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Nutrient Uptake and Yield of Physic Nut (*Jatropha curcas* L.) as Affected by Nutrient Source and Intercropping

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Abstract

Optimum species combination in intercropping would optimize the benefits of competitive interactions based on resource availability. Field trials were conducted between July 2019 and November 2020 at the Institute of Agricultural Research and Training research station, Ikenne, Ogun State, Nigeria to examine the effects of fertilizer application and intercropping on the nutrient uptake and yield of Jatropha curcas. The experiment was a split-plot arrangement in a Randomized Complete Block design, replicated three times. Main plots were fertilizer type (control; NPK (20:10:10); organic; 50% organic + 50% NPK), with sub plots of sole Jatropha; sole okra; Jatropha/okra intercrop. Nutrient uptake was determined at the onset of flowering, while the number of seeds and seed yield per hectare were assessed at fresh fruiting stage. Seed yield, N, P and K uptake were similar in sole and intercropped Jatropha even though more N and K were absorbed than P. Okra can be intercropped with Jatropha with no significant reduction in okra yield as the fruit yield in both intercrop, 2791.36 kg/ha and monocrop, 3305.39 kg/ha were comparable. Uptake of N (145.9 g/kg), P (4.9 g/kg) and K (69.24 g/kg) was significantly highest from organic source. Organic +NPK source had almost similar but lower values of N (138.1 g/kg) and P (4.25 g/kg) and K (55.04 g/kg) uptake than organic source but were significantly higher than the control which had lowest nutrient uptake. Jatropha seed yield was increased significantly by fertilizer application. Application of organic + NPK fertilizer produced significantly highest seed yield of 88.85 kg/ha and 92.02 kg/ha during the 1st and 2nd harvest cycle, respectively. This was followed by organic fertilizer application (52.35 kg/ha and 53.39 kg/ha). The least was from the control treatment with 13.12 kg/ha and 14.02 kg/ha during the 1st and 2nd harvest cycle, respectively. Since nutrient uptake of Jatropha was not affected by intercropping, Jatropha-okra intercrop can be adopted with the use of organic +NPK to sustain productivity.

Introduction

As long as most peasant farmers still depend on the use of hoe and cutlass, mono-cropping will be a mirage because of the drudgery involved in farming, which will better be compensated for when multiple crops are planted on the same farm plot to avert the possibility of crop failure. Thus, almost all crop production on small farms in the tropics involved more than one crop species (Usman, 2001). Multiple cropping offers farmers the opportunity to engage nature's principles of diversity on farms. Intercropping is a crop management system involving two or more economic species growing together for at least a portion of their respective production cycles (Usman, 2001). It plays a vital role in subsistence 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 nutrients (Seran and Brintha,

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2009). However, it may give low crop yield on a poor soil.

Soil degradation and nutrient depletion can become serious threats to agricultural productivity in that nutrients are essential for plant growth but on smallholder's farm, an inadequate supply is a key impediment to sustainable food production. The practice of leaving land to fallow for some years in order to maintain soil fertility can no longer meet up with the demand for food crop production in West Africa due to high pressure on the limited arable lands. Therefore, soil fertility maintenance is very essential in achieving and maintaining high crop yields over a period of time which may require application of fertilizers to maintain soil fertility (Ayoola and Makinde, 2014). To meet up with these challenges, there is need to promote good crop performance, increased yield per cultivated area, increased economic benefits for producers and farmers through sustainable maintenance of soil fertility.

Many countries of Africa are currently experiencing acute food, environment, and demographic crises due to inappropriate agricultural land management techniques (Ehui *et.al.*, 1990). Most agricultural food crops require high-quality agricultural land for growth which is scarcely available in Nigeria because of misuse and a disregard for sustainable agriculture like agroforestry. (Openshaw, 2000). Agroforestry is an age-old agricultural system practiced in various parts of tropical Asia and Africa. The concept is aimed at the overall management of land by combining trees with food crops to control soil erosion, improve soil conditions and conserve soil and water to meet the needs of crops and the general populace at minimal cost (Adesina *et al.*, 1999). While introducing this system, an appropriate tree/shrub species should be used which should be a low-input species, well adapted to semiarid regions and thrive on marginal land, with economic value (Kang *et al.*, 1995). Prominent among such shrub is Jatropha which has been singled out to deliver benefits through both small and large-scale cultivation (Gilbert, 2011).

