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Keywords: oil palm, alley, intercropping, arable, canopy, resources, competition, performance.

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Keywords: oil palm, alley, intercropping, arable, canopy, resources, competition, performance.

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I. INTRODUCTION

Intercropping is an important feature of the farming systems of the tropics, is defined as the simultaneous growing of two or more species in the same field for a significant period of their growth. Intercropping systems offer ecosystem service that supports food supplies and other livelihood activities. Such practices provide sustainable and stable yields, diversity of flora and fauna and lower risks of crop failure, and implement, sustain and enhance environmental quality, ecosystem services, livelihoods and sustainable landscapes [Ajayi et al., 2016, Agele et al., 2018a]. Intercropping practices are reported to optimize ecological processes, including the cycling of nutrients, maintains carbon stocks and its sequestration, conservation of soil water and modification of microclimate, and reduce soil degradation [Vanlauwe et al., 2011, Agele et al., 2018a]. Agroforestry involves growing trees in mixtures and arable/food crops and fruit tree species simultaneously on a farm (growing arable crops and fruit tree species together). Alley cropping is an agroforestry technique in which trees are planted in hedgerows, and annuals (arable or fodder) crops are planted in the "alley ways" between the hedge row plants. Alley cropping involves growing short duration trees and shrubs that are compatible with arable or fodder crops. The trees provide other benefits such as reducing erosion, maintaining soil fertility and providing additional income to farmers and landowners, and offers opportunities for farmers in terms of income, crop diversity and food security in the early years of tree establishment [Vanlauwe et al., 2011]. The advantages of alley cropping are attributable to increases in long-term sustainability by improving soil quality, increased economic diversity, carbon sequestration, farm yield, resource use efficiencies, and environmental resilience [Willey, 1995, Bedoussac and Justes, 2010, Malay et al., 2014]. Variable availability of growth resources with ages of trees following its establishment exists, thus the variability in the capture and use efficiencies by hedge row crops and alley crops (component species) [Rao et al., 1997, Reynolds et al., 2007, Wahla et al., 2009]. For plants grown together, interspecific competition may occur in relation to the use of growth resources. Jabar et al. [2009] and Malay et al. [2014] reported that competitive interactions occur if the agroforestry trees use resources from the same pool as that of the understory plants. Such biophysical interactions may have positive, and negative effects on trees and the alley crop species. Variable complimentality and compatibility between trees and the alley crop species in the fruit tree-based intercropping systems has been reported [Weigelt and Jolliffe, 2003, Olowe and Adeyemo, 2009, Iremiren et al., 2013].

Research on intercropping has shown that fruit trees can be intercropped successfully with arable crops during the early stages (1 to 5 years) of establishment [Rao et al., 1997, Makunda et al., 2006, Agegnehu et al., 2008, Quinkenstein et al., 2009, Peng et al., 2009, Mesike et al., 2009, Lithourgidis et al., 2011] . Information is inadequate concerning the performance of alley crops in the fruit tree-based agroforestry systems of the savanna agro-ecologies of Nigeria. There is, therefore, merit in research for enhanced understanding of growth and yield responses of arable species such as cassava, maize and pepper sown as alley crops in the early years of oil palm, and their relevance as food diversification and income for fruit tree farmers during the early stages (establishment) of fruit trees in plantation. The optimum specie combination in arable specie in the alleys of oil palm would optimize the benefits of competitive interactions based on resource availability and use by the intercrops and oil palm (complementary in resource uptake and use efficiencies).

The present study aimed at improving understanding of compatibility of oil palm with some selected arable crops in oil palm-based intercropping, generated information on the impacts of intercropping on morphological and physiological traits associated with the productivity of cassava, maize and pepper in oil palm-based intercropping system in a rain forest agro-ecological zone of Nigeria. Findings would be useful input in the development of alley crops management practices to enhance crop productivity within the first 2 to 6 years of oil palm growth.

II. MATERIALS AND METHODS

2.1 Experimental sites and conditions

The experiments were conducted at Ohosu Sub-station and NIFOR Head-Office of the Nigerian Institute of Oil Palm Research (NIFOR), Benin City, Nigeria. The experiments were carried out during the rainy season 2014, 2015, 2016, and 2017. Experiments were conducted on 2, 3, 4, and 5 years old oil palm fields (Teneral hybrid) at Ohosu Sub-station, and 3, 4 and 6 years old at NIFOR Head-Office, Benin City.

2.2 Pre-cropping soil sampling and analysis

Soil samples were collected randomly from the experimental locations before land preparation. Core samples were taken to a depth of 10-20 cm with soil auger, mixed, bulked and air-dried. The samples were crushed, sieved through 2 mm sieve, and subjected to routine laboratory analysis.

The experiment was 3 x 3 factorial combination of ages (2, 3, 4, 5, and 6 years) of oil palm plantations, and 3 species of arable crops which were arranged in a split-plot design. The inter-row spaces (alley) between oil palm plants constitute the main plot while the arable crop species was the sub-plot treatment. Treatments were replicated 3 times. The planting space for oil palms was 9 x 9 m triangular with eight (8) stands per field plot. Treatment plots were spaced by 1 m between plots and replicates (inter row) and 1m at the borders. Strip intercropping system was adopted in the experiments, and the intercrops were spaced at 1 x1 x m which gave 141 plants per treatment plot.

2.3 Data collection

Data collected on oil palm include number of leaves, canopy extent, and number of fresh fruit bunch (FFB). Canopy extent of oil palm was calculated as the product of canopy 'North-South spread' and 'East-West spread' thus:

$$Cs = Ns * EW$$

where: Cs = canopy spread, NS = North-South, EW = East-West

Oil palm canopy volume were calculated according to the equation given by Turell, (1965) as:

$$CV = 0.5236 * H *x D$$

where: CV = canopy spread (m^3), constant=0.5236, H = palm height and D = palm diameter

The ground coverage of the oil palm by canopy was worked out using the procedure used by Tripathy *et al.* (2015).

Radius of canopy (m) was calculated as:

$$R = \frac{D1 + D2}{3}$$

where: D1 = canopy spread in E-W direction (m),D2 = canopy diameter in N-W direction (m) over three replications.

$$\text{Ground coverage by canopy} = \frac{\text{Ground coverage by canopy}}{\text{actual area on the ground}}$$

Data were collected on the growth and yield variables of oil palm, which include number of fresh fruit bunches (FF), weight of fresh fruit bunch (FBB), and total bunch yield per treatment plots. The growth and yield data from the various intercrops were collected from ten tagged plants randomly selected from the experimental plots. The weights of cassava tuber, maize seed, and pepper fruits were collected in addition to root and shoot biomass yields.

$$\text{For maize, threshing percentage (\%)} = \frac{\text{weight of seds}}{\text{weight of seed+cob}}$$

$$\text{Harvest index (HI)} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

2.4 Indicators of crop mixture productivity and competitive interaction

Different measures or indices of productivity have been developed to determine the productivity of component crops in intercropping systems. These indices include relative yield, relative yield total and land equivalent ratio, aggressivity, among others.

Relative yield is the biomass or yield of a species in intercropping expressed as a ratio of its yield in monoculture (De Wit, 1960; De Wit and Van den Bergh, 1965). Relative yield total (RYT) is the sum of the relative yields of the component species expressed as a ratio of its yield in monoculture (De Wit and Van den Bergh, 1965). RYT is probably the oldest established measure of the yield advantage of crop mixture. It is a measure of resource complementarily and indicates to what extent species compete for limiting resources. RYT is expressed as:

$$RYT = ry_a + ry_b + \text{-----} + ry_n$$

where ry_a and ry_b are the relative yields of species a and b, respectively.

