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Effect of Organic Fertilizer Fortified with Phosphate Fertilizers and Arbuscular Mycorrhizal Fungi Inoculation on the Growth of Cashew in Two Ecologies in Nigeria

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ABSTRACT Cashew (*Anacardium occidentale, L.*) is an important export-earning crop in Nigeria. Its productivity is being limited mostly by soil fertility particularly phosphorous deficiency among others. Investigations were conducted to assess the influence of organic fertilizer fortified with inorganic phosphate fertilizers and arbuscular mycorrhizal fungi (AMF) on the growth of newly transplanted cashew (four months old at transplanting) in two ecologies in Nigeria. The experiments were conducted in the fields of Ibadan and Uhonmora in a split-split plot design with three replications involving AMF inoculation as main-plot factor at two levels (with and without), organic fertilizer made from ground cocoa pod husk applied at three levels (0, 2.5 and 5tha^{-1}) as sub-plot factor and phosphate fertilizers at 0 and 30kg P_2O_5 ha^{-1} from single super phosphate and Sokoto rock phosphate (SRP and SSP) sub-sub-plot factor. Organic fertilizer applied at 2.5tha^{-1} significantly ($p<0.05$) increased the height of cashew in Uhonmora by 20 % at 21 MAP compared to the control. Application of SSP in combination with 2.5tha^{-1} of organic fertilizer increased plant height significantly at 12 and 18 MAP by 84% and 52% respectively compared with the control in Uhonmora. In Uhonmora, organic fertlizer applied at 5t/ha improved leaf-P marginally by 10 % compared to the control, whereas, in Ibadan, organic fertilizer significantly ($p<0.05$) improved leaf-P by 33 %. Sokoto rock phosphate (SRP) had comparable effect with SSP on the growth of cashew, hence, SRP a viable alternative for cashew production.

INTRODUCTION

Cashew (*Anacardium occidentale* Linn) is an important cash crop grown principally for its nuts. The edible kennel are highly valued as a food and are widely used in confectionary (Ohler 1980). Cashew as a result its wide adaptation is often grown in very poor soils and this has affected its survival and establishment in most fields. Continuous cultivation in conjunction with residue removal and tillage are known to induce a more rapid mineralization of soil organic matter (SOM) within the first few years of cultivation (Tiessen and Stewart 1983). SOM is an important regulator of numerous environmental constraints to crop productivity (Woomer et al. 1994). Organic fertilizer application enhances the solubilization of rock phosphate that is made possible through the activities of microbes which produced organic acids such as humic and fluvic acids and thus making phosphorus easily available to crops (Laska et al. 1990). In Nigeria, cocoa pod husk (CPH) is a major farm waste and it constitutes more than 60% of fresh pod weight (Oguntuga 1975). The disposal of CPH is a big problem as it harbors pathogens for black pod disease in cacao (Ibiremo et al. 2006). CPH has been used extensively as organic fertilizer either singly or in combination with inorganic fertilizer sources in the cultivation of both arable and tree crops (Oladokun 1986; Ibiremo and Fagbola 2005). CPH has low nutrient value especially N and P in comparison with other organic wastes. The efficiency of CPH could be improved through amendment with inorganic nutrient sources such as SRP and SSP. In tropical and subtropical soils, the application of phosphorous is important for most crops because of its low availability due to fixation. Phosphorus is the second most limiting nutrient after nitrogen in the nutrition of cashew. Phosphorus plays an indispensable role as a universal fuel for all biochemical work in living cell and in particular root development which is very important to crop establishment in the field (Hafner et al. 1993). P-deficiency is often corrected through the use of inorganic phosphorus fertilizers such as single super phosphate (SSP), triple super phosphate (TSP), NPK fertilizers and other inorganic P-fertilizer sources. The application of these fertilizers on a long term basis often leads to reduction in pH and exchangeable bases thus making them unavailable to crops and productivity of crop declines (Zainol et al. 1993). In addition, the problem of affordability of these chemical fertilizers by resource – poor farmers and other attendant problems of fertilizers procurement and distribution make the use of rock phosphate for direct application a viable alternative (Chen and Hammond 1985; Adediran and Sobulo 1995).

