
$LSD_{0.05}$ Y × C	ns†			31.66		

Means in the same column with different letters indicate significant difference ($LSD_{0.05}$)
†ns, not significant

Table 9. Partial and total land equivalent ratios of maize and groundnut in maize-groundnut intercrop

Cropping system	mLER[†]	gLER	tLER
Weed-free intercrop	1.27	0.94	2.22
Weedy intercrop	2.19	1.05	3.24

[†]mLER, maize land equivalent ratio; gLER, groundnut land equivalent ratio; tLER, total land equivalent ratio

4.4 Weed suppression

4.4.1 Weed density

Year, cropping system and their interaction influenced weed density of broadleaves (Table 10). Weed density was higher in 2019 compared to 2018. Weed-free cropping systems, whether intercrop or sole, had higher density of broadleaves than weedy cropping systems. Weed-free sole maize had higher weed density compared to weed-free intercrop or weed-free sole groundnut. Weed density was similar in weed-free intercrop and weed-free groundnut. Weed density was comparable among the weedy cropping systems. The Y × CS interaction showed that in 2018, there were no significant differences among all cropping systems. But in 2019, differences occurred among the cropping systems for weed density. Weed density was higher among the weed-free cropping systems than in the weedy cropping systems.

The density of narrow leaf weeds was influenced by year and cropping system (Table 10). Narrow leaf weeds were more in 2018 compared to 2019. Weed-free cropping systems, whether intercrop or sole crop, had higher density of narrow leaves than weedy cropping systems. Weed-free sole maize had higher density of narrow leaves compared to weed-free intercrop or weed-free sole groundnut. Narrow leaf weed density was similar in weed-free intercrop and weed-free groundnut. Similarly, it was comparable among the weedy cropping systems.

Total weed density was influenced by year, cropping system and their interaction (Table 10). In 2018, weed-free cropping systems had similar weed density. Similarly, weedy cropping systems had comparable weed density. However, weed-free sole maize alone had higher weed density than the weedy cropping systems. In 2019, weed-free cropping systems, whether intercrop or sole crop, had higher density of weed density than weedy cropping systems. Weed-free sole maize had higher weed density compared to weed-free intercrop or weed-free sole groundnut.

Weed density was similar in weed-free intercrop and weed-free groundnut. Similarly, it was comparable among the weedy cropping systems.

4.4.2 Weed dry weight

Weed dry weight of broadleaves was not influenced by year (Table 11). It was however, influenced by cropping system. Mean broadleaf weed dry weight did not differ among weed-free cropping systems. Similarly, it did not differ among weedy cropping systems. However, weed-free sole maize permitted broadleaf weed dry weight that differed only from those of weedy sole maize and weedy sole groundnut.

Narrow leaf weed dry weight was influenced by year, cropping system and their interaction (Table 11). Narrow leaf weed dry weight was higher in 2018 compared to 2019. Mean narrow leaf weed dry weight was lower for weed-free cropping systems compared to weedy cropping systems. The significant Y × CS interaction for this trait showed that in 2018, differences did not occur among the weed-free cropping systems. Weedy intercrop and weedy sole groundnut had comparable narrow leaf weed dry weight. But weedy sole maize had higher narrow leaf weed dry weight relative to all other cropping systems. In 2019, narrow leaf weed dry weight did not differ among weed-free cropping systems. Similarly, it did not differ among weedy cropping systems. However, weed-free sole maize permitted narrow leaf weed dry weight that differed from those of weed-free cropping systems.

Year, cropping system and their interaction influenced total weed dry weight (Table 11). Weed dry weight was higher in 2018 compared to 2019. All weed-free cropping systems had comparable weed dry weight. For weedy cropping systems, weedy sole maize had higher weed dry weight than weedy intercrop and weedy sole ground, which were both comparable. The weedy cropping systems had higher weed dry weight than weed-free cropping systems. The significant Y × CS interaction showed that in 2018, weed dry weight was comparable among the weed-free-cropping systems but differed among the weedy cropping systems. In 2019, weed dry weight followed the same trend as in 2018 but weedy sole groundnut had the least dry weight among the weedy cropping systems.

4.4.3 Weed smothering efficiency

Weed smothering efficiency is summarized on Table 12. For broadleaves, weed smothering efficiency was higher in weed-free intercrop compared to weedy intercrop. This trend was also found for narrow leaves. The trend was not different when both broadleaves and narrow leaves were totaled. However, broadleaves were better controlled in both weed-free and weedy intercrops.

Table 10. Weed density in maize-groundnut intercrop at Benin City

Cropping system (C)	Broadleaves			Narrow leaves			Total		
	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean
					(no./m^{2})				
Weed-free intercrop	76a	626b	351b	159a	109a	135b	235ab	735b	485b
Weed-free sole maize	98a	1025a	561a	269a	225a	247a	367a	1249a	808a
Weed-free sole groundnut	84a	429b	257b	147a	99a	123b	231ab	528b	379b
Weedy intercrop	11a	32c	21c	17a	26a	21c	28b	58c	43c
Weedy sole maize	24a	40c	32c	34a	91a	62c	58b	131c	94c
Weedy sole groundnut	11a	35c	23c	9a	31a	20c	20b	67c	43c
Mean	51b	365a		106a	97b		157b	461a	
$LSD_{0.05}$ Y	112			34			123		
$LSD_{0.05}$ C	199			59			212		
$LSD_{0.05}$ Y × C	274			ns†			299		

Means with same letter in a column are not significantly different ($LSD_{0.05}$)
†ns, not significant

Table 11. Weed dry weight in maize-groundnut intercrop at Benin City

Cropping System (C)	Broadleaves			Narrow leaves			Total		
	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean
	(g/ m^2)								
Weed-free intercrop	8.5a	8.5a	8.5b	19.7c	6.0c	12.9c	28.2c	14.6c	21.4c
Weed-free sole maize	22.5a	51.7a	37.1ab	41.1c	22.7bc	31.9c	63.6bc	74.4bc	69.0c
Weed-free sole groundnut	9.00a	19.5a	14.3b	15.6c	5.9c	10.8c	24.7c	25.4c	25.1c
Weedy intercrop	41.4a	43.0a	42.2ab	140.3b	113.6ab	126.9b	181.7b	156.7ab	169.2b
Weedy sole maize	51.3a	105.9a	78.6a	371.3a	129.9a	250.6a	422.7a	235.8a	329.2a
Weedy sole groundnut	128a	45.8a	86.9a	185.7b	52.7abc	119.2b	313.7a	98.4c	206.0b
Mean	43.5a	45.7a		128.9a	55.1b		172.4a	100.9b	
LSDY	ns†			41.43			52.92		
LSDC	52.32			71.76			91.67		
LSD Y × C	ns			101.1			129.6		

Means with same letter in a column are not significantly different ($LSD_{0.05}$)

†ns, not significant

Table 12. Weed smothering efficiency of maize-groundnut intercrop at Benin City

Cropping System	Broad leaves			Narrow leaves			Total		
	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean
					(%)				
Sole maize	-	-	-	-	-	-	-	-	-
Weed-free intercrop	62.2	83.6	72.9	52.1	73.6	62.8	55.7	80.4	68.0
Weedy intercrop	19.3	59.4	39.3	62.2	12.5	37.4	57.0	33.5	45.3

