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Growth and yield of okra (*Abelmoschus esculentus* L. Moench) as influenced by fertilizer application under different cropping systems

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Abstract

Reduction in agricultural land in Nigeria with increasing population has led to land maximization by multiple cropping. A field experiment was conducted 2019 in Ikenne and Ibadan to assess the effect of cropping system and fertilizer application on the yield of okra intercropped with jatropha. The experiment was a split-plot arrangement in a Randomized Complete Block Design, replicated three times. The main plot was fertilizer sources: NPK, Organic, Organic + NPK and control while cropping system: sole okra, sole Jatropha and their intercrop were sub-plot. Data collected to determine okra growth includes: plant height, number of leaves/ plant, leaf area and the yield by number of days to 50 % flowering, number of fruits/ ha, fruit yield and fruiting duration and Jatropha growth by: plant height (cm), number of leaves/plant. Results showed that okra can be intercropped with jatropha without any significant reduction it its performance as the number of fruits/ha, 172.25 in sole crop and 147.23 in intercrop, and fruit yield/ha in both intercrop, 2791.36 kg/ha, 1057.44 kg/ha and monocrop, 3305.39 kg/ha, 1354.94 kg/ha in Ikenne and Ibadan sites respectively were not different significantly. Growth and yield of okra was significantly ($P \leq 0.05$) higher in fertilized plots than the unfertilized plots, with organic + NPK fertilizers at 75 kgN/ha producing the best results.

Keywords: Fertilizer, Growth, Intercropping, Jatropha, Okra, Yield.

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Introduction

The traditional agricultural cropping system of forest zone of southwestern Nigeria are based on growing crops in mixtures, a system most commonly referred to as mixed cropping (Amujoyegbe et al., 2018). Intercropping, a major component of cropping system is a system of managing two or more economic species growing together for at least a portion of the life cycle of the companion crop and is thus experience inter-specific competition among themselves (Usman, 2001). It plays a major role in peasant food production in both advanced and emerging countries (Adeoye *et al.*, 2005). It tends to give higher yield than sole crops, greater yield stability and efficient use of mineral resources (Seran and Brintha, 2009). Despite the advantages of monocropping, almost all peasant farmers in the developing world still practice intercropping because it allows complimentary interaction among crops (Wolfe, 2000), greater production of crops, reduce insect-pest incidence, reduce transfer of diseases (Ramert, 2002) and create good crop environment like greater soil and water conservation potential (Gilley *et al.*, 2002). Okra production in Nigeria either sole or in crop combination has increased due to its high nutritional and economic value and it can be found in almost every market in Africa (Ngbede et al., 2014) It provides important source of protein, vitamin A and C, carbohydrate, calcium, potassium, magnesium and other minerals which are often lacking in the diet of people. Its medicinal ability can be seen in the treatment of peptic ulcer and as source of plasma replacement in man's body fluid (Olawuyi *et al*., 2012). Despite light interception by the component crop varieties, okra productivity was still better under intercropping than sole cropping as evident in all the works reviewed, (Ijoyah and Usman, 2013) where land equivalent ratio (LER) values were all above 1.00, indicating yield advantage of intercrop, as well as the suitability and compatibility of okra as a potential intercrop for farmers and can therefore be recommended as a potential intercrop for farmers in Nigeria. Suitability of okra with sweet potato was also established by Njoku et al., (2010) where higher productivity per unit area was achieved by growing the two crops together than growing them separately. Of all the intercropping system investigated over the years, Jatropha was rarely considered by farmers probably because of the lack of knowledge about the inherent potential of the crop as soil fertility restorer or as an alternative to energy to drive the economy. Over the years, fossil fuels supply most of the energy requirements of industrialized nations, which has increased largely the greenhouse gas (GHG) concentration that threaten to seriously affect ecosystems through human-induced climate change, which compromises survival of humanity (Cotula *et al.,* 2008; Darkwah *et al.*, 2017). Jatropha, a non-food perennial shrub which is well adapted to semiarid regions, can serve as a new alternative for biofuel production, minimizing adverse effects on the environment and food supply (Caroline *et al*., 2009). Jatropha or Physic nut *Jatropha curcas* is one of the essential oil seed crop belonging to the *Euphorbiaceae* family same as rubber tree and cassava. Jatropha seeds can be processed into lesser polluting biodiesel than fossil diesel to provide light and cooking fuel for poor rural families. To achieve success in an intensive cropping like intercropping, the challenge of limited resources will have to be addressed headlong. Some of the major constraints identified to be responsible for low production of arable crops include poor soil fertility, high cost and unavailability of inorganic fertilizer, difficulty in getting enough quantity for large scale production and delay in the release of the essential mineral nutrients for immediate use of the plant (Olawuyi *et al.*, 2010). Hence, the use of fertilizers to sustain cropping systems on most tropical soils is necessary due to their generally low nutrient status (Adetunji, 1991). Nutrients can be supplied through organic or inorganic sources. Organic manure usually have relatively lower nutrient contents with slower rates of mineralization and nutrient forms that are not immediately available to plants (Makinde *et al.*, 2015). Nutrient concentrations from inorganic fertilizers are higher, usually in plant-available forms, and are released quickly for plant to use. Mineral fertilizers have been reported to be more suitable when growing short-time maturing vegetables (Makinde *et al.*, 2001) than long-time maturing crops like Jatropha. Therefore, to maximize the production of these essential crops, it is important to verify their compatibility and environmental conditions that could enhance their performance. The study was conducted to assess the effects of fertilizer type on the growth of okra as a sole crop or when intercropped with Jatropha.