LER is an indication of biological efficiency of intercropping in the use of environmental resources compared to sole crops (Mead, 1980). Mead and Willey (1980) expressed LER mathematically as:

$$LER = LER_A + LER_B$$

where, LER represent the LER_A and LER_B of individual crops (component A and B respectively). This can be expressed for situation of morre than two component crops as:

$$LER = LER_A + LER_B + \text{-----} + LER_n$$

The LER of individual crop component is expressed as:

$$LER = \frac{YA}{SA}$$

Thus LER can be expressed as:

where, Y_A and Y_B are the yields of the individual component crop in intercropping and S_A and S_B are their yields in sole crops.

$$LER = \frac{Yab}{Yaa} + \frac{Yba}{Ybb} + \frac{Ybac}{Ycc}$$

where, Yaa = pure stand yield of crop a (cassava), Ybb = pure stand yield of crop b (maize), Ycc = pure stand yield of crop c (pepper), Yab = intercrop yield of crop a (cassava), Yba = intercrop yield of crop b (maize), Ybac = intercrop yield of crop c (pepper)

The percentage of land saved from intercropping was estimated using the formula described by Willey (1980) as:

$$\text{Percent land saved} = 1 - \frac{1}{LER} \times 100$$

Aggressivity is a measure of competitive relationships between two crops in intercropping (Willey, 1979). It is an important competition function to determine the competitive ability of a crop when grown in association with another crop (Jabbar et al., 2009). Aggressivity compares the yields between intercropping and monoculture, as well as their respective land occupancy (McGilchrist, 1965, Li et al., 2001).

Aggressivity (A) is expressed mathematically as:

$$Aab = \left(\frac{Yab}{Yaa * Zab}\right) - \left(\frac{Yba}{Yba * Zba}\right)$$

where, Aab is the aggresivity value for the component crop "a".

III. RESULTS

3.1 Pre-cropping soil properties of experimental site

The results of pre-cropping soil physical and chemical properties prior to commencement of experiments for both Ohosu Sub-station and NIFOR Head Office, showed that the soils of sites of experiments were slightly acidic with pH values ranging from 5.6-6.0 (Ohosu) and 6.5-6.6 (NIFOR). However, such slightly acidic can be tolerated by both the main crop (oil palm) and the intercrop components (cassava, maize, and pepper). The soil organic matter (SOM) content (1.63cmol/kg) falls within the range that the crops can tolerate while soil organic matter content falls within the critical range (1.50 – 1.6 cmol/kg) classed as medium (Table 1). Nitrogen (N) content of the soil also falls below (0.16cmol/kg) value classified as low. The available phosphorus (P) range between 7-8cmo/kg and the exchangeable potassium (K) falls within the moderate range (0.14 cmol/kg). The low nutrient status of the soils indicate the need for improvements through fertilizer application. The soils of experimental sites was sandy loam in texture based on the results of laboratory analysis (sand, silt, and clay content of 92, 4.1, and 4.6 g/kg respectively. The texture of soils appears adequate to hold sufficient water for crop use.

The weather of the experimental sites (Ohosu and NIFOR Head office) during period of study is presented in Table 2. Average air and soil temperatures of 30 and 29 °C, humidity ranging from 64.3 to 80 $^{o}/_{o}$, solar radiation flux of 341.2 kca/cm^{2} , and annual rainfall of 2000 mm during the period of the experiment.

3.2 Effects of age of oil palm on yields of strip intercropped cassava, maize, and pepper in oil palm alley

For both sites of experiment, Ohosu Sub-station and NIFOR Head Office, the respective sole crops of cassava, maize, and pepper out-yielded the intercrops under the various ages of oil palm fields evaluated (Fig. 1a and b, 2a and b and 3a and b). The yields of the intercrops were higher and similar among ages of oil palm fields, these trends were similar for cassava (Fig. 1), maize (Fig. 2) and pepper (Fig.3).

3.3 Growth and yields of strip intercropped pepper, maize, and cassava in oil palm alley (Ohosu)

Age of oil palm had significant effects on leaf and height development of pepper plants (Table 3a). The mean number of leaves differed significantly among the ages of oil palm fields (2, 3 and 5 years). Pepper plants in the alleys of 5 years old palm produced highest number of leaves and branches but shorter plants compared to 2 and 3 years old palms. The lowest weight of root was recorded for 5 and 6 years old oil palm while shoot biomass yields obtained from 2 and 3 years old were similar but differed from those of 5 years oil palm. The ages of oil palm significantly influenced number and weight of pepper fruits. Harvesting of fruits of pepper started early for 2 and 3 years old oil palm and lasted for short time compared to 5 years which started a bit late but lasted longer. Pepper plants transplanted into 5 and 6 years old oil palm plot extended its production till the following year. Harvest index (HI) were not significantly different among oil palm ages. The ages of oil palm affected yield and yield components of pepper, and number and weight of fruits harvested decreased as the age of oil palm increased. Weight of pepper fruits were heavier for the 2 and 3 years old palms compared with 5 years which was significantly lower.

Leaf development (number and areas of leaves) of maize were better for 2 and 3 years old palms compared with 4 and 5 years (Table 3a). Especially for the 5 and 6 years old oil palm, leaf areas were significantly lower for plant stands close to the canopy base of oil palm. Maize sown in the alleys of 2 and 3 years old oil palm were significantly taller than those sown under 5 and 6 years old palms. Across the ages, maize plants sown close to the oil palm were stunted compared to those sown in the centre of the alleys. The canopy extent for 2, 3 and 5 years old oil palm were 1.5, 2.3 and 3.5 respectively, showing that canopy spread increased as the age of the oil palm increased. The ages of oil palm had significant effects on shoot biomass of maize, shoot biomass obtained was highest for 2 and 3 years, the 5 years oil palm recorded the lowest root and shoot weights. The cob and seed weight and number of seeds/cob were significantly different among the ages of oil palm to which the maize was alley cropped. The weight of cob was high for 2 and 3 years old oil palm. There was reduction in value for 5 years old oil palm. The seed weight of maize alley in oil palm of 2 years old recoded high compared to other ages of oil palm. The highest seed yield were obtained for 2 and 3 years oil palm while seed yield of maize sown in the alley of 5 years old oil palm had low yield. Shoot biomass yield, cob weight, number of seed, seed weight, seed yield, canopy spread, air and soil temperature were significantly affected by the ages of oil palm (Table 3). Significant differences were found among treatments for leaf and height developments of cassava sown into 2, 3 and 5 years old palm fields (Table 3). There were significant differences in height of cassava planted in the alleys of 2, 3 and 5 years old oil palm fields. Age of oil palm fields also affected shoot biomass yield, number of tubers, tuber yield and harvest index (HI), significant differences were found between values of these variables for 2 and 3 and 5 and 6 years oil palms.

3.4 Age of oil palm and the performance of cassava, maize and pepper (NIFOR Head Office)

The growth and yields of alley intercrops of cassava, maize and pepper as affected by ages of oil palm (3 to 6 years) fields is presented in Table 4 while the performance of intercrops (cassava, maize and pepper) as affected by ages of oil palm (across sites) is presented in Table 4. The ages of oil palm influenced the number of leaves. The responses of growth and yield strip intercropped cassava, maize and pepper varied among the ages of oil palm fields, 3 and 4 years old fields favoured growth and yield characters of intercropped oil palm fields compared to the 6 years old oil palm. In the alleys of young palms, the component crops had enough access to space, soil nutrient, water and sunlight because the canopy had not created shade compared to 5 and 6 years old oil palm. This reduced the crops competition between oil palm over soil nutrient water and sunlight. The canopy spread of 3 and 4 years old oil palm at this stage was average of 1.8 meter. The number of leaves reduced more from 6 years old field, especially for plants that were close to the base of oil palm. Poor vigour of growth of intercropped species under 5 and 6 years old palms may be due to large canopy spread which would have conferred shade and resultant interception of light. The ages of oil palm did not significantly enhance the biomass yields of cassava and maize. Contrary to the results obtained from cassava and maize, the height and leaf development of pepper were not significantly different among the ages of oil palm fields. Although, root and shoot biomass and pepper yields of pepper were better for young palms (2 and 3 years), differences were not significant. The age of palm was not significant for harvest index (HI), values were close among the ages.