CHAPTER FIVE

DISCUSSION

5.1 Nutrient status of experimental site

The percentage of soil nitrogen is 0.9g/kg which was less than 1.50g/kg. This implied it is below critical level for maize crops performance. This low level of nitrogen in the soils could be as a result water runoff, crop removal, soil erosion, volatilization, leaching and denitrification which characterize rainforest soil (Mbagwu, 1989). The percentage organic carbon that is important in the determining responses to nitrogen and phosphorus fertilization was higher than the critical level of 3%. The percentage of available phosphorus on the experimental site was moderate level for most crops. Therefore, the soils on the experimental site were less in fertility due to low essential plant nutrients. The soils were acidic sand with low level of nutrients which is a typical characteristic of ultisol soils. This agreed with Mbagwu, (1985) who reported that ultisols constistute the agricultural lands of Southern Nigeria and are deficient in essential plant nutrients with high acidic contents. The observation is also in agreement with the findings of (Ezikiel *et al.* 2009), who studied the ultisols of Southern Nigeria are low in exchangeable potassium, calcium and magnesium. The deficient levels of the major nutrients in the soil of study site were compensated for those plots treated with inorganic fertilizers during the two experimental seasons.

The significant year × cropping system interactions for maize plant height, number of cobs, grain yield, and stover yield as well as for groundnut plant height, days to maturity, seed weight and fodder yield suggest that cropping systems differed between the two years in their influence on these variables. And these may be due to seasonal variation in climatic conditions.

Higher plant height, higher number of cobs, higher seed weight, higher grain yield and higher stover yield were recorded for maize plants in weed-free sole maize compared to weedy sole maize. Similarly, higher number of cobs, higher seed weight, higher grain yield and higher stover yield were recorded for maize plants in weed-free intercrops compared to weedy intercrops. It took lesser number of days for maize plants in weed-free intercrop and sole crop to tassel, silk and mature when compared to those that were in weedy intercrop and sole crop. This may be expected because with the regular and timely weed removal in the weed-free systems, competition for nutrient, moisture and light was minimal. This promoted fast and good plant growth and development that resulted in better assimilate production and distribution for greater yielding. This finding agrees with an earlier report (Ijoyah and Dzer, 2012) that removal of weeds in intercropping systems ensures utilization of light and other resources, reduce erosion, suppress weed growth, and thereby help to maintain greater stability in crop yield.

Even though maize plants had similar plant height, similar number of days to tasselling, similar number of days to silking, similar number of days to maturity in both weed-free intercrop and weed-free sole crop, number of cobs and grain yield were higher in weed-free intercrop compared to weed-free sole crop. This may indicate that where weed control is adequate, intercrop yield of maize will be higher than sole maize yield. However, some competition should be expected between maize and groundnut growing together. This should reduce the yield of intercrop maize compared to the yield of sole maize. Instead, the yield of maize was greater, revealing that groundnut must be playing a complementary role rather than having competitive interaction with maize. This trend was observed as well for weedy intercrop versus weedy sole crop.

The lower plant height recorded in weedy intercrop groundnut relative to weed-free groundnut was due to the presence of weeds that competed for the limited environmental resources. Groundnut took shorter time to mature in weed-free intercrop relative to weed-free sole groundnut, weedy intercrop and weedy sole groundnut. This may be due to the competitive advantage of maize in the weed-free intercrop and presence of weeds in the weedy intercrop and sole crop. Number of pods, pod yield and fodder yield were higher in both weed-free intercrop and sole groundnut compared to weedy intercrop and sole groundnut. This was due to the little or no competition for nutrients, moisture and light that took place in the former. These findings show that weeds are adverse to crop growth, pod production, seed weight and fodder yield. According to Caballeru *et al.* (1995) and Assefa and Ledin (2001) weed removal in maize and groundnut intercrop resulted in lesser competition for resources such as nutrients, water and light.

Land equivalent ratio in maize was superior and more competitive than in groundnut in both weed-free and weedy intercrops, meaning that maize was the main component influencing productivity in the intercrops. This may be so because it was the dominant crop with groundnut as the understory crop in the intercrop. Total land equivalent ratios for maize in weed-free and weedy intercrop were greater than 1 (2.22 and 3.24, respectively). This implied that it would take 22% and 24% more land if the component crop were planted sole to obtain the same yield as obtained in the intercrop. Thus, land was more efficiently utilized in maize-groundnut intercrop compared to the sole crop. This agreed with Omovbude *et al.* (2017) who reported that land equivalent ratio generally above one indicating that the crops perform better in intercrop than in sole crop. Ullah *et al.* (2007) reported that LER of greater than one recorded in intercropping patterns shows that resource consumption or land, utilization efficiency for intercropping pattern was more advantageous than sole cropping. Ijoyah and Dzer (2012) reported that intercropping ensures efficient utilization of light and other resources thereby reducing soil erosion, suppressing weed growth for maintaining greater stability in crop yield in okro/cowpea intercropping system. It also guarantees greater land occupancy and thereby higher net returns (Susan and Mini, 2005).

Weed density, whether broadleaves, narrow leaves or total, were lower in weedy intercrop and their sole crops compared to weed-free intercrop and their sole crops because in the former weeds were allowed to grow throughout the period of production whereas in the later weeds were removed at given intervals (three times in all), making it possible for more weeds to emerge following each removal. Weed-free sole maize had higher weed density for broadleaves, narrow leaves and their total compared to weed-free intercrop and weed-free sole groundnut because it had lower canopy cover. Whereas groundnut was more able to suppress weeds because of its creeping nature, thus serving as a cover crop, the combined canopies of maize and groundnut in the intercrop enabled greater canopy for ground cover and weed suppression. Weed dry weight was higher in weedy intercrop and their sole crops compared to weed-free intercrop and their sole crops because in the former weeds were allowed to grow, accumulating dry matter continuously throughout the period of production whereas in the later, weeds were removed at given intervals, creating a lag in time, and therefore, a reduction in dry weight. More so, weedy sole maize had higher weed dry weight compared to weedy intercrop and weedy sole groundnut because it had lower canopy cover which permitted higher light penetration that favoured higher dry matter accumulation by the understory weeds. These findings corroborate the reports given by McGill-Christ and Trenbath (1984) who reported that sole cropping encourages weed growth and development due to sparsely formed canopy and Udensi *et al.* (2017) that attributed the higher weed densities and dry weight in sole maize to sparse canopy which encouraged weed growth and development.

Weed smothering efficiencies, for broadleaves, narrow leaves and their total were higher in weed-free intercrop compared to weedy intercrop, indicating that manual weeding, three times during the production period, was more efficient in controlling weeds than relying on an intercrop. That broadleaves were better controlled in both weed-free and weedy intercrops than narrow leaves may be due to the fact that the narrow leaves, mainly Panicum maximum, are aggressive and perennial weed and very difficult to control. This agreed with Mangara *et al.* (2008) who reported that among the predominant weeds, *Panicum maximum* has been described as a highly successful invader in the tropics. It is very competetitive, highly resistant to fire and quickly invades gaps left in natural vegetation after fire. Also, Duke (1983) stated that *Panicum maximum* grow well on a wide variety of a well drain soils and its suited to areas of 870 mm to 1000 mm of rainfall which support crop yields.