Early publications noted the potential of Jatropha for degraded land regeneration, as it does not compete substantially with arable crops for nutrients and thus reduce the cost of production, prevents erosion alongside energy provision, being a major source of biofuel (Openshaw, 2000). Jatropha, a non-food perennial shrub which is well adapted to semiarid regions, minimizing adverse effects on the environment and food supply because of its potential for degraded land regeneration due to litter fall of jatropha (Caroline *et al.,* 2009). In intercropping situations involving okra with other component crop varieties, productivity was still better under intercropping (Ijoyah and Usman, 2013) where land equivalent ratio (LER) values were all above 1.00, indicating yield advantage, as well as the suitability and compatibility of okra as a potential intercrop for farmers. Over the years, Jatropha was rarely considered as an intercrop by farmers in Nigeria probably because of the lack of knowledge about the inherent potential of the crop as soil fertility restorer, repellent agent or as an alternative energy source to drive the economy. 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 obtaining adequate amount for large scale agriculture (Olawuyi *et al.*, 2010). Therefore, use of fertilizers to sustain cropping systems on most tropical soils is necessary due to their low nutrient status (Adetunji, 1991).

In agriculture worldwide, efforts to increase crop yields and quality to meet rising demand for food from growing population, has been based on the use of fertilizers both from inorganic and organic origins (FAO, 2011). Fertilizer application has been reported to improve nutrient use efficiency and chemical and nutritional quality of crops (Agele *et al.,* 2011). However, high N uptake and utilization efficiency by crops without deleterious effect on yield and ecosystem are required (Agele *et al.,* 2008). Availability of soil N, the efficiency of its uptake and use in biomass and fruit production are also affected by crop types, soil and climatological characteristics of a region. Crop yields may therefore increase

under fertilizer treatments possibly due to improved efficiency of nutrient uptake and use. (Agele *et al.*, 2008, 2011). Although these attributes vary in diverse ecologies, there are however, inadequate information on the uptake of soil N, P and K in Jatropha-based cropping system in the rainforest ecological zone of the country. To ascertain its potential in enhancing nutrient uptake from the soil, this study was conducted with the objective of assessing the effect of fertilizer application and intercropping on the nutrient uptake and seed yield of Jatropha.

Materials and Methods

Experimental sites

The experiment was conducted between July 2019 and November 2020 at the Institute of Agricultural Research and Training (I.A.R&T) research station at Ikenne, Ogun State, Nigeria. Ikenne research station is in the rainforest belt. It lies within Latitude 6º 51' 21.11 N", Longitude 3º 42' 20.23" E.

Soil sampling and sample preparations

Eight randomly selected core samples were obtained from the topsoil at 0-15 cm depth across the experimental site. The samples were bulked, and a composite sample was taken to the laboratory obtained for soil analysis before planting. The soil sample was air-dried, crushed and passed through a 2mm sieve.

Experimental design and crop arrangement

Jatropha curcas var Linnaeus seeds were obtained from the 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. According to Makinde and Salau, (2017), soil organic matter increases with cassava peel compost, hence, organic compost was made from cassava peel and poultry waste at ratio 2:1; NPK (20:10:10) fertilizer was sourced from farmers market in Ibadan. The experiment was a split-plot arrangement in a Randomized Complete Block design with 12 treatment combinations, replicated three times. Fertilizer type was the main plot while the cropping system was sub-plot. The treatments consisted of four nutrient sources (applied at the rate of 75 kg N/ha) sourced from NPK, Organic, Organic + NPK (50:50), with no fertilizer as control and three cropping systems comprising of sole okra, sole Jatropha and okra intercropped with Jatropha. Jatropha hedges were established by direct seeding at the onset of the rainy season at a spacing of 2.5 x 1.2 m in the main plot of 7.5 x 3.6 m, giving 16 plants/plot. Okra was planted when Jatropha was eight weeks and fifty-eight weeks old at the 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. Okra was later thinned to one plant per stand 2 weeks after planting (WAP). Weeding was done manually before the introduction of okra and at 5 weeks after planting okra, based on the recommendation of Temnotfo and Henry, (2017). Compost was applied a week before planting Jatropha while N: P: K fertilizer was applied in split: At 2 WAP and at 6 WAP in the appropriate plots. Compost was slightly alkaline, with higher amounts of N, K and organic C with respect to the soil (Table 2) but lower value of P (Table 1).