3.5 Effects of age oil palm on competitive interactions and crop mixture productivity

The ages of oil palm and fertilizer types affected competition for growth resources, and productivity of strip intercropping involving cassava, maize and pepper in the alleys of oil palms (Table 5). The age of oil palm affected relative yield of intercrops. Relative yield of cassava increased in 3 and 4 years old oil palm plot relative to cassava sown in the alleys of 5 and 6 years old palm fields. Results showed that the Land Equivalent Ratio (LER) and Relative Yield Total (RYT) were significantly influenced by for cassava, maize and pepper sown in 3, 4 and 6 years old oil palm fields. Relative yield total which was greater than unity (RYT > 1) confirms yield advantages in intercropping oil palm of different ages with cassava, maize and pepper in 2016 and 2017. Relative yield total (technically known as land equivalent ratio (LER) of 0.25, 0.5,075 and 1 for cassava, maize, and pepper means that land area 0.25, 0.5, 0.75 and 1 hectares of sole crops will be required to produce equivalent yield from one hectare of the crop mixture. LER's translate that 5, 10 and 15 hectare of sole crops will be required to produce similar yields from intercropping cassava, maize, and pepper

3.6 Effects of strip intercropping of cassava, maize and pepper in oil palm alleys on the performance of oil palm

Strip intercropping of cassava, maize and pepper in oil palm alleys of 2, 3,4,5 and 6 years olds did not affect the growth and yield performance of oil palm for both Ohosu and NIFOR Head office (Table 6). The strip intercrops in the alleys of palms of different ages did not significantly affect growth of oil palm. The number of leaves increased as the of oil palm age increased, 5 and 6 years old oil palm produced the highest number of leaves. The average number of leaves per palm for 2, 3, 5 years old ranged from 16, 18 and 35 respectively. Fresh fruit bunches were harvested from 5 and 6 years old oil palm while the 2 and 3-years old palms had not come to fruit-bearing. The Fresh Fruit Bunch (FFB) were harvested quarterly in all the experimental plots. The records of FFB harvest obtained for sole crops were the same for intercrops in the alleys of 2 to 6 years old oil palm. The presence of cassava, maize, and pepper in the alleys did not significantly affect development and yield performance of oil palm.

IV. DISCUSSION

For oil palms of 2 to 6 years old, the leaves had not grown vigorous enough while canopy cover had not created shade overlap over the alleys to restrict space and solar radiation interception for the alley crops. This is consistent with the report of Hartley (1988) that 1 to 6 years old oil palm produced no deleterious effects for alley crops. For trials which were conducted on forest land near Benin City, Nigeria, concluded that alley cropping remained possible before complete canopy closure by oil palm (McGilchrist, 1965, CRIN, 2010). These experiments evaluated maize, yams and cassava, and shade-resistant cocoyam as alley crops up until 12 years of oil palm establishment. For the first 2 or 3 years old palms, good yields of the alley crops and growth of oil palm were obtained. Similar results were obtained for cocoyam (*Xanthosoma sagittifolium*) in a more recent experiment at Benin City, Nigeria during the 5th and 6th years after planting oil palm (CRIN, 2010). The yields of cocoyam and oil palm fresh fruit bunch (FFB) were satisfactory expect for cocoyams that were planted close to the base of palms which suggests that nutrient deficiency may be attributed to such low yields. It was concluded that intercropping oil palm with cocoyam was successful during the first 5 years of oil palm establishment.

4.1 Effects of age of oil palm on competitive interactions and mixture productivity of strip intercrop cassava, maize, and pepper.

There was increase in the relative yield (RY) of cassava, maize and pepper strip intercropped in the alleys of 2, 3 and 4 years old. The relative yield of crop species was greater than one (1) signifying that there was no inter-specific competition existed among oil palm, cassava, maize and pepper intercrops. The values of relative yield (RY) above one (1) infer that the intercropping system was advantageous and complementary being able to utilize the resources applied efficiently. Accordingly, Malay et al. (2014) submitted that when RYT is greater than one (1) there is an intercropping advantage in terms of improved use of growth resources by the plants. However, the reverse is the case for oil palm of different ages and crop species which produced relative yield total (RYT) less than one (1). It appears that strong inter-specific competition existed among oil palm of 2, 3, 4, 5 and 6 years old and the intercrop species. This is similar to the report of Carruthers et al. (2000) and Agele et al. (2018), that RYT less than one (1) shows inter –specific competition among species. Relative yield is defined as the sum of relative yields of the species in mixture expressed as a ratio of its yield in monoculture. The relative yields of component crops in the mixture over were lower compare with their counterpart sole crops, generally, relative yield total (RYT) was best for cassava among the intercrops and lowest for maize. The relative yield total (RYT) were (>1) across the intercrop combinations indicting yield advantage of alley cropping of cassava, maize and pepper in the first 2-6 years of establishment. It further indicated that the intercrops stimulated the growth of one another. However, apart from the yield advantage, RYT can be used, as indicators for expressing economic feasibility of intercropping system. This observation further confirm the benefits of the intercrops in relation to their sole crops.

The envisage advantage of growing crops in mixture for efficient use of growth resources and input (fertilizer) utilization are what attract farmers to intercropping (Malezieux et al., 2009, Muncheru et al., 2010). In this study, the effects of 2 to 6 years oil palm on the performance of strip intercrops of cassava, maize, and pepper was evaluated. The partial land equivalent ratio for cassava, maize and pepper sowed into 2 and 3, 4 years old oil palm compared with 5 and 6 years was high, the values across treatments ranged from 0.2 to 0.8, indicators of good availability and use of resources in intercropping. Land equivalent ratio (LER) represents the land required for sole crop to produce the total yield produced by the component crops in an intercropping. LER indicates the overall biological advantage of intercropping, and expresses the magnitude of yield advantage of crop mixtures over sole crops. The percentage of land saved for intercropping is larger than for sole crops. Over sole crops, intercrop combinations of cassava, maize, and pepper) in the alley of oil palm had yield advantage going by the high values of LER which was greater than one (>1) and equivalence and percentage of land saved (PLS), thus indicate high productivity of the intercropping system. This observation is consistent with those of Miller and Palardy (2001), Omesi et al. (2009) and Agele et al. (2018) on intercrop species. The land equivalent coefficient (LEC) was greater than 0.25 across intercrops types (ranged between 0.2 to 0.8) which indicates that cassava, maize and pepper can grow together in mixture without adverse effect on each other but offer yield advantage when intercropped in the alley of oil palm (2 to 6 years old). Similar findings were reported by Mahundi et al. (2011) and Malay et al. (2014) on maize-legume intercropping systems and Agele et al. (2018) on cashew-based intercrop involving sesame and bambara groundnut in the guinea savanna of Nigeria. The relative yields of cassava, maize, and pepper was less than one (1) signifying that the likelihood of inter-specific competition between oil palm and the alley crops. According to Kooli (2014) when RYT is greater than one (1), such is an indication of intercropping system advantage concerning the use efficiency of environmental resources by plants. However, RYT was greater two (>2) for the oil palm-based intercropping involving cassava, maize, and pepper. This result indicated little competition between the intercrops, and may also implied that the component crops stimulated the growth of one another (Kooli 2014). However, Daniel et al. (2001) reported that RYT value of less than one (1) indicates high inter-specific competition among intercrop species. The competitive functions were computed in the form of aggressivity (Agg) and competitive ratio (CR). The relative species competition was therefore evaluated using CR, which is a measure of the times by which one component crop is more competitive than the other. The competitive ability of a crop for resources relative to other intercrops was evaluated by calculating the competitive ratio of one component crop in the mixture with respect to others The competitive ability indicates the degree of competition, thus the number of times in which the dominant species is more competitive than the recessive species. Agressivity is used to determine the competitive ability of crops grown together. In this study, the competitive relation between the intercrops were 0.01 in sole cassava, maize and pepper intercropped into 6 years old oil palm. This implies equal competition. However, cassava, maize and pepper had both negative and positive symbol greater than one (1). Relative crowding coefficient (RCC) results values (2.59-4.36) indicated that cassava, maize and pepper utilization had a non-competitive interference in this intercropping system. This is in line to the work of (Kooli et al., 2014) who stated that crowing coefficient (k) greater than one (1) had a yield advantage while equal to one (=\1) has no yield advantage and disadvantageous when its less than 1.00. It can be concluded in this study that the highest relative crowding coefficient of 4.36 exist because of the difference in cassava, maize and pepper plants populations. Competition ratio (CR) also indicates the degree with which one crop competes with the other in an intercrop system. If the competition index is less than one (1) there is advantage of intercropping. The results obtained in this study was above one (1). This indicated that intercropping of cassava, maize and pepper with oil palm of different ages (2-6) years old were equally competitive with the different types of fertilizer utilization of growth resources for better performance and higher productivity like the results obtained for aggressivity in this study.