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

This study highlights weed suppression in maize-groundnut intercropping systems at Benin City in a Rainforest Agro-ecology. The field experiment was conducted during the rainy seasons of 2018 and 2019 at the experimental site of the Faculty of Agriculture, University of Benin, Nigeria. The experiment was laid out in a Randomized Complete Block Design (RCBD) and replicated three times. The experiment consisted of six treatments (weed-free intercrop, weed-free sole maize, weed-free sole groundnut, weedy intercrop, weedy sole maize and weedy sole groundnut. The attributes measured were plant height, days to flowering, days to ear and pod maturity, cob and pod yields, seed weight, grain yield, stover yield and land equivalent ratio, weed density per m^2, weed dry weight per m^2, and weed smothering efficiency. Data obtained for the two-year trial were subjected to analysis of variance (ANOVA) using the PROC ANOVA procedure of SAS.

For maize, the study showed that year influenced all the traits except number of cobs. Cropping system influenced all the traits studied. Year × cropping system interaction was found for plant height, number of cobs, grain yield and stover yield. This means that in a year, cropping system influenced maize performance differently.

For groundnut, year influenced days to flowering, days to maturity, number of pods and pod yield but did not affect plant height, 100-seed weight and fodder yield. Cropping systems influenced plant height, days to maturity, number of pods, 100-seed weight, pod yield and fodder yield but not days to flowering. Year × cropping system interaction was significant for plant height, days to maturity, 100-seed weight and fodder yield. It was however, not significant for days to flowering, number of pods and pod yield. The lack of significant year × cropping system interaction means that influence of cropping system on these traits did not depend on year. Average pod yield was similar for weed-free intercrop groundnut and weed-free sole groundnut. Similarly, weedy intercrop groundnut and weedy sole groundnut produced similar pod yield. However, the former was higher than the later. Total and partial land equivalent ratios were generally above one in both weed-free and weedy intercrop showing that it was more advantageous growing maize and groundnut together instead of the respective crops alone.

For weed suppression, year influenced weed density of broadleaves, narrow leaves and the total of both. Cropping system also influenced these traits. The interaction between year and cropping system was significant for broadleaves and total except narrow leaves. weed-free intercrop suppressed weeds relative to weed-free sole maize cropping system. Weed biomass of narrowleaves and the total of broadleaves were influenced by year with the exception of Broadleaves. Cropping system influenced the weed density and biomass of broadleaves, narrow leaves and the total of both. Significant year × cropping system interaction for weed density was found in broadleaves and total except narrowleaves. Also, for weed biomass significant year × cropping system interaction occur narrowleaves and total except broadleaves. Weed-free sole maize and weedy sole maize had more weeds, whether broadleaves, narrowleaves or both than weed-free intercrop and weed-free groundnut as well as weedy intercrop and weedy sole groundnut. Weed biomass in weedy sole maize and groundnut were higher relatively to weed-free sole. Weed smothering efficiency for broadleaves and narrowleaves was higher in weed-free intercrop. Both weed-free and weedy intercrops, broadleaves were better controlled.

6.2 Conclusion

The study showed that weed-free intercrop suppressed weeds relative to weed-free sole maize cropping system. Maize plant grew taller in weed-free cropping systems. Number of cobs and 1000-seed weight including grain yield significantly increased under weed-free intercrop. Weedy intercrop maize had the least stover yield. Groundnut grew taller under weed-free cropping systems. Number of pods, 100-seed weight and grain yield were higher in weed-free intercrop. Land equivalent ratios were generally above one showing that it was more advantageous growing maize and groundnut together instead of the respective crops alone. Weed density of broad leaves, narrow leaves and their total were all higher in weed-free cropping systems. However, weedy sole cropping systems produced the highest weed dry weight which was lesser in weed-free intercrop. Weed smothering efficiency for broadleaves and narrowleaves were higher in weed-free intercrop. Broadleaves were better controlled in both weed-free and weedy intercrops.

6.3 Recommendations

Greater weed suppression was achieved in maize-groundnut intercrop relative to growing each crop alone. Based on the results obtained from the two-year study, it may be recommended that:

1. Maize farmers at Benin City in a Rainforest agro-ecology should be encouraged to intercrop maize with groundnut for better weed suppression.
2. Maize and groundnut should be planted together in intercrop, since they have better yield advantage as showed by LER. .
3. Farmers should be encouraged to adopt maize-groundnut intercrop as a means of reducing weed population and dry weight that could lower yield
4. For weeds to be properly smothered, farmers should adopt maize-groundnut intercropping systems due to its low input technology.

REFERENCES

Abe, M.O. (2006). Effect of cover cropping on weed population density and moisture conservation in a rice field in South Western Nigeria. *Crop Science and Land management,* 16: 58-586.

Abera, T., Feyissa, D. and Yusuf, H. (2005). "Effects of inorganic and organic fertilizers on grain yield of maize-climbing bean intercropping and soil fertility in Western Oromiya, Ethiopia," In *Proceedings of Conference on International Agricultural Research for Development*, October 11-13.

Atilola, N.C.P. (2007). Effect of intercroplant groundnut with maize on soil organic carbon and yield of groundnut. *Soil Fertility Research*, 16: 81-86.

Addo-Quaye, A.A., Darkwa, A.A. and Ochoo, G.K. (2011). Growth analysis of compound crops in a maize-soybean intercropping system as affected by time of planting and spatial arrangement. *ARPN Journal of Agricultural and biologkical Science,* 6: 34-44.

Adebomi, O.O. (2008). Effect of intercropped groundnut *(Arachis hypogaea L.)* densities on the performance of weed control treatments in maize *(Zea mays L.)* production B.S.c. Project, Nigeria pp 25-30.

Addo-Quaye, A.A., Darkwa, A.A. and Ochoo, G.K. (2011). Growth analysis of compound crops in a maize-soybean intercropping system as affected by time of planting and spatial arrangement. *ARPN Journal of Agricultural and biological Science* 6: 34-44.

Adesoji, A.G., Abubakar, I.U., Tanimu, B. and Labe, D.A. (2013). Influence of incorporated short duration legume follow and nitrogen on maize *(Zea mays L.)* growth and development in northern guinea savannah of Nigeria. *American-Euroasian Journal of Agriculture and Environmental Science,* 13: 58-67.

Adhikary, S. and Sarkar, B.K. (2000). Pigeonpea *(Cajanus cajan)* intercropping with legumes in Bihar Plateau at different levels of phosphate and cropping patterns. *Indian Journal of Agronomy,* 45: 279-831.

Adhikary, S., Bagchi, D.K., Ghosal, P., Banerjee, R.N. and Chatterjee, B. N. (1991). Studies on maize-legume intercropping and their residual effects on soil fertility status and succeeding crop in upland situation. *Journal of Agronomy of Crop Science,* 167: 289-931.