Arbuscular mycorrhizal fungi (AMF) are ubiquitous beneficial soil micro-organisms associated with roots of most plants (Howeler et al. 1982). The fungi link plant and soil by transporting mineral nutrients to the plant and carbon compounds to the fungi (Reid 1990; Hangen and Smith 1993). The potential of AMF to enhance crop production is well recognized (Arias et al. 1987; Fagbola et al. 2001). Phosphorus is generally considered to be the most important plant-growing factor, which can be supplied by mycorrhizal associations because of the many abiotic and biotic factors, which restrict its mobility in soils (Hartley and Smith 1983; Hayman 1983).

At present, the cultivation of cashew is on the increase in many ecological zones in Nigeria but its response to fertilizer application especially organic fertilizer integrated with inorganic fertilizer and mycorrhizal inoculation, has not been well studied. Therefore, the objective of this study was to determine the effect of AM fungi inoculation, organic and phosphate fertilizers on the growth and establishment of cashew under field conditions.

MATERIALS AND METHODS

Two sites: Ibadan (7^0 25^1N, ^{02} 5^1) and Uhonmora (6 $^05^1$ N , $^050^1$E) were used for the study. The soils are classified as oxic-paleustalf (Smyth and Montgomery 1962) and Vertic-ochraqualf (Ogunkunle et al.1980) respectively for Ibadan and Uhonmora. The sites were under-brushed and trees were felled and later cross-cut and placed within the avenues. The sites were marked out and each experimental unit was 7m X 12m. Holing was done with aid of a specially made digger to a depth of 25cm with a diameter of 12cm. Cashew seedlings were raised from large cashew nuts at the nursery for 2 months. At the nursery, cashew seedlings designated for inoculation were inoculated with 20g of AM fungi (consisting of spores, chopped roots of maize used in the production of inoculum and soil culture) in small polythene bags (12 X 25cm) filled with 2kg top soil. On the field, cashew seedlings were transplanted at 7m X 12m that gave a population density of 238 plants ha^{-1}. The experimental design was a split-split plot design with three replicates, having AM inoculation as main plot factor at two levels (with and without), organic fertilizer made from cocoa pod husk (CPH) was applied as sub-plot. The CPH contained 0.95, 0.11, 4.3, 1.20 0.24 % N, P, K, Ca and Mg respectively. SSP has 18 and 27.0 % for P_2O_5 and CaO respectively while SRP had 33.7, 44.23, 0.95 and 7.90 % for P_2O_5, CaO, MgO and $CaCO_3$ respectively.

Soil samples were collected randomly at both locations (Ibadan and Uhonmora) and analysed for both physical and chemical properties using the methods described in International Institute of Tropical Agriculture Manual (IITA 1982).

Statistical Analyses

Analysis of variance was performed on all data to test the treatment effect on different parameters measured using a SAS analytical package of 9.20 version. Duncan's multiple range test and Least Significant difference ($P<0.05$) was used to separate the

RESULTS AND DISCUSSION

Physical and Chemical Properties of the Soils

The soil in Ibadan was near neutral with a pH of 6.7 while that of Uhonmora was slightly acidic with pH of 5.8 (Table 1). However, the clay content of Uhonmora was 51.6 % higher than Ibadan soil. The cashew is known to grow on a wide range of pH of 4.5 - 8.0 (Ohler 1980). The organic carbon content of Ibadan soil was 39.0% less than the organic carbon of Uhonmora soil. The sand fraction of Ibadan soil was 13.8% higher than that of Uhonmora. However, the clay content of Uhonmora was 52 % higher than that of Ibadan soil. The total nitrogen of Uhonmora soil was 22 % higher than the total nitrogen of Ibadan soil. The Ca^{2+}, Mg^{2+} and Na^+ in Uhonmora soil were higher than that of Ibadan by 8%, 47% and 22% respectively Similarly, the water holding capacity (WHC) of Uhonmora was 40.4% higher than that of Ibadan. Conversely, the exchangeable K^+ in Ibadan soil was 17.5% higher than that of Uhonmora soil. The total exchangeable acidity of Uhonmora soil was more than twice the value of acidity in Ibadan soil. The fertility status of Uhonmora soil in terms of ECEC was 32.5% higher than that of Ibadan soil. The soil of Uhonmora site was moderately acidic but that of Ibadan was near neutral. The total soil nitrogen of both sites was adequate for cashew production while the available P is moderate for Uhonmora and Ibadan soils (Falade 1978).