4.2 Effects of strip intercropping on oil palm growth and yield

Three plots planted with 2, 3 and 4 year old oil palm while 3, 4 and 6 year old oil palm. Crop species such as cassava, maize and pepper were intercropped into the different ages of oil palms as sub-crops across the plots through out the experimental years. The oil palm plants have not closed canopy but expected to create increase for competition in both above-ground and below-ground for alley crops. The measured growth attributes of oil palm tree of 2-6 years of age include, number of leaves, canopy extent, number of fresh fruits bunch (FFB) and weigh of fresh fruits bunch (FFB). The results showed that there was increase in growth parameters measured at three months interval, before and after introducing the cassava, maize and pepper as intercrop in the study. The growth and development of oil palm especially, canopy formation during the early years of establishment (1 to 6 years) appeared to favour alley crops evaluated (cassava, maize and pepper), the alley crops exerted no significant detriment on the measured characters of oil palm (McGilchrist, 1965, NIFOR, 2010). The effect of intercrop in oil palm alley though had no significant difference but brought about changes in oil palm vegetative and canopy developments. Oil palm canopy spread increased as the age of the oil palm increased, canopy extent was largest for 5 and 6 years old palm trees compared with the 2, 3 and 4 years. Harvesting of fresh fruit bunch (FFB) was done only on 4, 5 and 6 years old palms. The 2 years had not reached production age. At 3 years old, the oil palm flowered and produce small bunch which are discarded after harvest because of its percentage of sluge and very low in special palm oil (SPO) content. The FFB were harvested at 3 months interval and the number of FFB obtained 4, 5 and 6 were not affected by the component crops. The increase in number of FFB is based on the age of oil palm. The number of FFB increased more in 4 years old oil palm followed by 5 and 6 years palm. The average FFB produced and recorded from 4, 5 and 6 years palms were within the range of 10-16, 8-16, and 10-15 per palm respectively in line with NIFOR record on oil palm production (NIFOR, 2010). The weight of FFB was low in young (4 years) palms compared to older palms (5 and 6) years old while the number of FFB in young palms were more and small in size and less in weight. The number of FFB in older palms were few and bigger in size and increased in weight. The number of bunches diminishes with the age of palm but the weight of the bunch increases as the oil palm gets older. The FFB recorded on 4, 5 and 6 years palms were not significantly affected by the component crops. The yield of FFB obtained from 6 years old oil palm plot was higher and significantly higher than what was obtained in 3 and 5 years old oil palm. The average FFB yield from 4, 5 and 6 years oil palm plots per palm were 8.98, 9.28 and 31.93kg/m. The average FFB obtained for the experimental years were 9.8, 9.9, 31.9kg per palm. The cassava, maize and pepper intercropped into 4-6 years oil palms had no negative effect on the yield of fresh fruit bunch of the oil palm. The results obtained from the FFB of oil palm of 4 -6 years old palms were of NIFOR standard.

The tested plant species grown in mixtures had enhanced productivity over their respective sole crops possibly by exploiting species complementarities for resource capture in time and space. The complementarity could have resulted in part from competition avoidance responses that maximize resource capture and growth of the individual plants (Malay et al., 2014, Agele et al., 2018b). Individual organs accommodate different resource levels, concerning nitrogen content and photosynthetic capacity or by size (for example, shade avoidance). As a result, resource acquisition in time and space improved and performance of the system as a whole is increased (McGilchrist, 1965, Seran and Brintha, 2010, Solanki et al., 2011). Crop performance is as a result of individual plant's ability for resource acquisition and utilization which may invoke competitive and complementary interactions under intercropping.

The strength of competition and hence the vigour of growth of individual species, may drive resource capture and utilization. It is imperative to improve insight of the primary drivers and dynamics of competitive or complementary interactions in intercropping. Such developments in knowledge would promote the use of crop mixtures for sustainable and increased crop yields, in addition to improved functioning of the intercropping ecosystems

V. CONCLUSIONS

The results of the competitive functions and crop mixture productivity indicate the yield advantage of crop mixtures over sole cropping and hence the overall biological advantage of intercropping of cassava, maize and pepper in the oil palm-based intercropping system. Over their respective sole crops, the strip intercrops of cassava, maize, and pepper exhibited high values of land equivalence, percentage land saved (PLS) and low aggressivity in the alleys of oil palm which indicates the yield advantage of crop mixtures over sole crops. It has also demonstrated that intercropping cassava, maize, and pepper in the alleys of oil palm of different ages (2 to 6 years old) exhibited some levels of compatibility, complementary and competitive interactions, high efficiency in the utilization of land (space), nutrients, and other gro th resources in addition to higher percentage land saved under intercropping. Oil palm growth and development was not affected by the presence of alley crops of cassava, maize, and pepper. Strip intercropping of cassava, maize and pepper in the alleys of 2 to 6 years old oil palm in the rainforest zone had no negative effects on the growth and yield of oil palm. The study has generated information on the impacts of intercropping on morphological traits associated with the productivity of cassava, maize, and pepper in the oil palm-based intercropping systems in a rainforest agro-ecology in Nigeria.

REFERENCES

1. Adetiloye, P. O., Ezedinma, F. O. C., and Okigbo, B. N. (1983). A land coefficient concept for evaluation of competitive and productive interactions on simple complex mixtures. Ecol. Model. 19:27-39.
2. Agegnehu, G., Ghizam, A., and Sinebo, W. (2006). Yield performance and land-use efficiency of barley and faba bean mixed cropping in Ethiopian highlands. Eur. J. Agron. 25: 202-207.
3. Agegnehu, G., Ghizam, A., and Sinebo, W. (2008).Yield potential and land use efficiency of wheat and faba bean mixed intercropping. Agron Sustain Dev. 28:257-263.
4. Agele, S. Nduka, B., and Aiyelari, P. 2018a. Agro-Waste Reuse and Effects on Growth and Yields of Sesame and Bambara Nut Alley Crops in a Cashew-Based Intercropping System of the Guinea Savanna Agroecology of Nigeria. *Adv. Recycling Waste Manage. 3(2): 159*. DOI: 10.4172/2475-7675.1000159
5. Agele, S. Nduka, B., and Aiyelari, P. 2018b. Manuring Effects on Competitive Interactions and Mixture Productivity of Sesame and Bambara Nut in Cashew-Based Intercropping in the Guinea Savanna Zone of Nigeria. *SciFI J. Plant Physiol*. 1(2); 1-13.1000007
6. Ajayi, A. J., Agele, S. O., and Aiyelari, O. P. (2016). Growth, Yield and Yield Components of Pineapple in a Pineapple-Pepper-Cowpea Intercropping System International Journal