Adhikary, S., Chakraborty, T. and Bagchi, D.K. (2005). Bio-economic evaluation of maize *(Zeamays)* and groundnut *(Arachis hypogea)* intercropping in drought-prone areas of chotonagpur plateau region of Jharkhand, *Indian Journal of agronomy,* 50:113-15

Ado, S.G. (2007). Weed management need in Nigeria in the context of the millennium development goals. *Nigerian Journal of Weed Science* 20: 67-72.

Adigun, J.A and Lagoke, S.T.O. (2003). Weed management with various herbicide combinations in maize-groundnut intercrop. *Nigerian Journal of Crop Protection,* 20: 12-23.

Agahiu, A.E, Udensi, U.E, Tarawali, G. Okoye, B.C, Ogbuji, R.O. and Baiyeri, K.P. (2011). Assessment of weed management strategies and intercrop combinations on cassava yield in the middle belt of Nigeria, *African Journal of Agricultural Research*, 6: 5729- 5735.

Agengnehu, G., Ghizaw A. and Sinebo W. (2008). Yield potential and land-use efficiency of wheat and faba bean mixed intercropping. *Agronomy for Sustainable Development,* 28: 257-263.

Agengnehu, G., Ghizaw, A. and Sinebo, W. (2006a). Yield performance and land use efficiency of barley and faba bean mixed cropping in Ethiopian highlands. *European Journal of Agronomy,* 25: 202-207.

Ajeigbe, H.A., Waliyar, F., Echekwu, C.A., Ayuba, K., Motagi, B.N., Eniayeju, D. and Inuwa, A. (2014). A Farmer's Guide to Groundnut Production in Nigeria. ICRISAT, Kano.

Akobundu, I. O. (1996). Principle and prospects for integrated weed management in developing countries. *Proceeding of 2nd International Weed Control Congress,* 11: 1591- 1600.

Akobundu, I.O. and Ekeleme, F. (2001). Effects methods of *Imperata cylindrical* management on maize grain yield in the derived savanna of southwestern Nigeria. *Weed Research,* 40: 335-341.

Akter, N., Alim, A.,Islam, M.M., Naher, Z., Rahman, M. and Iqbal Hossein, A.S.M. (2004).Evaluation of mixed and intercropping of lentil and wheat. *Journal of Agronomy,* 3:48-51.

Alabi, J.Y.M. (1997). Junior Agriculture- An Introduction to Agricultural Science, Africana Educational Publishers, Onisha, pp.10.

Amanullah, Faisal;K; Haji, M., Abbas, U.J. and Ghaffar, A. (2016). Land equivalent Ration, Growth yield and yield components Response of Mono-cropped Vs. inter-cropped common Bean and Maize with and without compost Application. *Agriculture and Biological Journal of North America,* 7:40-49.

Amanullah, M., Vaiyapuri. and Alagesan, A. (2006). Effect of intercropping and organic manures on the yield and biological efficiency of cassava intercropping system *(Manihot esculenta Crantz.). Resource Journal of Agricultural Biological Science,* 2: 201-208.

Ashish, K. and Yadav, R.S. (2013). Effect of intercropping systems on intercrops and weeds. *International Journal of Agriculture and Food Science Technology,* 4: 643-646.

Awodoying, R.O. and Ogunyemi, S. (2005). Use of sicklepod, *Senna obtusifolia (L.)* Irwin and barneby, as mulch interplant in cayenne pepper, *(Capsicum frutescens L.) production. Emirate Journal of Agricultural Science,* 17: 10-22.

Ayeni, A.O. (2000). Hand/Mecchanical Weed Management as an Option in Nigerian Agriculture, *Nigeria Journal of Weed Science,* 4: 71-77.

Ayisi, k.k., Putman, D.H., Vance C.P., Russela, M. and Allan, D.L. (1997). Strip cropping and nitrogen effects on seed, oil and protein yields of canola and soybean. *Agronomy Journal,* 89: 23-29.

Assefa, G and Ledin, l. (2001). Effect of variety soil type and fertilizer on the establishment, growth, forage yield, quality and voluntary intake by cattle of oats vetches cultivated in pure stands and mixtures. *Animal Feed Science and Technology*, 92: 95-111.

Badmus, A.A. (2005). Effect of groundnut *(Arachis hypogea L.)* intercrop on weed control in maize *(Zea mays L.)* production MSc. Thesis, University of Agriculture, Abeokuta, Nigeria, 90-101.

Banik, P, Midya, A. Sarkar, B.K. and Chose, S.S. (2006).Wheat and chick pea intercropping systems in an additive experiment. Advantages and weed smothering. *European Journal of Agronomy,* 24: 325-332.

Baumann, D.T., Bastiaans, L. and Kroff, M.J. (2001). Performance in a Leek- Celery. Intercropping system.Crop Science Society of America. *Competition and Crop Science,* 41: 764-774.

Bedry, K.A. (2007). Effect of weeding regimes on Fababean (*Vicia faba L.*) yield in the Northern State of Sudan. *University of Khartoum Journal Agricultural Science,* 15: 220-231.

Beets, W.C. (1990). Raising and sustaining productivity of small l holder systems in the tropics: A handbook of sustainable Agricultural development. Alkamaar, Netherlands: Agbe publishing.

Bilalis, D., Papastylianou, P., Konstants, A., Patsiali, S., Karkanis, A. and Efthimiadou, A. (2010). Weed suppressive effects of maize-legume intercropping in organic farming. *International Journal of Pest Management,* 56: 173-181.

Caballeru, R. Goicoechea, E.L. and Hernaize, P.J. (1995). Forage yield and quality of common Vetch and oat sown at varying seedling ratios and seedling rates of common vetch. *Field Crops Resources,* 41: 135-140.

Carr, P.M, Gardner J.C, Schartz B.J., Zulinger S.W. and Gulden J. (1995). Grain yield and biomass of a wheat + lentil intercrop. *Agronomy Journal,* 87: 547-579.

Celette, F., Wery, J., Chantelot, E., Celette, J. and Gary, C. (2005). Belowground interactions in a vine *(Vitis vinifera L.)*-tall fescue *(Festuca arundinacea Shreb.)* intercropping system: water relatios and growth, *Plant Soil* 276: 205-217.

Climate-Data.org. (2018). Climate: Benin City. Available from URL: http://en.climate-data.org/location/764230/. Accessed Nov. 18, 2016.

Chauhan, B.S. (2012). Weed ecology and weed management strategies for dry-seeded rice in Asia. *Weed Technology,* 26: 1-13.

Chemeda, (1996). Effect of bean and maize intercropping on bean common bacteria blight and rust diseases. *International Journal of Pest Management,* 42: 51-54.

Chen, C., Westcott, M., Neill, K., Wichman, D. and Knox, M. (2004). Row configuration and nitrogen application for barley-pea intercropping in Montana. *Agronomy Journal,* 96: 1730-1738.