Table 1: Physical and chemical characteristics of the soils of Ibadan and Uhonmora at 0 – 30 cm

Soil properties	*Unit*	*Value*	
Physical		Ibadan	Uhonmora
Sand	g kg^{-1}	694.00	610.00
Silt	"	149.55	152.85
Clay	"	156.45	237.15
Textural class	-	Sandy loam	Sandy clay loam
WHC	%	38.60	65.06
Chemical			
pH (H_2O) 1:1	-	6.66	5.83
Organic Carbon	g kg^{-1}	1.81	2.95
Total Nitrogen	"	0.65	0.79
Available Phosphorus	mg kg^{-1}	8.87	9.81
Exch. Bases			
K^+	cmol kg^{-1}	0.67	0.57
Ca^{2+}	"	2.07	2.23
Mg^{2+}	"	2.01	2.95
Na^+	"	0.55	0.67
Mn^{2+}	"	0.03	0.06
Exch. Acidity			
Al^{3+}	"	0.13	0.10
H^+	"	0.04	0.27
ECEC	"	5.14	6.81
Base saturation	%	96.76	94.47

ECEC - Effective Cation Exchange Capacity
WHC - Water Holding Capacity

Vegetative Growth of Cashew under Field Conditions

Organic fertilizer applied at 2.5 and 5.0t/ha improved the height of cashew by 15.60% and 7.65% respectively compared to the control in Uhonmora field trial at 6 MAP. However, in Ibadan, the influence of organic fertilizer application on the height of cashew was less than the control at 3 and 6 MAP (Fig. 1). Organic fertilizer applied at 2.5tha^{-1}significantly ($p<0.05$) improved the height of cashew in the field at 9,15, 18 and 24 months after planting (MAP) in Uhonmora soil compared to the control. This result is consistent with the findings of Moyin-Jesu and Atoyosoye (2002) and Odedina (2002) in which organic fertilizer enhanced the growth and nutrient uptake of cocoa seedlings and fruit yield of tomato respectively. Organic fertilizer applied at 2.5tha^{-1} increased the height of cashew by 9.5% compared to the control while 5tha^{-1} depressed height by 14.5% at 12 MAP compared to 2.5 tha^{-1} in Uhonmora field. Application of

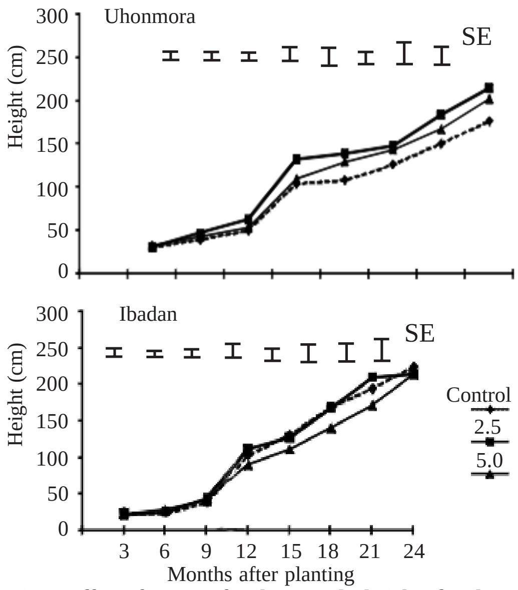

Fig. 1. Effect of organic fertilizer on the height of cashew grown under field conditions in two locations