of Horticulture 6 (1) DOI: 10.5376/ ijh.2016.06.0001
7. Carruthers, K., Prithiviraj, B., Fe, Q., Cloutier, D., Martin, R. C., and Smith, D. L. (2000). Intercropping corn with soybean, lupin and forages: yield component responses. Euro J. Agron. 12:103-115.
8. Dahmardeh, M., Ghanbari, A., Syahsar, 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. Afr. J. Agric. Res., 5: 631-636.
9. De Wit, C. T., and Van den Bergh, J. P. (1965) Competition between herbage plants. Netherlands. J. Agric. Sci. 13 (2), 212–221.
10. De Wit, C. T., and Van den Bergh, J. P. (1965) Competition between herbage plants. Netherlands Journal of Agricultural Science, 13 (2), 212–221.
11. Ghanbari, A., Dahmardeh, M., Siahsar, B.A., and Ramroudi, M. (2010). Effect of maize (*Zea mays* L.) - cowpea (*Vigna unguiculata* L.) intercropping on light distribution, soil temperature and soil moisture in and environment. J. Food Agr. Environ. 8:102-108.
12. Iremiren G.O, Ipinmoroti R.R, Olufemi S., and Akanbi O.S.O (2013). Performance of Okra (*Abelmoschus esculentus* L.) and Maize (*Zea mays* L.) under okra/maize intercrop as Influenced by nutrient sources at Ibadan, Nigeria. Int. J. Plant and Soil Sci. 2(2), 190-201.
13. Jabbar, A. R. Ahmad, I. H. Bhatti, Z. A. Virk, W. D., and Khan, M.M. (2009). Assessment of yield advantages, competitiveness and economic benefits of diversified direct seeded upland rice-based intercropping systems under strip geometry of planting. Pak. J. Agri. Sci. 46(02):96-101.
14. Koohi, S.S., and Nasrollahzadeh, S. (2014). Evaluation of yield and advantage indices of sorghum (*Sorghum bicolor* L.) and mungbean (*Vigna radiate* L.) intercropping systems. Int. J. Adv. Biol. Biom. Res. 2(1): 151-160.
15. Kurt, G.S. (1984). Intercropping in tropical smallholder agriculture with special reference to West Africa. GTZ pp 1-233.
16. Li, L.S.C, Sun J, Zhang F, Yang S., and Rengel Z (2001) Wheat/Maize or Wheat/ Soybean Strip Intercropping: Field Advantage and Interspecific Interactions on Nutrients. Field Crops Res. 71(2): 123-137.
17. Lithourgidis, A.S., Dordas, C.A., Damalas, C.A., and Vlachostergios, D.N. (2011). Annual intercrops: an alternative pathway for sustainable agriculture (Review article). Aus. J. Crop Sci. 5(4):396-410 .
18. Makinde, A.A., Bello, N.J., Olasantan, F.O., Adebisi, M.A., and Adeniyi, H.A. (2011). Seasonality and crop combination effects on growth and yield of two sorghum (*Sorghum bicolor)* cultivars in sorghum/maize/okra intercrop in a Forest-Savanna Transition Zone of Nigeria. Agric. J. 6(3): 92-99.
19. akumba, W. Janssen, B. Oenema, O, Akinnifesi, F.K. Mweta, D., and Kwesiga, F, (2006). The long-term effects of a Gliricidia-maize intercropping system in Southern Malawi, on Gliricidia and maize yields, and soil properties. Agric. Ecosys. Environ. 116, 85-92.
20. Malay Kumar Mandal, Mahua Banerjee, Hirak Banerjee, Animesh Pathak and Rajib Das (2014). Evaluation of cereal-legume intercropping systems through productivity and competition ability. Asian J. Sci. Tech. 5,(30: 233-237.
21. Malézieux E, Crozat Y, Dupraz C, Laurans M, Makowski D, Ozier-Lafontaine H, Rapidel B, de Tourdonnet S, Valantin-Morison M (2009). Mixing plant species in cropping systems: concepts, tools and models:A review. Agron Sustain Dev 29:43-62.
22. McGilchrist, C.A. (1965). Analysis of Competition Experiments. Biometrics 21: 975-985.http://dx.DOI:org/10.2307/ 2528258
23. Mead, R., and Willey, RW. (1980)The concept of a "land equivalent ratio" and advantages in yields from intercropping. Exp. Agric. 1980; 16: 217-228.

24. Mesike, C. S., Owie, O. E. D., and Okoh, R. N. (2009). Resource use efficiency and return to scale in small holder rubber farming system in Edo state, Nigeria. J. Humid Ecol. 23(3); 183-186.
25. Miller, A.W., Pallardy, S.G. (2001). Resource competition across the tree-crop interface in a maize-silver maple temperate alley cropping stand in Missouri. Agrofor. Syst. 53: 247-259.
26. Mucheru-Muna, M. Pypers, P. Mugendi, D. Kung'u, J. Mugwe, J. Merckx, R., and Vanlauwe, B. (2010). A staggered maize-legume intercrop arrangement robustly increases crop yields and economic returns in the highlands of Central Kenya. Field Crops Res. 115:132-139.
27. Olowe, V.I.O., and Adeyemo, AY. (2009). Enhanced crop productivity and compatibility through intercropping of sesame and sunflower varieties. Ann. Appl. Biol. 155:285-291.
28. Peng, X. Zhang, Y. Cai, J. Jiang, Z., and Zhang, S. (2009). Photosynthesis, growth and yield of soybean and maize in a tree-based agroforestry intercropping system on the Loess Plateau. Agrof. Syst. 76: 569–577.
29. Quinkenstein, A. Llecke, J.W. Bohm, C. Grunewald, H. Freese, D., and Schneider, B.U. (2009). Ecological benefits of the alley cropping agroforestry system in sensitive regions of Europe. Environ. Sci. Policy. 12:1112-1121.
30. Rao, M. R., Nair, P. K. R., and Ong, C. K. (1997). Biophysical interactions in tropical agroforestry systems. Agrofor. Syst. 38: 1-49.
31. Reynolds, P.E. Simpson. J.A. Thevathasan, N.V., and Gordon, A.M. (2007). Effects of tree competition on corn and soybean photosynthesis, growth, and yield in a temperate tree-based agroforestry intercropping system in southern Ontario, Canada. Ecol. Eng. 29: 362-371.
32. Seran, T. H., and Brintha, I. (2010). Review on maize based intercropping. J. Agron. 9 (3): 135 – 145.
33. Solanki, N.S. Singh, D., and Sumeriya, H. K. (2011). Resources utilization in Maize (*Zea mays*)-based intercropping system under rainfed condition. Indian J. Agric. Sci. 81(6):511-515.
34. Tripathy. P. Sethi, K. A. Patnaik K., and Mukherjee S. K. (2015). Nutrient Management in High Density Cashew Plantation under Coastal Zones of Odisha. Int. J. Bio-Resource Stress Manage. 6(1):093-097. DOI: 10.5958/0976-4038.2015.00025.1
35. Turell, F.M. (1965). Comparative nocturnal thermal budgets of large and small citrus trees. Ecology. 46:25-34.
36. Vanlauwe, B. Kihara, J. Chivenge, P. Pypers, P. Coe, R., and Six, J. (2011): Agronomic use efficiency of groundnut varieties as influenced by sowing dates. Journal of SAT Agricultural varieties. Res. Crops, 6(1): 173 – 174.
37. Wahla, I. H. Ahmad, R. Ehsan Ullah, A.A., and Jabbar, A. (2009). Competition functions of component crops in Barley-based intercropping systems. Int. J. Agric. Biol. 11:69-72.
38. Weigelt, A., and Jolliffe P. 2003. Indices of competition. J. Ecology. 91,707–720.
39. Willey, R.W. (1979). Intercropping its importance and research needs. I. Competition and yield advantages. Field Crop Abst. 32: 1–10.
40. Willey, R. W. (1990). Resource use in intercropping systems. J. Agric Water Manage. 17: 15-231.