Chianu, J.N. and Akintola, J.O. (2003). Labour needs for weeding: Implications for the adoption of improved follow management systems in the derived savannas of southwestern Nigeria. *Nigerian Journal of Weed Science,* 16: 1-7.

Chikoye, D, Manyong, V.M. and Ekeleme, F. (2006). Characteristics of speargrass *(Imperatacylindrica)* dominated fields in West Africa: crops soil properties, farmer's perceptions and management strategies. *Crop Protection,* 19: 481- 487.

Chikoye, D, Manyong, V.M, Carsky, R.J, Ekeleme. F, Gbehounou, G. and Ahanchede, A. (2002). Response of speargrass *(Imperata cylindrica)* to cover crops integrated with hand weeding and chemical in maize and cassava. *Crop production,* 21: 145- 156.

Chipomho, J., Mapope, N., Masuka, B., Ngezimana, W. and Chipomho, C. (2015). The influence of cropping systems and maize-bean intercrop spatial patterns on companion crop yield, weed density and biomass.*International Journal of Agriculture and Crop Science Available online at www.ijagcs.com.issn*, 227 -670.

Chui, T., Kuhumbwa, T. and Kusewa, T.M. (I997). Farm weed control using cultural, physical and chemical methods. Proceedings of an International Conference held at Brighton Centre and the Stakis Brighton, November 17-20. International *Maize and Wheat Improvement Centre Mexico City,* 67- 70.

Dado, R.G. (1999). Nutritional benefit of specialty Maize grain Hybrid in Dairy diets. *Journal of Animal Science,*197-207.

Dahmardeh, M., Ghanbari, A., Syahsoar, B.A. and Ramrodi, M. (2010).The role of intercropping maize *(Zea mays L.)* and Cowpea *(Vigna unguiculata L.)* on yield and soil chemical properties. *African Journal of Agricultural Resources,* 5: 631-636.

Dariush, M., Ahad, M. and Meysam, O. (2006). Assessing the land equipment ration (LER) of two MAIZE *(Zea mays L.)* varieties intercropping at various nitrogen levels in karaj, 7:359-64.

Davis, J.H.C., Woolley, J.N. (1993). Genotypic requirement for intercropping. *Field Crops Resources,* 34: 407-430.

Dozier, H, Gaffney J. F., Mcdonald S.K, Johnson E.R. and Shilling, D.G. (1998). Congo grass in the United States: history, ecology, impacts and management, *Weed Technology,* 12: 737-743.

Duke J.A. (1983). Handbook of energy crops.(unbublished) cited by Purdue University. Retrievedfromhttp;//www.hort.purdue.edu/newcrop/dukeenergy/Panicum maximum.html Acce.

Ekpo, T. U.U., Udosen, U.U. and Udom, G.N. (2010). Performance of maize as influenced by different weed management options in the rainforest zone of Nigeria. *Nigerian Journal of Agriculture, Food and Environment,* 6 (1&2):1- 5.

El Naim, A.M., El day, E.M. and Ahmed, A.A. (2010). Effect of plant density on the performance of some Sesame *(Sesamum indicum L)* cultivars under Rainfed. *Research Journal of Agricultural and Biological Science,* 6: 498-504.

Eskandari, H. and Ghanbari, A. (2010). Effect of different planting pattern of wheat *(Tricticum aestivum)* and bean *(Visia faba)* on grain yield dry matter production and weed biomass. *Notulae Scientia Biogicae,* 2: 111-115.

Eskandari, H. (2011). Intercropping of wheat *(Triticum aestivum)* and bean *(Vicia faba*): Effects of complementarity and competition of intercrop components in resource consumption on dry matter production and weed growth. *African Journal of Biotechnology,* 10: 17755-17762.

Eskandari, H. and Kazemi, K. (2011). Weed control in maize-cowpea intercropping system related to environmental resources consumption. *Notulae Scientia Biologicae,* 3: 57- 60.

Ezekiel, P.O., Ojeniyi, S.O., Asawanam, D.O. and Ano, A.O. (2009). Effect of oil palm bunch ash and soil NPK and root yield of sweet and bitter cassava. *Nigeria Journal of soil science,* 19: 1-10.

Fatokun, C. A., Tarawali, S.S., Singh, B.B, Korimawa, P.M. and Tamo, M. (2002). Challenges and opportunities for enhancing sustainable cowpea production. Proceeding of the world cowpea conference 111 held at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, 4- 8 September, 2000, IITA, Ibadan, pp 214- 220.

Fininsa, C. (1997). Effect of planting pattern, relative planting data and intra-row spacing on aharicot bean/maize intercrop. *African Crop Science Journal,* 5: 15-22.

Fujita, K., Ofosu-Budu, K.G. and Ogata, S. (1992). Biological nitrogen fixation in mixed legume-cereal cropping systems. *Plant Soil,* 141: 155-175.

George, O. and Jeruto, P. (2010). Sustainable horticultural crop production through intercropping: The case of fruits and vegetable crops: A review. *Agriculture and Biological Journal of North America,* ISSN print: 2151-7517, ISSN Online: 2151-7525.

Getachew, A., Ghizaw, A. and Sinebo, W. (2006). Yield performance and Land use efficiency of barley and faba bean mixed cropping in Ethiopian highlands. *European journal of Agronomy,* 25: 202-207.

Giwa, M .B. (2007). Effect of groundnut *(Arachis hypogaea L.)* intercrop on weed control in maize *(Zea mays L.)* production. BSc. Project University of Agriculture, Abeokuta, Nigeria, 22- 30.

Harker, K. N., O. and' Donovan, J. T. (2013). Recent weed control. *Weed Technology*, 1- 11. http://doi.or/10.164/WT-D-12-00109.1.

Hauggaard-Nielsen, H., Ambus, P. and Jensen, E.S. (2001). Interspecific competition, N use and interference with weeds in pea- barley intercropping. *Field Crops Research,* 70: 101-109.

Hauggard-Nielsen, H., Gooding, M. and Ambus, P. (2009). Pea-barley intercropping for efficient symbiotic N2-Fixation, soil N acquisition and use of other nutrients in European organic cropping systems // *Field Crop Research*, 113: 67-71.

Henrik, H., Neisen J. and Bjame Steen, J.E. (2003). Legume-cereal intercropping as a weed management tool 4th E. W. R. S workshop. Crop/ weed competitive interaction. Universita Tuscia Viterbo Italy. 10- 12 April.

Hugar, H.Y. and Palled, Y.B. (2008). Effect of intercropping vegetables on maize and associated weeds in vegetable intercropping systems. *Karnataka Journalof Agricultural Science,* 21: 159-161.

Hart, R.D. (1975). A bean, maize, monioc polyculture cropping systems 11. Comparison between yields and economic returns from monoculture and polyculture cropping systems.Turrialba 25: 27280.Ibeawuchi, I.K. (2007). Intercropping a food production strategy for resource poor farmers, *Nature and Science,* 5: 46-49.

Ijoyah, M.O. and Usman, U. A. (2013). Okkra: A potential Intercrop for farmers in Nigeria. *Journal of Global Biosciences,* 2: 222-235.