organic fertilizer applied at 2.5t/ha significantly ($p<0.05$) increased the height of cashew at 2 MAP in Ibadan compared to the control (Fig. 1). This is an important factor to be considered in the use and management of organic fertilizer in crop production. Phosphate fertilizer application did not produce significant effect on the height of cashew at 3, 6, 9, 12 and 24 MAP in Uhonmora field (Fig. 2). However, at 15 and 18 MAP both SSP and SRP significantly enhanced the height of cashew in the field at Uhonmora. In Ibadan field, application of SSP made cashew to be taller than when SRP was applied. This is however contrary to the findings of Ghosh (1999) in which finely ground rock phosphate was as effective as SSP. Generally speaking, application of P-fertilizers to cashew in Ibadan did not show significant effect compared with the control. This may be attributable to fact that the initial available P in both sites was very close to the sufficiency level required by cashew, a view earlier expressed by Ayodele and Agboola (1981) and Ogoke et al. (2003). Application of organic fertilizer and phosphate fertilizers in combination with AMF inoculation did not significantly affect the height of cashew under field conditions in Uhonmora at 18 and 24MAP (Table 2). However, application of organic fertilizer at 2.5tha^{-1} in combination with SRP to AMF-inoculated cashew signifi-

Table 2: **Height of cashew (cm) as influenced by organic fertilizer amended with phosphate fertilizers and AMF inoculation in two locations.**

P Source	*Rate (t ha^{-1})*	*Mycorrhiza Inoculation*	*Months After Planting*			
			6	*12*	*18*	*24*
Uhonmora						
Control	0	M	38.00ab	82.63bcd	102.51c	135.42c
	0	NM	45.75ab	136.55ab	126.83bc	214.87abc
SRP	0	M	46.33ab	123.75abc	151.67abc	186.40abc
	0	NM	32.79ab	104.50abcd	129.73abc	159.29bc
SSP	0	M	31.48ab	99.13abcd	130.51abc	170.99abc
	0	NM	46.55ab	77.85cd	117.92bc	189.54abc
Control	2.5	M	49.75a	128.58abc	116.17bc	209.99abc
	2.5	NM	45.89ab	118.00abcd	152.06abc	241.50a
SRP	2.5	M	40.17ab	153.08a	141.00abc	212.33abc
	2.5	NM	47.50ab	122.65abcd	161.00ab	210.17abc
SSP	2.5	M	54.25a	143.00a	179.67a	218.71ab
	2.5	NM	41.94ab	126.65abc	135.17abc	196.71abc
Control	5.0	M	42.33ab	111.13abcd	112.42bc	202.39abc
	5.0	NM	37.11ab	117.77abcd	117.39bc	196.83abc
SRP	5.0	M	45.81ab	119.25abcd	162.00ab	216.33abc
	5.0	NM	52.08a	101.13abcd	158.75ab	186.37abc
SSP	5.0	M	50.08a	139.75a	180.15a	231.67ab
	5.0	NM	35.22ab	67.00d	130.00abc	178.04abc
ANOVA						
Organic fertilizer (F)			ns	*	ns	ns
P sources (P)			ns	ns	*	ns
P x F			ns	ns	ns	ns
Mycorrhiza(M)			ns	ns	ns	ns
F x M			ns	ns	ns	ns
P x M			ns	ns	*	ns
P x F x M			ns	*	ns	ns
Ibadan						
Control	0	M	31.05ab	103.83abc	194.97ab	198.02ab
	0	NM	21.73b	87.17bc	157.80abc	244.30ab
SRP	0	M	25.28ab	85.00bc	152.40abc	215.07ab
	0	NM	25.18ab	89.75abc	136.15abc	205.68ab
SSP	0	M	39.50ab	152.00a	210.67a	249.62ab
	0	NM	28.58ab	97.83abc	160.10abc	234.02ab
Control	2.5	M	29.92ab	116.67abc	153.40abc	206.16ab
	2.5	NM	25.90ab	112.50abc	201.00ab	253.00ab
SRP	2.5	M	24.17ab	130.33ab	186.97abc	246.42ab
	2.5	NM	35.12ab	132.78ab	187.15abc	145.50ab
SSP	2.5	M	28.46ab	98.83abc	175.50abc	267.00a
	2.5	NM	25.75ab	83.17bc	108.37c	171.78ab
Control	5.0	M	39.00ab	113.00abc	162.95abc	227.80ab
	5.0	NM	23.65b	82.97bc	138.92abc	228.22ab
SRP	5.0	M	25.50ab	125.17ab	139.92abc	193.58ab
	5.0	NM	30.50ab	80.00bc	118.78bc	228.35ab
SSP	5.0	M	25.00ab	56.33c	153.43abc	217.28ab
	5.0	NM	55.34a	80.00bc	125.43bc	190.82ab
ANOVA						
Organic fertilizer (F)			ns	ns	ns	ns
P sources (P)			ns	ns	ns	ns
P x F			ns	ns	ns	ns
Mycorrhiza(M)			ns	*	ns	ns
F x M			ns	ns	ns	ns
P x M			ns	ns	ns	ns
P x F x M			ns	ns	ns	ns