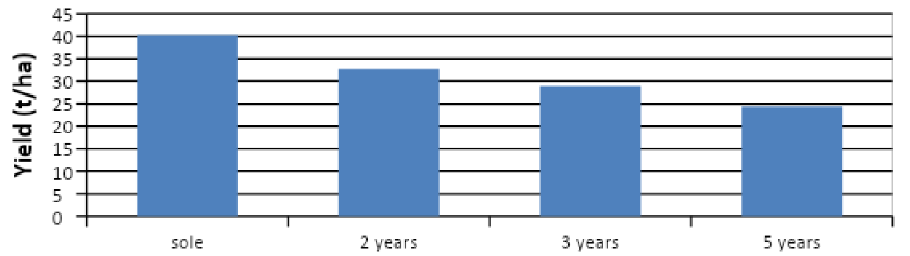

Figure 1a.Effect of age of oil palm field on cassava tuber yields in oil palm-based intercropping system(Ohosu)

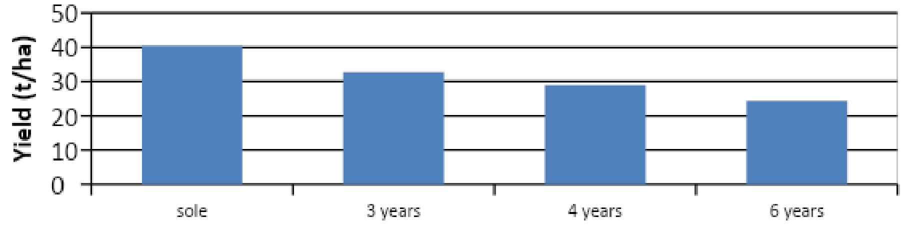

Figure 1b. Effect of age of oil palm field on cassava tuber yields in oil palm-based intercropping system(NIFOR)

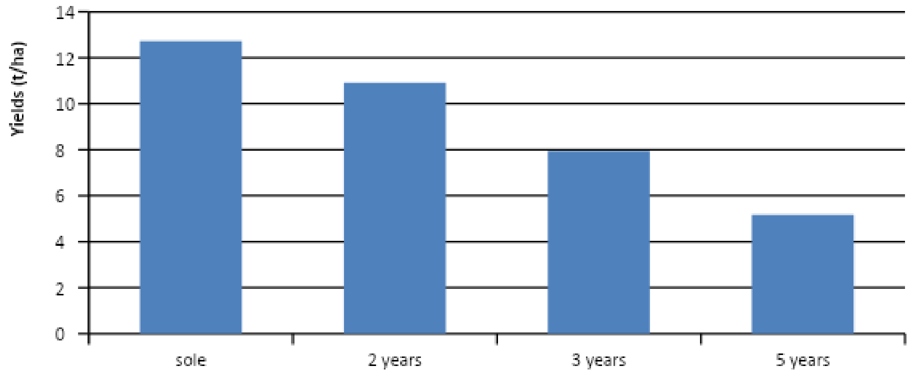

Figure 2a.Effect of age of oil palm field on maize seed yields in oil palm-based intercropping system (Ohosu)

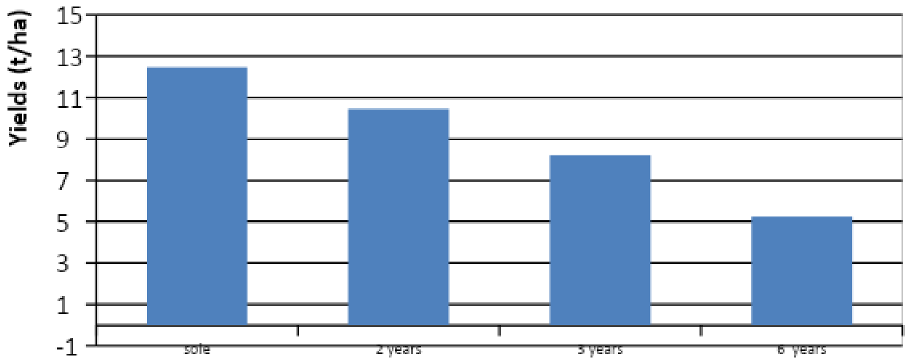

Figure 2b. Effect of age of oil palm on maize seed yields in oil palm-based intercropping system (NIFOR)

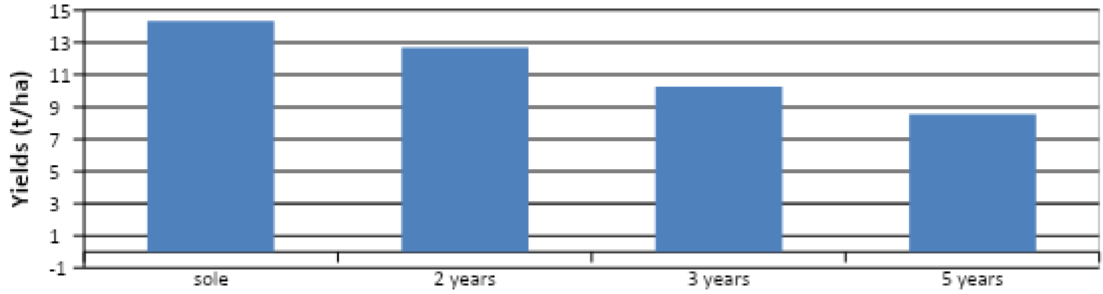

Figure 3a. Effect of age of oil palm on pepper fruit yields in oil palm-based intercropping system (Ohosu)

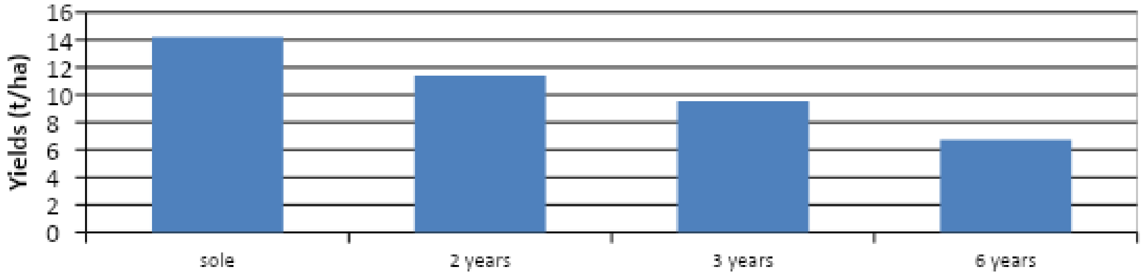

Figure 3b. Effect of age of oil palm on pepper fruit yields in oil palm-based intercropping system