Ijoyah, M.O. and Dzer, D.M. (2012). Yield performance of okra *(Abelmoschus esculentus L. Moench)* and maize *(Zea mays L.)* as affected by time of planting of maize in Makurdi, Nigeria. *International Scholas Research Network.*

Ijoyah, M.O., Adagba, E.O. and Lorlamen, T. (2012). Productivity of okra-maize intercropping system as influenced by varying maize plant densities in Makurdi, Nigeria. *International Journal of Current Research,* 4: 59-63.

International Institute of Tropical Agriculture (IITA). (2007).Cassava in tropical Africa. *A reference manual*, pp 176.

Iqbal, J., Cheema, Z.A. and An, M. (2007). Intercropping of field crops in cotton for management of purple nutsedge (*Cyperus rotundus* L.). *Plant Soil,* 300: 163-171.

Joshi, K. R. (2004). Effect of time of weeding and levels of N and P2O5 Fertilizer on the grain yield of maize. *Nepal journal of Agricultural Research,* 5: 69-70.

Katsaruware, R.D. and Manyanhaire, I.O. (2009). Maize cowpea intercropping and weed suppression in leaf stripped detasselled in Zimbabwe. Electronic Journal of Environmental Agricultural and Food Chemistry. 8: 1218-1226.

Koucheki, A., Nassiri Mahallati, M., Mondani, F., Feizi, H., and Amirmoradi, S. (2009). Evaluation of radiation interception and use by maize and bean intercropping canopy. *Journal of agroecology,* 1:13-23.

Kruidholf, H.M., Bastiaans, L. and Kropff, M.J. (2008). Ecological weed management by cover cropping: Effects of weed growth in autumn and weed establishment in spring. *Weed Resources,* 48: 492-502.

Khan, Z., Saeed, A., Zada, K. and Ahmad, S. (1992). Biological and studies on yield and nitrogen fixation of soyabean and maize. *Sarhad Journal of Agriculture* 8: 613-622.

Launay, M, Brisson, N., Satger, S., Hauggaard-Nielsen, H., Corre-Hellou, G., Kasynova E, Ruske, R., Jensen, E.S. and Gooding, M.J. (2009). Exploring options of managing strategies for pea-barley intercropping using a moldeling approach. *European Journal of Agronomy,* 31: 85-98.

Lavabre, E.M. (1991). Weed control (The Tropical Agriculturalist Macmillian/ CTA) London, pp 1-40.

Liebman, M. and Elizabeth, D. (1993). Crop rotation and intercropping strategies for weed management. *Journal of Applied Ecology,* 3: 92-122.

Liebman, M. and Dyck, E. (1993). Crop ration and intercropping strategies for weed management. *Ecological Application*, 3: 92-122.

Lithourgidis, A.S., Alachostergios, D.N., Dordas, C.A., Damalas, C.A. (2011).Dry matter yield, nitrogen content, and competition in pea-cereal intercropping systems.European. *Journal of Agronomy,* 34: 287-294.

Lithourgidis, A.S., Vasilakoglou, I.B., Dhima, K.V., Dordas, C.A. and Yiakaoulaki, M.D. (2006). Forage yield and quality of common vetch mixtures with oat and triticale in two seeding ratios. *Field Crop Resources,* 99: 106-113.

Lucas, E.O. (1990). Transfer of Agricultural innovation result. Demonstration of optimum plant population for maize at farm level in Oyo State, Nigeria, proceedings of a conference by the Agricultural and development, Department of the National Productivity Centre at ASCON, Topo, Badagry, 25-33.

Maerer, S.B., Lingaraju B.S. and Shashidhara G.B. (2007). Productivity and economics of maize and pigeon pea intercropping under rainfed condition in northern transitional zone of karnataka. *Karnataka Journal of Agricultural Science,* 20: 1-3.

Maereka, E. K., Madakadze, R.M. and Nyakanda, C. (2009). Productivity and weed suppression in maize- pumpkin intercrops in small scale farming communities of Zimbabwe. *Africa Journal of Crop Science,* 9: 93- 102.

Magani, I.E. (1990). Effects of period of weed interference and season long weed control on maize *(Zea mays L.)* M.S.c. Thesis, Department of Agronomy, Ahmadu Bello University, Zaria, Nigeria 73-80.

Makinde, E.A., Ayoola, O.T. and Makindea, E.A. (2009). Intercropping leafy greens and maize on weed infestation, crop development and yield. *International Journal of Vegetable Science,* 15: 402-411.

Mangara A., N daadopo A. A., Boraud M. K., Kobenan K., Lejoly J. and Traore D. (2008). Inventaire de la flore adventice en culture d ananas (Ananascomosus) Dasns la ocalite de bonoua en basse Cote d Ivoire. *Agronomie Africaine,* 20 (1): 23-35.

Mangasini, A.k., Mwanahawa, L.M., Arbogast, G.M. and Neema, P.K. (2012). Agronomic factors limiting groundnut production: A case of smallholder farming in Taboraregion. 17th Annual Research Workshop Dares Salaam, Tanzania; March 28-29, 2012.

Mashingaidze, A.B., Nyankanda, C., Chivinge, O.A., Mwashairen, A. and Dube, K.Y. (2004). Influence of pumpkin live mulch on weed dynamics and Maize African Crop Protection 6: 57-63.

Mead, R. and Willey R.W. (1980).The concept of LER and advantages in yield from intercropping. Experimental Agriculture 16: 217-228.

Mbagwu, J.S.C. (1989). Subsoil productivity of an Utisols in Nigeria as affected by Organic Wastes and Inorganic Fertilizer Amendment. *Soil Science,* 140: 446-1441.

Mbagwu, J.S.C. (1985). The agricultural soils of Nigeria: Properties and agronomic significance for increased productivity. *Beitr Trop Landwirtsch Veterinarmed* 27: 395-409.

McCann, J.C. (2007). Maize and Grace. Africa's Encounter with a New World Crop 1500-2000. Harvard University Press, Cambridge, Massachusetts, pp. 287.

Midega, C.A.O, Khan, Z.R., Amudavi, D.M., Pittchar, J. and Pickett, J.A. (2010). Integrated management of Striga hermonthica and cereal stem borers in finger millet *[Eleusine coracana(L.) Gaertn.]*through intercropping with *Desmodium intortum*. *International Journal of Pest Management,* 56: 145-151.

Midya, A., Bhattacharjee, K., Ghose, S.S. and Banik, P. (2005). Defferred seeding of blackgram *(Phaseolus mungo L.)* in rice *(Oriza sativa L.)* field on yield advantages and smothering of weeds. *Journal Aronomy of Crop Science,* 191: 195-201.

Mohammed, M.A., Variyapuri, K., Alagesan, A., Somasundaram, E., Sathyamoorths, K. and Pazhanivelan, S. (2006). Effect of intercropping and organic manures on yield and biological efficiency of cassava intercropping system *(Manihot esculenta, Crantz). Research Journal of Agriculture and Biological Sciences,* 2: 201- 208.