Materials and methods

Experimental sites

The experiment was conducted during the growing seasons of 2019 in Institute of Agricultural Research and Training (I.A.R&T) stations in Ibadan and Ikenne, Southwestern Nigeria to compare their performance in different ecological environment. Ibadan is located in the Rainforest-Savannah Transitional vegetation zone of Nigeria on Latitude $07^0 23^1$N, Longitude 03^0 50^1E; 160m above sea level. The soil belongs to Typic Kanhaplustalf (Soil survey Staff, 1975) and was locally classified as Iwo series in the order Alfisol by Oluwatosin, (2009) as described by Symth and Montgomery, (1962). The soil is generally well drained and the pH of the soils show moderately acid to weakly acidic soil. It is generally sandy and so is subject to leaching. Ikenne research station is in Rainforest belt. It lies within latitude 6^{o}N and 8^{o}N and longitude 2^{o}E and 5^{o}E. Ibadan has mean total rainfall of 1128.0 mm, while Ikenne has mean annual rainfall ranging from 1725.9 mm. Rainfall distribution in both site is bimodal with peaks in June and September respectively (Table 2). The mean maximum temperature is 30.50 ^{o}C (Ibadan) and 30.92^{o}C (Ikenne) however, while Ikenne is in the rain forest agro ecology, Ibadan is in the fringes of the rain forest and derived savanna of Nigeria (Demographia, 2015*)*.

Soil sampling and sample preparations

Several core samples were obtained from 0-15cm depth over the experimental site, collated samples was bulked and a composite sample was obtained for soil analysis before planting begins. The soil samples were air-dried, crushed and passed through a 2mm sieve. Routine analyses was carried out according to International Institute of Tropical Agriculture (1979) procedures include the following: Soil pH was determined in distilled water at 1:1 (soil : water). Percentage organic matter was calculated by multiplying percentage organic carbon by a factor of 1.72 (Broadbent, 1953). Total N was determined by the micro-Kjedahl digestion method. Available P was determined by Bray's P1 test; using 0.03 NH4F in 0.02 N HCl as the extractant and measuring extracted P colorimerically at 660 nm by the molybdenum blue method (Bray and Kurtz, 1945). Exchangeable bases was determined by extraction with neutral normal NH4OAC at a soil: solution ratio of 1:10. Extraction of exchangeable Ca, K, Mg, and Na was with 1 N ammonium acetate, pH 7.0, and measured with a flame photometer. Magnesium was determined by atomic absorption spectrophotometry.

