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RESPONSE OF CASHEW SEEDLINGS FROM DIFFERENT NUT SIZES TO PHOSPHATE FERTILIZERS AND ARBUSCULAR MYCORRHIZAL INOCULATION IN TWO SOILS IN NIGERIA

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ABSTRACT: Cashew (*Anacardium occidentale* Linn) is an export-earning crop and is cultivated in many agro – ecological zones in Nigeria. Its growth and productivity are being limited by low soil fertility particularly phosphorus deficiency among others. Hence an investigation was carried out to evaluate response of cashew seedlings from different nut sizes to phosphate fertilizers and Arbuscular mycorrhizal fungi (AMF) inoculation under greenhouse conditions. The three factors investigated were nut sizes (small and large), phosphate fertilizers (Single super phosphate – SSP and Sokoto rock phosphate – SRP) applied at 11kg $P_20_5ha^{-1}$ and AM fungi inoculation – at two levels (with and without). Cashew nuts were planted into 5kg top soil (0-30cm) obtained from the two sites. The trial was conducted in the greenhouse using completely randomized design and four replicates. Height, stem diameter, dry matter and nutrient uptake were assessed. Data were analyzed using descriptive statistics and ANOVA. In the study, the interaction of phosphate fertilizer application, nut size and mycorrhizal inoculation did not significantly influence the height and stem diameter of cashew seedlings in Ibadan soil at 1-4 MAP while in Uhonmora the interaction was only significant ($p<0.05$) at 3 MAP. The shoot and total dry matter yield of seedlings from large nuts without AM inoculation under SSP application was significantly ($p< 0.05$) higher than the shoot and total dry matter yield of seedlings from small nuts with or without AM inoculation in Uhonmora. In Ibadan soil, phosphate fertilizer, nut sizes and AM inoculation significantly ($p< 0.05$) enhanced the total N, P, K, Ca and Mg uptake of cashew seedlings. Soil pH and inorganic P were significantly ($p< 0.005$) affected by phosphate fertilizer, nut sizes and AM inoculation in Uhonmora soil. SRP had a comparable influence with SSP particularly under AM inoculation on cashew seedling growth performance in the two soils.
Key words: mycorrhizal, inoculation, cashew, nut size, phosphate fertilizer, dry matter, nutrient uptake.

INTRODUCTION

Cashew is an important commodity crop with great potentials as foreign exchange earner and source of industrial raw materials with the prospect of becoming a major commercial tree crop in Nigeria. Cashew as a result of its wide adaptation is often grown in very poor soils and this has affected its survival and establishment (Topper, *et al.,* 2001). Adebola *et al.,* (1999) have shown that bigger nuts have good seedling growth characteristics. In tropical soils, the application of phosphate fertilizer is important for most crops because of its low availability, which is not unconnected with fixation. Phosphorus (P) plays an indispensable role as a universal fuel for all biochemical work in living cells. High-energy adenosine triphosphate (ATP) bonds release energy for work when converted to adenosine diphosphate (ADP) (Agbede, 2009). Inorganic phosphate fertilizers are used to correct P deficiencies in our soils. However, the use of rock phosphate as an alternative P-source has been reported by various authors (Akande *et al.,* 2008) owing to its availability and cheapness coupled with its environmental friendliness. Arbuscular mycorrhizal fungi (AMF) readily form association with cashew roots (Haugen and South 1993). The potential of AMF to enhance crop production is well recognized (Fagbola *et al,* 2001).

Phosphorus is generally considered to be an important plant growing factor that can be supplied by mycorrhizal association because of the many abiotic and biotic factors that restrict its mobility in soils (Haugen and Smith, 1993). At present, there is paucity of information on the nutritional requirements of cashew with respect to phosphate fertilizers and AMF. Hence an investigation was carried to evaluate the response of cashew seedlings from different nut sizes to phosphate fertilizers and AM fungi inoculation in two soil types in Nigeria.