For each location means in columns followed by the same letter(s) are not significantly different by Duncan's Multiple Range Test at ($p < 0.05$). M = with *mycorrhiza inoculation,* NM = without *mycorrhiza inoculation,* ns = not significant

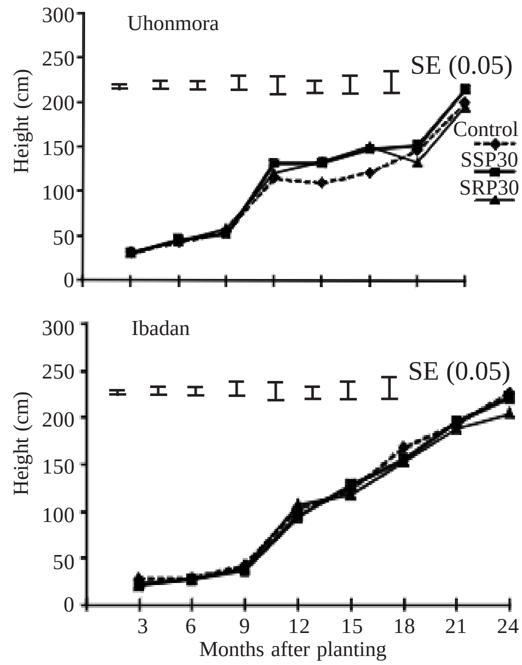

Fig. 2. Effects of phosphate fertilizer sources on height of cashew grown under field conditions in two locations

cantly (p< 0.05) improved the height of cashew compared to other treatments. Similarly, application of SSP in combination with 2.5t/ha organic fertilizer improved the height AMF inoculated cashew at 12 and 18 MAP by 84% and 52% respectively compared with its counterpart without organic fertilizer, non-inoculated cashew in Uhonmora field. AMF inoculation of cashew, SSP application and organic fertilizer application (5t/ha) increased the height of cashew by 109% compared with those without AMF inoculation in Uhonmora field at 12 MAP.