Experimental design and crop arrangement

Jatropha curcas var Linnaeus seeds was obtained from Forestry Research Institute of Nigeria (FRIN) and Okra seeds (LD 88), spineless, late maturing cultivar was sourced from the National Institute for Horticultural Research and Training (NIHORT), Ibadan, Nigeria. Organic compost made from cassava peel and poultry waste at ratio 2:1 was used while NPK (20:10:10) fertilizers was sourced from Ibadan. The experiment was a split-plot arrangement in a Randomized Complete Block design, replicated three times. Fertilizer types were the main plots while the cropping systems were sub-plot. The treatment consist of four fertilizer sources (applied at the rate of 75 kgN/ha) sourced from NPK, Organic, Organic + NPK (50:50) and control (no fertilizer) and three cropping systems comprising of sole okra, sole Jatropha and okra intercropped with Jatropha. Jatropha hedges was established by direct seeding at the onset of rainy season at a spacing of 2.5 x 1.2 m in the main plot of 7.5 x 3.6 m giving rise to16 plants/plot. Okra was planted eight weeks after planting Jatropha at the recommended spacing of 30 x 50 cm (NIHORT,

1985) in the sole and in the alleys (2.5 x 1.2 m) of Jatropha where okra was planted, 2-3 seeds/hole, at a depth of 2-3 cm and was later thinned to one plant per stand 2 weeks after planting, WAP. Weeding was done manually before the introduction of okra at 5 weeks after planting (WAP) okra based on the recommendation of Temnotfo and Henry, (2017) who identified 5 WAP as the critical period of weed interference in okra which represents the equality point of control and interference, which determines the equality of increasing or decreasing crop yield in response to competitive conditions. Organic compost was applied a week before planting Jatropha while N: P: K fertilizer was applied in splits: first at 2 WAP and at 6 WAP okra in the appropriate plots.

Data collection and analysis

Data were collected from 4 plants per plot from inner rows from 4 weeks after planting (WAP) and at 2 weeks interval to determine okra growth which includes: plant height, number of leaves per plant, leaf area. Leaf area was estimated by the non-destructive method of Olasantan and Salau (2008). The leaf area was calculated by the estimated regression equation between leaf area (Y) and leaf length (X) is: $Y= -386.93 +40.56X$ ($r= 0.91$). Two fully expanded leaves from five sample plants were used whose mean length represents X. Okra yield was assessed by: number of days to attain 50 % flowering, number of fruits per ha, fruit yield and fruiting duration. Jatropha plant growth parameters taken at full establishment on the field before the introduction of okra at 8 WAP and at bimonthly intervals include: plant height (cm), number of leaves/plant. Data were subjected to Analysis of variance (ANOVA) using SAS (SAS, 1990) and Duncan's Multiple Range Test (DMRT) was used for significant means separation at 5% probability level.

Results and discussion

The result of the physical and chemical properties of the soil for both sites before trial establishment showed that the soil is strongly acidic (4.67 and 5.48) and the textural class of the soils in both sites was loamy sand (Table 1). The total Nitrogen were low (0.3 and 0.6g/kg) as they were below the critical level of 1.6-2.0 g/kg. Organic carbon was also low (1.7 and 3.8) as they were below the critical level of 10-14 g/kg while available phosphorus content was moderate as it fell within the critical level of 7-20 mg/kg. The K status of the soil used at both Ibadan and Ikenne were low (0.11 and 0.17 respectively) as they were both below the critical level of 0.31c mol/kg (FFD 2012). Hence, both sites are expected to show good response to fertilizer application. However, compost was slightly alkaline with higher amount of N, K and organic C with respect to the soil but lower value of P.