Table 1: Compost nutrient composition

Properties	Value
pH (1:1 Soil:H_20)	8.30
Total N (g/kg)	2.90
Organic matter (g/kg)	129.86
Organic C (g/kg)	75.50
Available P (mg/kg)	0.42
Exchangeable Bases (g/kg)	
Ca^{2+}	55.9
Mg^{2+}	14.2
K^{+}	18.5
Na^{+}	3.8
Micronutrients (mg/Kg)	
Mn^{2+}	497.00
Fe^{2+}	662.00
Cu^{2+}	25.20
Zn^{2+}	68.71

Nutrient uptake determination

Nutrient uptake was determined by uprooting four sampled plants at the onset of flowering. The plant was separated into shoot and root, dried at 75^0C till constant weight and grinded. Each of the samples (0.25 g) was taken for laboratory analysis. It was weighed into a 2 ml conical flask and 8.0 ml of aqua regia (HCl: HNO_3, ratio 3:1) was added to the sample, heated at low temperature until all brown fumes have disappeared and allowed to cool down. The digest was washed into 50 ml volumetric flask and made up to mark with distilled water. Phosphorus in the solution was determined on spectrophotometer using Vanado-Molybdate method. K was determined by Flame photometry method. Total N was determined by the Macro Kjeldah procedure as described by IITA, (1975). Nutrient uptake was calculated using the formula: dry matter × nutrient content of plant (%) (Ombo, 1994).

Data collected

Data were collected from 4 plants per sub-plot from inner rows at 24 WAP at the onset of flowering to determine the nutrient uptake of Jatropha. Seed yield components were determined at 18 and 48 WAP.

Jatropha yield components

i) Days to first flowering per plot was taken by counting the number of days from sowing to when flower initiation began in each plot.
ii) Days to attain 50 % flowering per sub-plot was taken by counting the number of days from sowing to when 50 % population had flowers.
iii) Number of seeds per plant was obtained from a sample of 4 plants in each plot and averaged.
iv) Seed yield/plant (g/plant) was estimated from the sampled plants and extrapolated to yield per hectare.

Statistical analysis

Data collected were subjected to Analysis of variance (ANOVA) and significantly different treatment means were separated using Duncan's Multiple Range Test (DMRT) at $P \leq 0.05$ using the SAS (1999) statistical package.

Results and Discussions

Pre-cropping soil analysis

The soil was strongly acidic with pH of 5.48 and the textural class of the soil was loamy sand (Table 1). Total Nitrogen was low (0.6 g/kg) as it was below the critical level of 1.6-2.0 g/kg (FFD, 2012). Organic carbon was also low (3.8 g/kg), relative to the critical level of 10-14 g/kg while available phosphorus content was moderate, falling within the critical level of 7- 20 mg/kg (FFD, 2012). The soil K status was low (0.17 cmol/kg), coming below the critical level of 0.31 cmol/kg (FFD, 2012).

Table 2: Pre-cropping soil analysis and Compost nutrient composition

Properties	Soil value
pH(H_20)	5.48
Total N (g/kg)	0.6
Organic matter (g/kg)	6.54
Organic C (g/kg)	3.8
Available P (mg/kg)	13.64
Exchangeable Bases (cmol/kg)	
Ca	6.43
Mg	1.54
K	0.17
Na	0.48
Al+H	0.12
ECEC	8.74
Base Saturation (%)	98.63
Micronutrients (mg/Kg)	
Mn	22.65
Fe	1.25
Cu	0.91
Zn	1.84
Particle size (g/kg)	
Sand	938.0
Silt	14.0
Clay	48.0
Textural class	Loamy sand

Effect of cropping system and fertilizer sources on the nutrient uptake of Jatropha

Uptake of N, P and K by Jatropha plant did not vary with sole or intercropping systems (Table 3). Higher N and K were assimilated than P uptake although the values were similar under both systems. Fertilizer improved significantly N, P and K uptake than the control plants. Organic fertilizer application produced the highest N (145.9 g/kg); P (4.90 g/kg) and K (69.24 g/kg) values, which were comparable with other sources except the control plant which had the least uptake of N (115.6 g/kg); P (3.04 g/kg) and K (31.09 g/kg). This observation was in line with the report of Santos *et al.*, (2017) where the nutrients that were more taken up by Jatropha plants were N while the order of macronutrients uptake was: N > K > P. Reduction in the P uptake may be due to the acidic nature of the soil which made soluble inorganic phosphorus fixed by aluminum and iron (Ch'ng *et al*., 2014). However, there was no significant interaction between the cropping system and type of fertilizer applied.