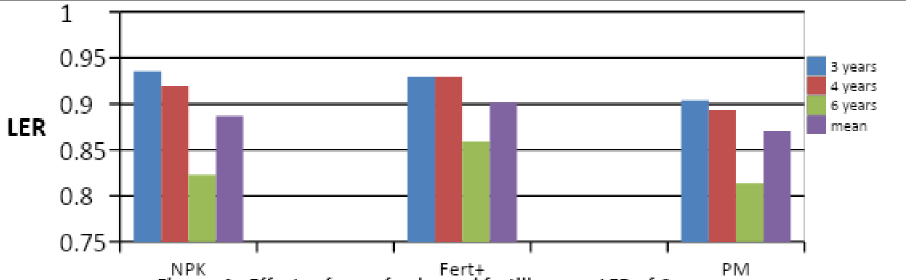

Figure 4a.Effects of age of palm and fertilizers on LER of Cassava

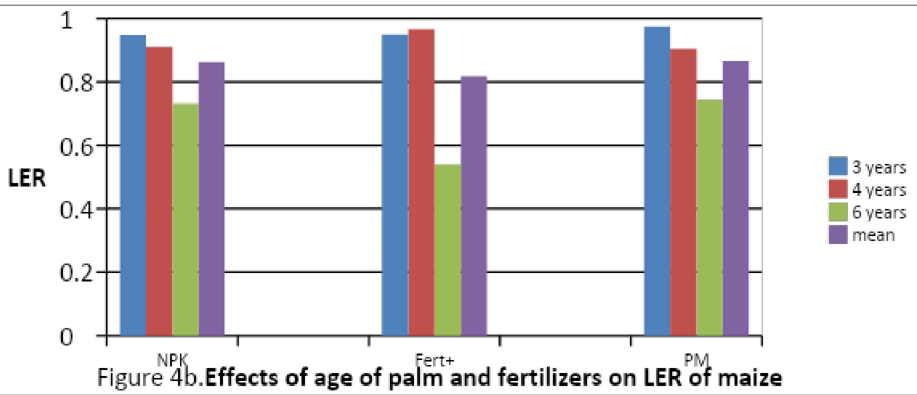

Figure 4b.**Effects of age of palm and fertilizers on LER of maize**

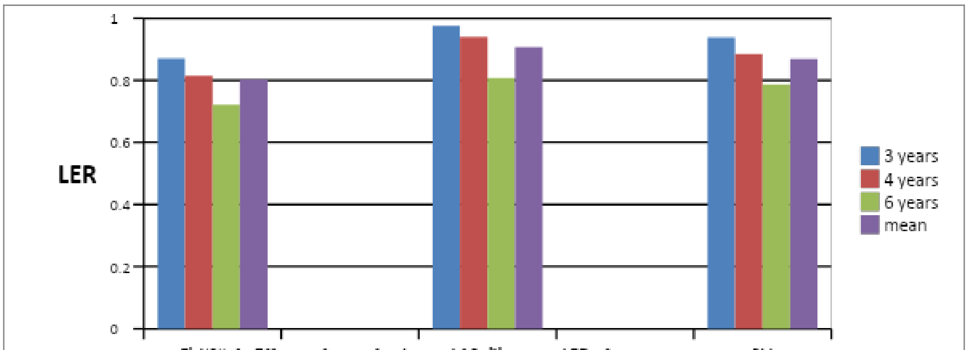

Figure 4c.Effects of age of palm and fertilizers on LER of pepper

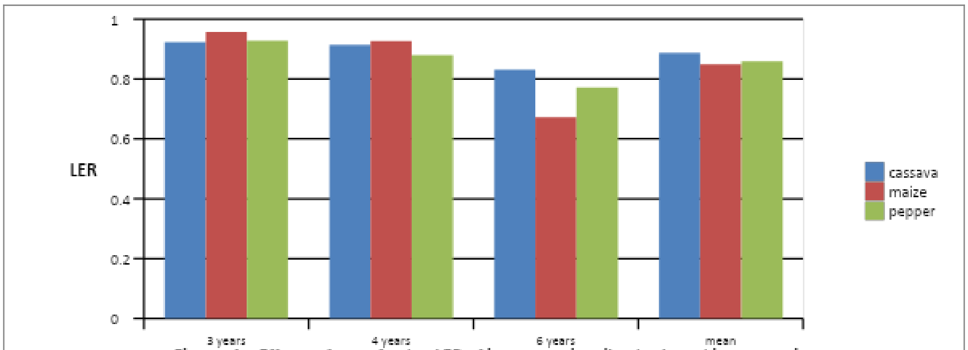

Figure 4e. Effects of age of palm LER of intercrops in oil palm-based intercropping system

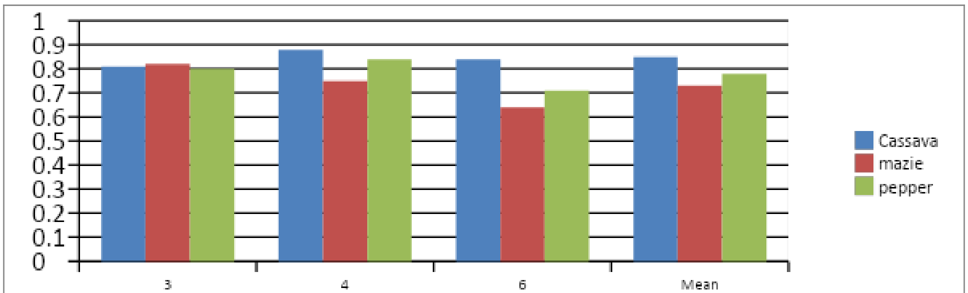

Figure 5a. Effects of age of palm relative yields of intercrops in oil palm-based intercropping system

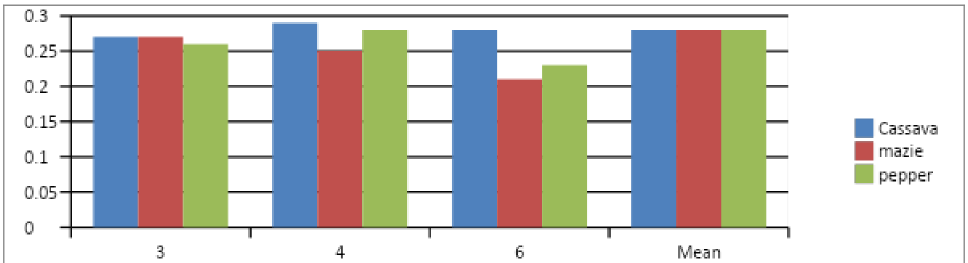

Figure 5b. Effects of age of palm aggressivity among intercrops

Table 1: Results of pre-cropping soil physical and chemical properties prior to commencement of experiments for both Ohosu Sub-station and NIFOR Head Office

Soil Properties	Ohosu Sub-station		NIFOR Head office	
Physical properties	2014	2015	2016	2017
Sand (%)	91.60	84.65	91.31	83.65
Clay (%)	4.8	4.91	4.00	4.80
Silt (%)	4.6	4.08	3.8	3.80
Chemical properties				
PH (water)	6.46	5.58	6.60	5.92
Organic Matter %	1.52	1.49	1.61	1.33
Total N %	0.13	0.16	0.14	0.14
Available P cmo/kg	8.83	8.17	8.74	7.92
Exchangeable K cmo1/kg	0.14	0.12	0.15	0.14
Exchangeable Ca cmo1/kg	0.78	0.81	0.90	0.49
Exchangeable Mg cmo1/kg	0.64	0.58	0.48	0.59
CEC	2.36	2.30	2.28	2.30
Textural Class	Sandy loam	Sandy loam	Sandy loam	Sandy loam

Table 2: Some weather variables of the experimental site during periods of study

Weather indices		Jan	Feb	Mar.	April	May	June	July	Aug.	Sept	Oct	Nov	Dec
Radiation(kcal/cm²)		304.3	402.5	348.3	382.4	366.0	327.1	264.9	241.5	296.3	330.8	368.8	424.7
Rainfall(mm)		21.5	6.7	108.7	132.7	154.6	208.6	139.0	437.2	246.0	16.6	125.0	0.6
Temperature(oC)	Air	32.2	30.3	30.3	30.1	31.0	30.0	32.2	30.1	30.0	31.2	32.1	32.3
	Soil	29.2	29.1	27.9	28.2	29.8	29.0	29.2	29.2	29.3	29.2	29.2	29.0
Relative humidity(%)		80.3	86.7	88.1	83.2	88.2	79.3	72.3	67.2	62.7	78.7	79.2	80.2

Table3b: Effects of age of oil palm field on growth and yield of maize (Ohosu)

Variables	2years	3 years	5 years	mean	LSD (0.05)
Number of leaves	148.2	157.1	218.3	174.3	6.49
Leaf area (cm²)	18.9	23.2	23	21.7	1.63
Plant height(cm)	65.3	63.2	62.9	63.8	1.21
Root biomass(g)	13.29	13.22	11.76	12.75	0.97
Shoot biomass(g)	74.2	73.48	70.53	72.73	1.46
No of fruit per stand	66.8	65.82	63.43	65.35	1.38
Fruit yield(g)	41.3	39.1	36.6	39.3	1.61
Fruit weight(g)	411.6	390.9	364.3	388.9	5.12
Harvest index	4.7	4.46	4.16	4.45	0.54