Table 1: Pre-cropping soil analysis and compost nutrient composition

	Ibadan	**Ikenne**	**Compost**
Properties			
pH(H_20)	4.67	5.48	8.30
Total N (g/kg)	0.3	0.6	2.90
Organic matter (g/kg)	2.92	6.54	129.86
Organic C (g/kg)	1.7	3.8	75.50
Available P (mg/kg)	18.36	13.64	0.42
Exchangeable Bases (cmol/kg)			(g/kg)
Ca^{2+}	4.86	6.43	55.9
Mg^{2+}	4.55	1.54	14.2
K^{+}	0.11	0.17	18.5
Na^{+}	0.46	0.48	3.8
Al+H	0.14	0.12	ND
ECEC	10.12	8.74	ND
Base Saturation (%)	98.62	98.63	ND
Micronutrients (mg/Kg)			
Mn	30.60	22.65	497.00
Fe	3.00	1.25	662.00
Cu	0.50	0.91	25.20
Zn	2.03	1.84	68.71
Particle size (g/kg)			
Sand	938.0	938.0	ND
Silt	14.0	14.0	ND
Clay	48.0	48.0	ND
Textural class	Loamy sand	Loamy sand	ND

ND: not determined

Table 2: Monthly rainfall, minimum and maximum temperatures, relative humidity and sunshine hours in 2019

	Ibadan					Ikenne		
Month	Mean Max. Temp (^{0}C)	Mean Min. Temp (^{0}C)	Mean R.H (%)	Mean Sunshine hours (hr/day)	Mean monthly rainfall (mm)	Mean monthly rainfall (mm)	Mean Max. Temp (^{0}C)	Mean Min. Temp (^{0}C)
January	33	21	62	7	7	35.7	35	22
February	34	22	65	7.3	14	98.8	34	23
March	34	23	79	7.8	26	64.5	34	21
April	34	22	72	7	149	37.7	31	22
May	33	21	89	6.8	151	148.3	28	22
June	31	20	88	7.4	184	353.2	27	21
July	30	22	82	7.6	94	112.1	27	21
August	30	23	80	6.8	144	37.8	33	23
September	31	20	86	7	186	335.2	27	22
October	32	21	64	7	162	406.7	27	22
November	34	21	54	7	11	95.9	34	21
December	34	21	48	7	0	0	34	21
Total					1128.0	1725.9		
Mean	32.50	21.42	72.42	7.14	102.5	156.9	30.92	21.75

Source: Meteorological Station, Institute of Agricultural Research and Training, Ibadan.

Effect of cropping system and fertilizer sources on the growth of ***Jatropha curcas.***

Jatropha had similar growth attributes as a sole crop and when intercropped with okra, indicating the compatibility of both crops at both sites. (Table 3). Although, jatropha produced taller plants with more leaves as a sole crop relative to intercropping, its performance is not significantly better than when it is grown as an intercrop. This is similar to the work of Geply *et al.*, (2011) who observed that intercropping of jatropha with arable crops does not negatively affect the height of jatropha. Fertilizer application

Table 3: Effect of cropping system and fertilizer sources on the growth of *Jatropha curcas*

Treatments	**Number of leaves/plant**		**Plant height (cm)**	
	8 WAP	16 WAP	8 WAP	16 WAP
Ikenne site				
Cropping systems (C)				
Sole	13.46a	44.69a	23.77a	63.10a
Intercrop	12.17a	41.29a	24.14a	61.56a
Fertilizer (F)				
Control	10.25b	25.46b	21.76a	44.50c
NPK	10.46b	34.00b	21.34a	57.58b
Organic	18.00a	67.21a	28.55a	83.10a
Organic + NPK (50:50)	12.54ab	45.29b	24.18a	64.13b
C x F	Ns	Ns	Ns	Ns
Ibadan site				
Cropping systems (C)				
Sole	6.08a	11.73a	12.86a	22.67a
Intercrop	5.42a	9.33a	13.31a	20.00a
Fertilizer (F)				
Control	6.17a	7.75a	13.98a	17.99a
NPK	4.71a	11.50a	11.67a	22.62a
Organic	6.46a	10.54a	14.66a	23.12a
Organic + NPK (50:50)	5.67a	12.33a	12.04a	21.60a
C x F	Ns	ns	ns	ns