Mucheru-Muna, M., Pypers, P., Mugendi, J., Kurgu, J., Mugwe, J., Merckx, R. and Vanlauwe, B. (2010). A staggared maize-legume intercrop arrangement robustly increases crop yields and economic returns in the highlands of central Kenya. *Field Crops Resources,* 115: 132-139.

Musa, M., Singh, A., Abubakar, L., Noma, S.S., Alhassan, J. and Haliru, B.S. (2012). Influence of cultivar and sokoto phosphate rock levels on the yield and yield components of groundnuts (Arachis hypogea L.) in dry sub-humid sokoto area, Nigeria. *Nigerian Journal of Basic and Applied Science,* 20: 49-54.

Musambasi, D., Chivinge, O.A. and Mariga, I.K. (2002).“Intercropping maize with grain legumes for striga control in Zimbabwe.” *Africa Crop Science Journal,* 10: 163-171.

McGill- Christ, C.A. and Trenbath B.R (1984). Revised Analysis of plant Competition Experiments. Biometrics 27: 659-671.

Ndjeunga, J. and Ibro, A. (2010) Groundnut Trends and Prospects in West and Central Africa. A Report of International Crops Research Institute for the Semi-Arid Tropics, (ICRISAT). Unpublished Paper.

Njoku, D. and Muoneke, C.O. (2008). Effect of cowpea planting density on growth, yiel d and productivity of component crops in cowpea/cassava intercropping system. *Agro-Science Journal of Tropical Agriculture, food, Environment and Extension,* 7: 106-113.

Nielson, Haugaard, H., Jornsgaard, B. and Steen, J.E. (2003). Legumes-cereal intercropping system as a weed management tool. In: Proceedings of the 4th European Weed Resources Society Workshop: crop weed competition interaction. University Trusca, Viterbro, Italy, 10-12th April.

Nwankwo, C.N. (2010). Evaluation of acquifer characteristics ground water quantity using geoelectrical method in choba, Port Harcourt. *Journals of Scholar Research Library,* 2, 396- 43.

Nyam, T. (2005). Opening address: In Chikoye, D., Ellis-Jones, J., Lum, A.F., Tarawali, G. and Avav, T. (editors): Reducing poverty through improved *Imperata* control. Proceeding of the second Imperata management stakeholders’ conference, held in Makurdi, Benue State, Nigeria, 14-15 September 2004, IITA, Ibadan, Nigeria pp119.

Odedina, J.N., Fabunmi, T.O., Adigbo, S.O., Odedina, S.A. and Kolawole, R.O. (2014). Evaluation of cowpea varieties *(Vigna unguiculata L. Walp)* for intercropping with okra *(Abelmoschus esculenta, L. Moench). American Journal of Research Communication,* 2 (2): agrc.journa@gnail.com.

Odhiambo, G.D., and Ariga E.S. (2001). Effect of intercropping maize and beans on striga incidence and grain yield.Proceedings of the Eastern/Southern Africa Regional Maize Conference 7: 183-186.

Ofosu-Amin J. and Limbani N.V. (2007). Effect of intercropping on the growth and yield of cucumber *(Cucumis sativus L.)* and okra *(Abelmoschus esculentus L.)* Moench. *International Journal of Journal of Agriculture and Biology,* 9: 594- 597.

Olatunji, A.S., Abimbola, A.F. and Asowata, I.T. (2014). Geochemical Evaluation of Soils and Road Deposited Sediments of Benin City. Using GIS and Multi-variance Approachs. *British Jounal of Applied Science and Technology*, 4 (18); 2590-2606.

Olorunmaiye, P.M. (2010). Weed control potential of five legume cover crops in maize/cassava intercrop in a southern guinea savanna ecosystem of Nigeria. *Australian Journal of Crop Science,* 4: 324-329.

Olufemi, O.R., Pitan and Odebiyi, J.A. (2001).The effect of intercropping with maize on the level of infestation and damage by pod-sucking bugs in cowpea. *Journal of Crop Protection, 20*: 367-372.

Omovbude, S., Udensi, U.E., Orluchkwui, J.A. and Amadi, J .(2017). Effect of intercropping on weed suppression and maize *(Zea mays L.)*yield in a humid forest agro-ecology of South-Eastern, Nigeria. *Journal of Agriculture and Verterinary Science, 11 September* 2017, pp 40-46.

Orluchukwul, J.A. and Udensi, U.E. (2013). The effect of intercropping pattern of okra, maize, pepper on weeds infestation and okra yield. *African Journal of Agricultural Research,* 8: 986-902.

Poggio, S.L. (2005). Structure of weed communities occurring in monoculture and intercropping of field pea and barley. *Agriculture, Ecosytems and Environment,* 109: 48-58.

Poodineh, O., Keighobadi, M., Dehghan, S. and Raoofi, M.M. (2014). Evaluation of intercropping system on weed management, forage quality, available of nitrogen and resource use. *International Journal of Agriculture and Crop Sciences,* 7: 1298-1303.

Rahimy, M.M., Mazaheri, D., Khodabandeh, N. and Heidari, H. (2003). Assessment of product in MAIZE and soybean intercropping in Arsanjan region. *Agricultural Science,* 9: 109-126. (In Persian).

Remison, S. U. (2005). Arable and Vegetable Crop of the Tropics, (Gift Print Associates City).

Ronald, M., Peter, J., Charles, K. and Tibugari, H. (2011). Integrated weed management in Zimbabwe's smallholder sector, where are we?: a review. *Modern Applied Science*, pp. 111- 117.

Saad, I., Sbai, H. and Haouala Rabiaa. (2016). Weed dynamic and communities, structure under different planting pattern and planting dates of cauliflower-lettuce intercropping system. *International Journal of Innovative Science, Engineering and Technology,* 3 issue 3, march 2016.

Sagar M., Tanmoy Shankar and Pradipta Banerjee (2020). Potential and Advantages of Maize-Legume Intercropping System, Maize - Production and Use, Akbar Hossain, IntechOpen, DOI: 10.5772/intechopen.91722. Available from: https://www.intechopen.com/chapters/71463.

Sagar M., Tanmoy Shankar and Pradipta Banerjee (March 16th 2020). Potential and Advantages of Maize-Legume Intercropping System, Maize - Production and Use, Akbar Hossain, IntechOpen, DOI: 10.5772/intechopen.91722. Available from: https://www.intechopen.com/chapters/71463.

Sajj, S.K. and Safar, N. (2014). Evaluation of yield and advantage indices of sorghum (Sorghum bicolor L.) and mung bean*(Vigna radiate L.)* intercropping systems. *International Journal of Advanced Biological and Biomedical Research,* 2:151-160.

Sanginga, N. and Woomer, P.L. (2009). Integrated soil fertility management in Africa: Principles, practices and Development process. (Eds.). Tropical Soil Biological and Fertility.*Institute of the International Centre for Tropical Agriculture,*. Nairobi.

Sanjay, K. Dwivedi, Shrivastava, G.K., Singh, A.P. and Lakpale, R. (2012).Weeds and crop productivity of maize+bklackgram intercropping system in Chhattisgarh plains. *Indian Journal of Weed Science,* 44: 26-29.