Cashew Leaf Nutrient Composition, Flowering Intensity and AMF Root Colonization

Organic fertilizer significantly (p<0.05) enhanced the N and Ca content of cashew leaf under field conditions in Uhonmora but not in Ibadan field (Table 3). The P, K and Mg contents of cashew leaf were not significantly influenced by addition of organic fertilizer in both locations. In Uhonmora field, organic fertilizer applied at 5t/ha improved leaf P marginally by 10% compared to the control, whereas in Ibadan, organic fertilizer improved leaf P by 33 %. Similarly, organic fertilizer applied at 2.5 t/ha improved the leaf Mg content by 3% and 6% compared to the control in Uhonmora. In Uhonmora field, organic fertilizer applied at 2.5t/ha significantly (p<0.05) enhanced the flowering intensity of cashew compared to 5t/ha and the control. The flowering intensity of cashew was significantly (p<0.05) improved by SSP application compared to the control in Uhonmora field, whereas phosphate fertilizer application did not produce significant effect on the flowering intensity of cashew in Ibadan field (Table 3). SRP application in combination with organic fertilizer applied at 5t/ha and AMF inoculation significantly (p<0.05) increased the leaf Ca compared to plants without AMF inoculation in Uhonmora. Similarly, applications of organic fertilizer in combination with SSP fertilizer and AMF inoculation significantly (p<0.05) increased the leaf Mg. In Uhonmora, AMF root colonization as affected by organic fertilizer in combination with phosphate fertilizers and AMF inoculation ranged from 49 % when organic fertilizer was applied singly without and without AMF inoculation to 83 % when SRP was applied in combination with 2.5t of organic fertilizer in addition to AMF inoculation (Table 4). Root colonization by AMF was significantly reduced when organic fertilizer (5t/ha) was applied singly without either P fertilizers or AMF inoculation compared to its counterpart under similar situations. In Ibadan, root colonization was significantly reduced in the control compared to its counterpart with organic fertilizer and without AMF inoculation. SSP and AMF inoculation

Table 3: Influence of organic fertilizer on nutrient compositions of cashew leaf under field conditions in two locations

Variable		*Organic Fertilizer ($t\ ha^{-1}$)*			*LSD (0.05) (0.05)*
		0	2.5	5.0	
			Uhonmora		
Leaf N	(%)	2.10	1.96	2.13	0.12
Leaf P	(%)	0.20	0.20	0.22	ns
Leaf K	(%)	1.05	3.25	1.18	ns
Leaf Ca	(%)	0.36	0.33	0.38	0.03
Leaf Mg	(%)	0.29	0.28	0.30	ns
Flowering intensity	(%)	38.30	72.20	37.50	15.21
			Ibadan		
Leaf N	(%)	2.10	2.07	2.00	ns
Leaf P	(%)	0.15	0.15	0.20	ns
Leaf K	(%)	0.97	0.95	1.03	ns
Leaf Ca	(%)	0.53	0.61	0.54	ns
Leaf Mg	(%)	0.27	0.31	0.27	ns
Flowering intensity	(%)	4.00	4.67	3.87	ns

ns = not significant

Table 4: Root colonization of cashew as influenced organic fertilizer fortified with phosphate fertilizers and AMF inoculation

P source	*Organic fertilizer*	*AMF inoculation*	*Root infection (%)*	
			Uhonmora	*Ibadan*
Control	0	NM	77.41a	40.23c
	0	M	73.25a	60.02b
	2.5	NM	67.71ab	57.26b
	2.5	M	78.87a	57.20b
	5.0	NM	49.22c	67.34b
	5.0	M	82.77a	58.11b
SSP	0	NM	60.06b	49.77c
	0	M	54.01bc	82.67a
	2.5	NM	80.31a	63.56b
	2.5	M	76.28a	76.15a
	5.0	NM	78.87a	55.34b
	5.0	M	82.77a	62.37b
SRP	0	NM	72.48a	65.11b
	0	M	80.63a	76.53a
	2.5	NM	67.68ab	54.55b
	2.5	M	83.45a	60.16b
	5.0	NM	70.63ab	36.39c
	5.0	M	74.45a	77.57a
ANOVA				
P			ns	ns
C			ns	ns
PXC			ns	ns
M			*	ns
PXM			ns	ns
CXM			ns	ns
PXCXM			*	*

For each location means in columns followed by the same letter(s) are not significantly different by Duncan's Multiple Range Test at ($p < 0.05$). M = with *mycorrhiza inoculation,* NM = without *mycorrhiza inoculation,* ns = not significant

significantly enhanced the root colonization of cashew compared to its counterpart with organic fertilizer application.

CONCLUSION

SRP had comparable effect with SSP on the growth and development of cashew in the field, hence, when SSP is not available, Nigerian SRP is a viable alternative for cashew production. Organic fertilizer applied at 2.5tha^{-1} in Uhonmora resulted in improved plant height compared to the control and at 5tha^{-1}. Organic fertilizer combined with phosphate fertilizer and AM inoculation had positive influence on the growth of cashew in the field.

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