MATERIALS AND METHODS

The experiment was conducted in the greenhouse of Cocoa Research Institute of Nigeria (Latitude $7^0 25^1$ N and Longitude 3^0 25^1 E) in 2007/2008 seedling production season. Soil samples (top soil) were collected randomly at the plantations of the stations at 0-30 cm depth. The soil was air-dried and sieved using 2mm sieve. Sub-samples were analyzed for physical and chemical parameters. Twelve treatment combinations comprising two nut sizes (S_1 – Small nut sizes of 4 to 6g/nut and S_2 – large nut size of 8 to 12g/nut), two phosphate fertilizer types (Single super phosphate and Sokoto rock phosphate with a control – no P application) and two levels of AM inoculations (with and without). The AM used for the study was *Glomus clarum* (Nicolson and Schenck). The treatments were replicated four times and then arranged in a completely randomized design (CRD). Two viable nuts of the two nut sizes were planted in each of the 5-litre buckets containing five kilograms topsoil. The phosphate fertilizers were applied at rate equivalent to 11kg P_20_5 ha^{-1} which was equivalent to 5kg Pha^{-1} while 20g of the AM fungi containing spore, hyphae and roots of the cultural plant was applied just below the nuts at planting. Watering was done regularly thrice a week. Data on height, stem diameter and number of leaves were regularly taken on monthly basis. At four months after planting (MAP), the plants were destructively sampled and separated into leaves, stem and roots. The fresh plant samples were dried in an oven to constant weight to determine the dry matter yield and the samples were milled using in electric hammer and nutrient analysis was carried out for major nutrients in the leaves, stems and roots. The nutrient uptake was calculated as the product of the concentration and dry matter yield.

Uptake = Nutrient concentration x dry matter yield (Osonubi *et al.,* 1991). Soil samples were collected randomly at both locations (Ibadan and Uhonmora) and analyzed for both physical and chemical properties using the methods described in International Institute of Tropical Agriculture Manual (IITA, 1982). 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.

RESULTS AND DISCUSSION

The sand fraction of Ibadan soil was 13.8% higher than that of Uhommorra (Table 1). However, the clay content of Uhonmora was 51.6% higher than Ibadan soil. Similarly, the water holding capacity (WHC) of Uhonmora was 40.4% higher than that of Ibadan. The soil of Ibadan was near neutral with a pH of 6.66 while that of Uhonmora was slightly acidic with pH of 5.83 (Table 1). The total soil nitrogen of both sites was adequate for cashew production while the available P is moderate for Uhonmora and Ibadan (Adeoye 1986 and Agboola 1985). The exchangeable K^+, Ca^{2+}, and Mg^{2+} are adequate for cashew production. The exchangeable sites have enough basic cations thus resulting in very high base saturation values. The soils of Ibadan and Uhonmora are quite ideal for cashew production. The interaction of phosphate fertilizer application, nut size and mycorrhizal inoculation did not significantly influence the height of cashew seedlings in both soils (Table 2). In Ibadan soil, the height of cashew seedlings from large nuts was significantly ($p< 0.05$) enhanced by AM inoculation without phosphate fertilizer application at 2 MAP compared to seedlings from small nuts without AM inoculation. Similarly, at 3 MAP, the height of seedlings from small nuts inoculated with AM was significantly ($p< 0.05$) increased when no P was applied compared to seedlings from small nuts without AM inoculation.

Table 1: Physical and chemical characteristics of the soils of Onigambari, 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

Furthermore, large nuts without mycorrhizal inoculation under SSP application significantly ($p < 0.05$) increased the height of cashew seedlings at 4 MAP. Under mycorrhizal inoculation and SSP application, the height of seedlings from large nuts was 73.0 % higher compared to the seedlings from small nuts under similar treatments at 4 MAP in Ibadan. Similarly, the interaction of P-sources, nut sizes and AM inoculation did not significantly affect the stem diameter of cashew seedlings at 1, 2 and 4 MAP in Uhonmora soil and 1 to 4 MAP in Ibadan soil (Table 3). However, the stem diameter of cashew seedlings was significantly ($p < 0.05$) affected by the interaction of P-sources, nut sizes and AM inoculation in Uhonmora soil at 3 MAP. The stem diameter of seedlings from large nuts with or without AM inoculation under SSP application was significantly ($p < 0.05$) higher than seedlings from small nuts without AM inoculation at 3 MAP in Uhonmora soil. AM inoculation of seedlings from small nuts and SSP application increased the stem diameter of cashew seedlings by 55.8 % compared with seedlings from small nuts without AM inoculation at 3 MAP in Uhonmora soil. In addition, the stem diameter of cashew seedlings from large nuts without AM inoculation was significantly ($p<0.05$) higher than seedlings from small nuts with or without AM inoculation. The value was significantly ($p < 0.05$) higher than seedlings from small nuts with or without AM inoculation when no P was applied at 2 MAP in Ibadan soil.