Sanyal, D., Bhowmilk, C., Anderson R.L. and Shresther, A. (2008). Revisiting the perspective and ,progress of intergrated weed management. *Weed Science,* 161-167.

Sarkar, R.K. and Kundu, C. (2001). Sustainable intercropping system of sesame *(Sesameindicum)* white pulse and oilseed crops and rice fallow land. *Indian Journal of Agricultural Sciences,* 71: 545-550.

SAS Institute (2011). SAS for windows release 9.2 SAS Institute, Cary, NC.

Saucke, H. and Ackermann, K. (2006). Weed suppression in mixed cropped grain peas and false flax *(Camelina sativa).Weed Resources,* 46: 453-461.

Shah, S.N., Shroff, J.C, Patel, R.H. and Usadadiya, V.P. (2011). Influence of intercropping and weed management practices on weed yields of maize. *International Journal of Science of Nation,* 2: 47-50.

Sharma, R.C. and Banik, P. (2013). Baby maize-legumes intercropping system: 11 weed dynamics and community structure. *NJAS-Wagen Journal of Life,* 66: 11-18.

Sheaffer, C.C., Gunsolus J.L., Jewett G. and Lee S.H. (2002). Annual Medicago as a smother crop in soyabean. *Journal of Agronomical Crop Science,* 188: 408-416.

Singh, Mahender, Singh, P. and Nepalia, V. (2005). Integrated weed management studies in maize based intercropping system. *Indian Journal of Weed Science,* 37: 205-208.

Silva, P.S.L; Barbosa, Z; Oliveira, O.F; Antonio, R.P. and Silva, P.I.B. (2004b). Floristic composition and growth of weeds under custard apple (Annona squamosa L.) progenies. Planta Daninha, Vicosa, 22: 529.

Smith, M .A K. and Ayenigbara, E.A. (2003).Preliminary result of an assessment of weed control efficiencies of arable cover crops in maize/okra intercropping system, ASSES Series a 3: 85- 91.

Smith, S. (2002). Growing maize with companion crop legumes for high protein silage. Green Book Energy and Sustainable Agriculture Program pp 68-70. Minnesota *Department of Agriculture*, U S A.

Sogut., T., Ozturk, F. and Kizil, S. (2016) Effect of Sowing Time on Peanut (Arachis Hypogaea L.) Cultivars: II. Fatty Acid Composition. *Agriculture and Agricultural Science Procedia*, 10: 76-82.

Solanki, N.S., Sigh, D. and Sumeriya, H.K. (2011). Resource utilization in maize *(Zea mays L.)*-based intercropping system under rainfed condition. *Indian Journal of Agriculture Science,* 81: 511-515.

Song, Y.N., Zhang, F.S. and Marschner, P. (2007). Effect of intercropping on crop yield and chemical and microbiological properties in rhizosphere of wheat *(Triticum aestivum L.),* maize *(Zea mays L.)* and faba bean *(Vicia faba L.)// Biology and Fertility of soils,* 43: 565-574.

Sorrensen, R., Butts, C., Lamb, M. and Rowland, D. (2004). Five years of subsurface drip irrigation on peanut. *UGA/CPES Research and Extension Bulletin,* No. 2004.

Srikrihnah, S., Umarajini, S. and Seran, T.H. (2008). The effect of intercropping brinja *(Solanummelongena L.)* with groundnut *(Arachis hypogaea L.)* on weed population pp15-115. In: *Proceedings of the 2nd International Symposium*, July 8-12, Sabaragmuwa University, Sri-Lanka.

Subramanian, S., Ali, A.M. and Kumar, R.J. (1991). All about weed control (Publishers, New Delhi- 110002, India, (351).

Susan, A., and Mini, C. (2005). Biological efficiency of intercropping in okra *(Abelmoschusesculentus, L. Moench*). *Journal of Tropical Agriculture,* 43: 33-36.

Szumigalski, A. and van Acker R.C. (2008). Land equivalent ratios, light interception and water use in annual intercrops in the prescence or absence of in-crop herbicides//*Agronomy in annual Journal,* 100: 114-1153.

Takim, F.O. and Fadayomi, O. (2010). Influence of tillage and cropping systems on field emergence, growth of weeds and of maize *(Zea mays L.)* and cowpea *(Vigna unguiculata L.). Australian Journal of Agricultural Engineering, 1*: 14-148.

Tripathy, A.K., Anand, K., Somendra, N. and Yadav, R.A. (2008). Weed dynamics, productivity and net monetary return as influenced by winter maize based intercropping systems in central U.P. ISWS Biennial Conference on Weed Management in Modern Agriculture, February 27-28, 2008. Pusa, Bihar pp 120.

Udensi, U.E Egbage, O. and Omovbude, S. (2017). Tolerance of egusi- melon *(Citrilus colocynthis* (L.) schrad) and susceptibility of weeds to primextral doses. *Journal of Applied Bioscience,* 110: 10747- 10760.

Ullah, A., Bhatti, N.A, Gurman, Z.A. and Imran, H. (2007). Studies on planting patterns of maize *(Zea mays L.)* facilitating legumes intercropping. *Journal of Agricultural Research*, 45: 113-118.

Undie, U.L., Uwah, D.F. and Attoe, E.E. (2012). Effect of intercropping and crop arrangement on yield and productivity of late season Maize /soybean mixtures in the humid environment of Southern Nigeria. *Journal of Agricultural Science,* 4: 37-50.

Umweni, A.S., Uwadiae, I. and Okunsebor, F.E. (2014). Evaluating the distribution of some selected heavy metals in the soils of a university community farm land in Mid-Western Nigeria. *Journal of Research in Environmental and Earth Sciences*, 1 (3); 1-6.

World weather online: Benin City. Available from URL: https://www.worldweatheronline.com/benin-weather-averages/edo/ng.aspx. Accessed January 10, 2018.

Vijay, K.C., Anil, D. Paramasiram, S.K. and Bhagirath, S.C. (2014). Productivity, weed dynamics, nutrient mining. And monetary advantage of maize-legume intercropping in the eastern Himalayan region of Indian. *Plant productivity Science,* 17: 342-352.

Yeganehpoor, F., Salmasi, S.Z., Solymani, A., Valizadeh M. and Samadiyan, F. (2013). Effects of hoeing and not hoeing of weed and using of companion plants on some agronomic traits of MAIZE Sc 504. *International Journal of Agronomy and plant Production,* 1033- 1039.

Yih, W.K. (1982). Weed intercropping and Mulch in temperate zones and the tropics-some ecological implications for low technology agriculture. Ph.D. thesis. University of Michigan, Ann, Arbbor, MI.

Yilmaz, S., Atak, M. and Erayman, M. (2008). Identification of advantage of maize-legume intercropping over solitary cropping through competition indices in the East Mediteranean Region. *Turkish Journal of Agriculture,* 32: 111-119.

Zoufa, K., Tariah, N.M. and Isirimaah, M.O. (1992). Effects of groundnut, cowpea and melon on weed control and yields of intercropped cassava and maize. *Field Crops Resources,* 28: 309-314.