Table 3: Effect of cropping system and fertilizer sources on the nutrient uptake (g/kg) of Jatropha

Treatments	N	P	K
Cropping systems (C)			
Sole	132.1a	3.24a	54.16a
Intercrop	136.8a	3.35a	56.12a
Fertilizer (F)			
Control	115.6b	3.04b	31.09c
NPK	138.3a	2.97b	69.20a
Organic	145.9a	4.90a	69.24a
Organic+NPK (50:50)	138.1a	4.25a	55.04b
C*F	ns	ns	ns

Means with same letter (s) in a column are not significantly different at 5% level of probability according to Duncan multiple range test. ns = not significant.

Effect of cropping system and fertilizer sources on the seed yield and yield components of Jatropha

Cropping system did not have significant effect on the flowering, harvest duration and the seed yield of Jatropha (Table 4). Flower occurred early in the intercrop; 133 days after planting, (DAP), while flowering began two days after; 135 DAP in the sole crop, although they were not different significantly., sole and intercropping systems attained 50% flowering 141 DAP and 141 DAP days, respectively after the first flower appeared, while the first fruit set occurred 161 DAP and 161 DAP) days after the first flower appeared in the sole and intercropped plants respectively. The observed variation in the period between anthesis (flower opening) and fruit setting may be due to the interaction between various phytohormones with the plant environment (Bruns, 2009) which differ with plant type. Duration of harvest was similar in both cropping systems even though subsequent harvest duration (50 days in sole and 52 days in the intercrop) was longer than the initial harvest (44 days in sole and 40 days in intercrop). The non-determinate growth habit of Jatropha can bring about time of harvesting from anthesis as it can vary from as early as 37 days (Annarao *et al*., 2008) to 90 days (Heller, 1996).

Yield of jatropha did not suffer any setback as a sole crop or when intercropped with okra as the number of seeds/plots, number of seed/ha, seed yield/plot and seed yield/ha had similar values (Table 3). Jatropha under intercropping had more number of seed/plot (127.17 g/plot) than the sole crop (125.5g/plot) at the onset of fruiting, sole crop (113.75 g/plot) produced more seeds than intercrop (107.83 g/plot) with subsequent harvest, even though they are comparable. Number of seed/ha tend to increase over time as yield increase in sole crop from 51.34 kg/ha to 87.48 kg/ha and in intercrop from 56.26 kg/ha to 65.31 kg/ha. Similarly seed yield/ha in intercrop increased from 43.15 kg/ha to 45.86 kg/ha while a slight decline in yield occurred in sole crop as seed yield reduced from

Table 4: Effect of cropping system and fertilizer sources on the seed yield and yield components of Jatropha

Treatments	Days to 1st Flowering (DAP)	Days to 50% flowering (DAP)	Days to 1st fruiting (DAP)	Harvest duration (days)	No. of seed/ha	Seed yield (kg/ha)	No. of seed/plot	Seed yield (g/plot)
First Harvest Cycle								
Cropping systems (C)								
Sole	135.67a	144.83a	161.58a	44.92a	51.34a	43.66a	125.50a	98.27a
Intercrop	133.33a	144.33a	161.00a	40.25a	56.26a	43.15a	127.17a	97.09a
Fertilizer (F)								
Control	145.33a	158.17a	178.50a	30.33c	21.09c	19.12c	44.83c	30.61c
NPK	138.50b	149.00b	164.17b	46.67ab	16.79c	13.29c	107.33b	87.64b
Organic	128.33c	136.83c	153.00c	42.00b	72.01b	52.35b	144.50b	119.05ab
Organic + NPK (50:50)	125.83c	134.33c	149.50c	51.33a	105.31a	88.85a	208.67a	153.41a
C*F	ns	ns	ns	ns	ns	ns	ns	ns
Second Harvest Cycle								
Cropping systems (C)								
Sole				50.17a	87.48a	41.65a	113.75a	75.02a
Intercrop				52.25a	65.31a	45.86a	107.83a	83.43a
Fertilizer (F)								
Control				36.83b	21.03b	14.02c	46.00c	25.49c
NPK				51.33a	20.37b	15.57c	95.50b	66.43b
Organic				60.67a	140.77a	53.39b	143.33a	107.51a
Organic + NPK (50:50)				56.00a	123.42ab	92.05a	158.33a	117.48a
C*F				ns	ns	ns	ns	ns

Means with same letter (s) in a column are not significantly different at 5% level of probability according to Duncan multiple range test. ns = not significant, DAP = days after planting

43.66 kg/ha to 41.65 kg/ha. There was a decline in seed yield/plot over time as yield in sole crop reduced from 98.27 g/plot to 75.02 g/plot and from 97.09 g/plot to 83.43 g/plot in intercrop. Intercropping has been found to maximize water use efficiency, maintain soil fertility, and minimize soil erosion, which are the serious drawbacks of mono-cropping (Dodiya *et al*., 2018), improvement in yield as harvesting cycle continues may eventually unveil the benefits of intercrop over time.