Means with same letter (s) in a Colum are not significantly different at 5% level of probability by DMRT; WAP = weeks after planting ; ns = not significant

significantly ($p < 0.05$) had positive effect on the growth of jatropha in Ikenne site when compared with unfertilized plants, which reinforced the previous work of Ravi Kant and Surjeet, (2013), where fertilizer had significant effect on the growth parameters of *Jatropha curcas*, unlike in Ibadan site where both fertilized and control plots had similar growth performance, probably because of lower pH value which is far from pH $\geq$ 6 necessary for optimum availability of minerals for growing crops as reported by Robert (2013). Jatropha raised with organic fertilizer significantly had better growth than all the other fertilizer sources which are comparable with one another. Better results shown by organic fertilizer may be due to its ability to improve soil structure for nutrient and water retention and the lower C/N ratio which eases mineralization. Jatropha growth at Ikenne was at least 50 % better than that in Ibadan. However, at both sites, there was no significant interaction between the cropping system and type of fertilizer applied.

Table 4: Effect of cropping system and fertilizer sources on the growth of Okra at 8 WAP

Treatments	Number of leaves/plant	Leaf area (cm^2)	Plant height (cm)
Ikenne site			
Cropping systems (C)			
Sole	8.43a	146.19a	31.77a
Intercrop	6.89a	131.24a	27.86a
Fertilizer (F)			
Control	5.17b	53.20b	22.08b
NPK	8.18a	126.36ab	31.45ab
Organic	7.66a	152.74ab	28.71ab
Organic + NPK (50:50)	9.63a	222.55a	37.02a
C x F	ns	ns	ns
Ibadan site			
Cropping systems (C)			
Sole	7.22a	149.99a	21.41a
Intercrop	7.48a	129.73b	18.18a
Fertilizer (F)			
Control	4.63b	71.61c	15.11b
NPK	5.51b	191.23a	17.13b
Organic	7.43b	130.83b	21.05ab
Organic + NPK (50:50)	11.83a	165.77a	25.90a
C x F	ns	ns	ns

Means with same letter (s) in a Colum are not significantly different at 5% level of probability by DMRT; WAP = weeks after planting ; ns = not significant

Effect of cropping system and fertilizer sources on the growth of Okra at 8 WAP

On both sites, okra growth was not affected by the cropping system as they had similar growth pattern as a sole crop and under intercropping (Table 4). Number of leaves/plant, leaf area and plant height of okra at the peak of their growth were similar under sole and intercropping unlike the report of Silwana and Lucas (2002) that intercropping reduced vegetative growth of components crops due to high competitive ability of the component crops**,** except in Ibadan where leaf area of okra under sole cropping, 149.99 cm^2, was significantly wider than that under intercrop, 129.73 cm^2. Application of fertilizer significantly ($p < 0.05$) improved on the performance of okra in both sites than the unfertilized plants (Omotoso *et al.*, 2018). Okra grown with the complementary use of organic and inorganic fertilizer significantly had better growth in terms of plant height and leaf area expansion and than other fertilizer sources, as confirmed by Akande *et al.*, (2010) where complementary application of 2.5 tonnes of organic manure and 60kg N as NPK 20-10-10 mostly improved okra growth and yield, although similar results were obtained with other fertilizer sources in leaf production. Meanwhile, there was no significant interaction between the cropping system and type of fertilizer applied.