Table 3c: Effects of age of oil palm field on growth and yield of cassava (Ohosu)

Variables	2 years	3 years	5 year	mean	LSD (0.05)
number of leaves	40.3	40.1	38.3	39.6	1.091
leaf area (cm^2)	43.8	31.6	34.5	36.7	2.636
plant height(cm)	79.3	75.6	62.9	63.8	1.604
shoot biomass (kg))	2.62	2.15	203	2.23	0.203
no of tubers per stand	4.8	4.1	3.5	4.1	0.512
tuber yield (kg)	5.0	4.53	4.02	4.16	0.602
harvest index (hi)	4.7	4.46	4.16	4.45	0.541

Table 4a: Effects of age of oil palm field on growth and yield of maize (NIFOR Headquarter)

	2 YEARS	3 YEARS	5YEARS	MEAN	LSD (0.05)
number of leaves	9.3	9.6	7.9	8.9	1.000932
leaf area (cm^2)	294.4	307.4	297.3	210	2.744968
plant height(cm)	92.6	91	86.4	90	1.885171
root biomass(g)	6.58	6.66	6.2	6.48	0.520919
shoot biomass(g)	56.65	57.16	54.85	56.22	1.157549
cob weight(g)	143.3	141.2	119.1	134.51	3.847459
seed weight(g)	500.5	510	444.4	484.96	6.256444
no of seed per cob	87.3	90.1	76.6	84.66	2.804777
seed yield(g)	500.5	510	444.4	484.96	6.256444
harvest index (hi)	7.9	7.1	7	7.6	0.738008

Table 4b: Effects of age of oil palm field on growth and yield of pepper (NIFOR Headquarter)

Variables	2 years	3 years	5 years	Mean	LSD (0.05)
number of leaves	148.2	157.1	218.3	174.3	6.491337
leaf area (cm^2)	18.9	23.2	23	21.7	1.636966
plant height(cm)	65.3	63.2	62.9	63.8	1.2016
root biomass(g)	13.29	13.22	11.76	12.75	0.976629
shoot biomass(g)	74.2	73.48	70.53	72.73	1.465314
no of fruit per stand	66.8	65.82	63.43	65.35	1.383465
fruit yield(g)	41.3	39.1	36.6	39.3	1.611358
fruit weight(g)	411.6	390.9	364.3	388.9	5.116677
harvest index (hi)	4.7	4.46	4.16	4.45	0.546561

Table 4c: Effects of age of oil palm on growth and yield of cassava (NIFOR Headquarter)

Variables	2 years	3 years	5 years	mean	LSD (0.05)
number of leaves	41.8	43.1	39.4	39.9	1.072
leaf area (cm^2)	43.5	41.3	36.5	39.3	2.145
plant height(cm)	81.2	77.7	65.2	65.1	1.713
shoot biomass (kg))	2.91	2.36	2.51	2.47	0.31
no of tubers per stand	4.9	4.4	3.8	4.3	0.542
tuber yield (kg)	5.42	4.81	4.23	4.38	0.72
harvest index (hi)	4.81	4.53	4.24	4.452	0.471

Table 5: Performance of intercrops (cassava, maize and pepper) as affected by ages of oil palm (across sites)

Variables	3 years	4 years	6 years	mean	LSD (0.05)
Cassava					
Number of leaves	44	41.3	42.1	45.8	1.237441
Leaf area (cm^2)	36.4	32	39.2	35.86	2.001865
Plant height (cm)	83.6	77.8	80.9	80.79	1.790118
Shoot biomass (kg)	3.04	2.13	2.01	2.06	0.788598
Tuber weight (kg)	4.8	4.4	4.4	4.53	0.504964
Number of tuber per stand	5	4.8	4.3	4.7	0.630952
Tuber yield (kg)	4.8	4.4	4.4	4.5	0.504964
Harvest index (HI)	1.59	2.06	2.18	1.94	0.586765
Canopy extent (m)	2.3	3.2	4.3	3.2	1.051652
Average air temperature (°C)	33	32	31	32	1.050777
Average soil temperature (°C)	30	30	29	29	0.798418
Variables	3 years	4 years	6 years	Mean	LSD (0.05)
Maize					
Number of leaves	9.3	9	8.4	8.9	0.711321
Leaf area (cm^2)	201.4	190	172.3	187.9	4.023698
Plant height (cm)	62	76	61.3	66.46	3.025868
Root biomass (g)	6.34	6.23	6.17	6.24	0.308537
Shoot biomass (g)	70.02	68.13	70.24	69.46	1.131687
Cob weight (kg)	86.2	75.2	75.3	78.9	2.64207
Number of seed per cob	505.6	444.3	405.8	451.9	7.454761
Seed weight (g)	103.4	99.5	94.8	99.23	2.180508
Harvest index (HI)	6.62	5.97	9.31	5.96	1.398281
Canopy extent (m)	2.3	3.2	4.3	3.2	1.051652
Average air temperature (°C)	33	32	31	32	1.050777
Average soil temperature (°C)	30	30	29	29	0.798418
Variables	3 years	4 years	6 years	mean	LSD(0.05)

Pepper					
Number of Leaves	115.4	127.8	131.2	124.8	3.030222
Leaf area (cm²)	18.3	17	24.4	19.9	2.08863
Plant height (cm)	61	52.4	57.6	57	2.18685
Root biomass (g)	11.34	11.26	11.07	11.19	0.391313
Shoot biomass (g)	70.02	65.32	71.34	68.89	1.869143
Number of fruits per stand	65.7	63.6	54.6	61.3	2.551596
Fruit weight (g)	42.04	40.7	39.3	40.68	1.229953
Harvest index (HI)	5.16	5.31	4.76	5.07	0.560284
Canopy extent (m)	2.3	3.2	4.3	3.2	1.051652
Average air temp (°C)	33	32	31	32	1.050777
Average soil temp (°C)	30	30	29	29	0.798418

Table 6a: Effects of cassava, maize and pepper intercrops on the growth and yield of oil palm (Ohosu NIFOR substation)

Variable	2 years	3 years	5 years	Means	LSD (0.05)
2014					
No of leaves	16.22	17.97	34.96	23.05	1.13
Canopy extent (m)	1.41	1.51	2.35	1.76	0.25
No of bunch (FFB)/Palm (kg)			9.71	9.71	
Weight of bunch (FFB)/Palm (kg)			98.68	98.68	
Varables	2 years	3 years	5 years	Means	LSD (0.05)
2015					
No of leaves	14.75	15.85	27.12	19.24	0.92
Canopy extent (m)	1.2	1.68	2.36	1.74	0.27
No of bunch (FFB)/Palm (kg)			9.58	9.58	
Weight of bunch (FFB)/Palm (kg)			98.68	98.68	

Table 6b: Effects of cassava, maize and pepper intercrop on the growth and yield of oil palm (NIFOR Head Office)

Variables	2 years	3 years	5 years	Mean	LSD (0.05)
2016					
Number of leaves	16.22	17.97	34.96	23.05	1.13
Canopy extent (m)	1.41	1.51	2.37	1.76	0.25
Number of FFB(kg)			9.71	9.71	
Weight of FFB(kg)			98.28	98.28	
Number of leaves	14.75	15.85	27.12	19.24	0.92
Canopy extent (m)	1.2	1.68	2.36	1.74	0.27

Variables	2 years	4 years	6 years	Mean	LSD (0.05)
2017					
Number of leaves	26.77	38.7	39.4	28.29	0.94
Canopy extent (m)	2.3	3.2	4.3	3.26	0.35
Number of FFB(kg)		12.23	7.78	10.08	
Weight of FFB (kg)		8.98	54.88	31.93	
Number of leaves	18.65	24.06	33.12	25.27	0.94
Canopy extent (m)	1.42	1.62	2.32	1.76	0.25