Fertilizer encourages early flowering and subsequent fruiting of jatropha than unfertilized plants. Flowering came earlier in organic based

fertilizers (125-128 DAP) when compared with control plant that flowered 20 days after (145 DAP) and thus fruiting was set earlier in treated (149-164 DAP plants than untreated plants (179 DAP). The results are in agreement with previous report in *Jatropha* where nitrogen at higher level hastened the flowering process (Yong *et al.*, 2010) while nitrogen deficiency study in lupin resulted in delayed flowering (Ma *et al.*, 1997). Similarly, harvest duration was enhanced by fertilization as seed harvesting lasted between 42 and 62 days in fertilized plants as against 30 to 33 days in the unfertilized plants.

Yield in terms of number of seeds/plots, number of seeds/ha, seed yield/plot and seed yield/ha were improved with fertilizer application than the control, with highest from organic + NPK, followed by organic, NPK and lowest yield from control plant. For instance, the highest yield of 88.85 kg/ha was observed, at the onset of harvesting, in the organic + NPK, closely followed by organic with 52.35 kg/ha while NPK and control had similar values. However, subsequent harvest yield value increased as significant highest yield was from organic + NPK with 92.05 kg/ha, followed by organic with 53.39 kg/ha, with the least value of 14.02 kg/ha from the control plant. In comparison with the control, jatropha plant undergoing various doses of fertilizer treatments exhibited increased yield, as treated plant seed yield was about 433 % over untreated plants (Mahapatra and Panda, 2011). However, at both sites, there was no significant interaction between the cropping system and type of fertilizer applied. The present study clearly demonstrates the nutritional importance of fertilizer to jatropha plant for better economic returns as a commercial crop.

Effect of cropping system and fertilizer source on Okra yield

Sole planting of okra significantly produced more fruits/ha (352.02) than the intercrop, its fruit yield of 3305.39kg/ha is at par with the intercrop (2791.36 kg/ha) in 2019 (Table 5). In 2020, cropping system did not have any significant effect on the yield of okra as similar values were obtained, even though intercrop had higher number of fruits/ha (120.41) and fruit yield (564.15 kg/ha) than the sole crop, which indicated that intercropping okra with Jatropha will not negatively affect the yield of okra plant (Makinde *et al.*, 2020). Okra yield was improved by fertilizer application when compared with the control plants. In 2019, organic+NPK significantly produced the highest number of fruits/ha (352.02) and fruit yield (4488.94 kg/ha) even though it is comparable with other fertilizer sources. Meanwhile, with the residual planting in 2020, fruit yield was significantly increased with organic+NPK (975.68 kg/ha) > organic (812.6 kg/ha) > control (271.34 kg/ha). The observed increase in okra yield by plants treated with organic + NPK may be as a result of the initial nutrient release from the inorganic source and subsequent release by the organic source to ensure consistent supply of nutrients for crop growth and fruiting (Mishra *et al.*, 2020).

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

	2019		2020	
Treatments	No. of fruits/ha	Yield (kg/ha)	No. of fruits/ha	Yield (kg/ha)
Cropping systems (C)				
Sole	325.02a	3305.39a	110.15a	563.71a
Intercrop	283.35b	2791.36a	120.41a	564.15a
Fertilizer (F)				
Control	183.34c	1187.59c	90.10b	271.34c
NPK	305.57b	3459.67ab	104.22b	196.10c
Organic	352.80ab	3057.29b	111.12b	812.60b
Organic+NPK (50:50)	375.02a	4488.94a	155.68a	975.68a
C*F	*	ns	ns	ns

Conclusion

Yield of Jatropha were similar under sole cropping and intercropping providing evidence of its compatibility with okra. N, P and K uptake did not differ with intercropping even though more N and K were absorbed than P to ensure fruit development. Yield of jatropha were significantly improved by fertilizer application. Application of organic fertilizer complemented with inorganic type (50:50) ensures better seed yield than organic and NPK fertilizers and the least from control plant. Organic + NPK (50:50) enhanced nutrient uptake and use efficiencies than organic and NPK which corroborated with the observed highest seed yield of Jatropha. Therefore, to sustain productivity of Jatropha, the use of organic fertilizer or its combination with inorganic source is recommended either as a sole crop or in intercrop with okra.

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