Effect of cropping system and fertilizer sources on the yield and yield components of Okra

Okra variety used was a genetically stable variety as the plants flower at the similar time in both locations, under the investigated cropping systems, as seen in the similarity of days to 50 % flowering which is about 60 days from planting (Table 5). Plants grown from organic sources and in combination with inorganic sources significantly flower earlier than other sources in Ibadan as it helped to absorb nutrients for early initiation of the flowering bud and thus help to develop more flower within a shortest possible period (Kumar *et al.*, 2017). However, poor response of okra flowering to fertilizer application in Ikenne may be due to low or poor release of nutrient (Mishra *et al.*, 2020). Harvest duration was not affected by cropping system in both sites even though sole crops had higher value but fertilizer application increased duration of okra harvest in both site due to the better availability and uptake of plant nutrients for a longer time of crop growth. While sole cropping significantly produced more fruits in Ikenne, number of fruits/ha produced under both cropping system in Ibadan were similar which indicated that intercropping okra with Jatropha at its early stage will not affect the yield of okra plant (Makinde *et al.*, 2020). Fertilized plants produced more fruits than the control plots even though treated plants had similar results in both locations. Fruit yield of okra was similar in monocrop and intercrop in both locations even though monocrop slightly had higher values. Yield was enhanced by fertilizer application

Table 5: Effect of cropping system and fertilizer sources on the yield components of Okra

Treatments	Days to 50% flowering	Harvest duration (days)	Number of fruits/ha	Fruit yield (kg/ha)
Ikenne site				
Cropping systems (C)				
Sole	60.08a	25.08a	325.02a	3305.39a
Intercrop	59.83a	22.75a	283.35b	2791.36a
Fertilizer (F)				
Control	59.83a	19.83b	183.34c	1187.59c
NPK	60.17a	26.83a	305.57b	3459.67ab
Organic	60.17a	22.17ab	352.80ab	3057.29b
Organic + NPK (50:50)	59.67a	26.83a	375.02a	4488.94a
C x F	Ns	ns	*	ns
Ibadan site				
Cropping systems (C)				
Sole	60.08a	19.83a	172.23a	1354.94a
Intercrop	61.00a	18.67a	147.23a	1057.44a
Fertilizer (F)				
Control	61.83ab	15.17b	116.67a	877.46b
NPK	63.00a	21.00a	147.23a	1007.33a
Organic	58.83ab	21.00a	147.23a	1202.94a
Organic + NPK (50:50)	58.50b	19.83a	227.79a	1737.03a
C x F	ns	ns	ns	ns

Means with same letter (s) in a Colum are not significantly different at 5% level of probability by DMRT; ns = not significant; * = significant at $P \leq 0.05$

in both locations relative to the unfertilized plants. According to Molik *et al*., (2016), optimum crop performance is usually affected by inadequate availability of essential nutrients indicating the superiority of fertilized plants over non-fertilized and poorly fertilized ones in term of growth and subsequent yield. Meanwhile, in Ikenne, highest fruit yield was from okra raised with NPK fertilizer and in combination with organic type as a result of the initial nutrient release from the inorganic source and subsequent release by the organic source to ensure consistent supply of nutrient for crop growth and fruiting (Mishra *et al.*, 2020). However, there was no significant interaction between the cropping system and type of fertilizer applied except with the number of fruits/ha in Ikenne.

Conclusion and recommendation

Suitability of intercropping okra with jatropha at the early stage of jatropha growth is never in doubt with the results obtained as growth and subsequent yield of okra was not affected negatively by its intercrop with jatropha. Even though sole okra slightly had better performance in terms of plant height, leaf production and fruit yield, the result was not different significantly from the intercropped ones. Meanwhile, in both locations, fertilized plants significantly produced more yield than the unfertilized ones in that nutrients are readily available for early flowering and corresponding yield increase. Of all the fertilizer sources investigated, application of organic fertilizer complemented by inorganic type ensure better yield than all other sources in that it has the potential to continuously supply nutrient for plant growth as well as improving soil structure for a sustainable production. Production of okra was better in Ikenne, the rainforest zone than the transitional zone of Ibadan. In conclusion, intercropping of okra with jatropha is recommended with the supply of Organic + NPK (50:50) at 75 kgN/ha to maximize productivity.

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