Table 2: Height of cashew seedlings as influenced by phosphorus sources, nut size and mycorrhiza inoculation in soils from two locations under greenhouse conditions

P Sources	Nut Size	Mycorrhiza Inoculation	Months After Planting			
			1	2	3	4
		Uhonmora				
Control	Small	M	9.70a	18.18ab	19.40ab	20.25ab
	Small	NM	13.81a	18.00ab	26.33a	26.00a
	Large	M	11.50a	16.13ab	22.10ab	18.76a
	Large	NM	13.60a	18.20ab	22.50ab	29.00a
SSP	Small	M	12.20a	19.02a	27.40a	24.65a
	Small	NM	8.46a	12.03b	11.70b	21.91a
	Large	M	11.80a	16.83ab	20.05ab	30.66a
	Large	NM	12.90a	17.92ab	29.03a	30.66a
SRP	Small	M	14.66a	18.33ab	20.43ab	21.93a
	Small	NM	12.35a	16.33ab	25.40a	29.50a
	Large	M	12.78a	17.72ab	23.73ab	26.20a
	Large	NM	12.13a	17.17ab	18.86ab	21.43a
SE (0.05)			0.50	0.53	1.35	1.22
ANOVA						
P Sources (P)			Ns	Ns	ns	Ns
Nut size (NS)			Ns	Ns	ns	Ns
P x NS			Ns	Ns	ns	Ns
Mycorrhiza (M)			Ns	Ns	ns	Ns
P x M			Ns	Ns	ns	Ns
NS x M			Ns	Ns	ns	Ns
P x NS x M			Ns	Ns	*	Ns
		Ibadan				
Control	Small	M	12.30ab	18.50ab	23.30a	24.00bcd
	Small	NM	4.25b	7.05b	11.20b	12.70d
	Large	M	17.15a	22.45a	26.75a	27.50ab
	Large	NM	13.86ab	19.56ab	25.46a	25.56abc
SSP	Small	M	9.20ab	13.90ab	16.20a	14.83cd
	Small	NM	7.55ab	11.00ab	14.25a	14.50cd
	Large	M	13.03ab	16.93ab	23.50a	25.66abc
	Large	NM	16.75a	20.95a	22.65a	29.85a
SRP	Small	M	8.36ab	13.46ab	15.73a	16.66bcd
	Small	NM	8.90ab	11.10ab	15.55a	15.73cd
	Large	M	11.10ab	16.33ab	21.76a	22.16abcd
	Large	NM	15.10ab	18.50ab	25.55a	26.00abc
SE (0.05)			1.14	1.68	1.51	1.73
ANOVA						
P Sources (P)			ns	ns	ns	ns
0Nut size (NS)			**	**	**	**
P x NS			ns	ns	ns	ns
Mycorrhiza (M)			ns	ns	ns	ns
P x M			ns	ns	ns	ns
NS x M			ns	ns	ns	ns
P x NS x M			ns	ns	ns	*

For each location, means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test at ($p < 0.05$), M = with mycorrhiza inoculation, NM = without mycorrhiza inoculation *, ** significant at 5 and 1% respectively, ns = not significant.

Table 3: Stem diameter (cm) of cashew seedlings as influenced by phosphorus sources, nut sizes and mycorrhiza inoculation in soils from two locations under greenhouse conditions

P Sources	Nut Size	Mycorrhiza Inoculation	Months After Planting			
			1	2	3	4
Uhonmora						
Control	Small	M	0.46a	0.57ab	0.67ab	0.72a
	Small	NM	0.47a	0.58ab	0.76a	0.73a
	Large	M	0.58a	0.58ab	0.64ab	0.83a
	Large	NM	0.64a	0.59ab	0.69ab	0.66a
SSP	Small	M	0.50a	0.55ab	0.67ab	0.75a
	Small	NM	0.53a	0.52ab	0.43b	0.65a
	Large	M	0.52a	0.61ab	0.90a	0.77a
	Large	NM	0.59a	0.60ab	0.76a	0.81a
SRP	Small	M	0.49a	0.58ab	0.68ab	0.66a
	Small	NM	0.50a	0.60ab	0.72a	0.85a
	Large	M	0.62a	0.65a	0.70ab	0.80a
	Large	NM	0.58a	0.63ab	0.74a	0.71a
SE (0.05)			0.02	0.01	0.03	0.02
ANOVA						
P Sources (P)			ns	ns	ns	ns
Nut size (NS)			ns	*	ns	ns
P x NS			ns	ns	ns	ns
Mycorrhiza (M)			ns	ns	ns	ns
P x M			ns	ns	ns	ns
NS x M			ns	ns	ns	ns
P x NS x M			ns	ns	*	ns
Ibadan						
Control	Small	M	0.48ab	0.51cd	0.72bc	0.63bc
	Small	NM	0.33b	0.42cd	0.43cd	0.48c
	Large	M	0.45b	0.58abc	0.74bc	0.75abc
	Large	NM	0.49ab	0.62ab	0.82ab	0.66bc
SSP	Small	M	0.36b	0.48bcd	0.68bc	0.70abc
	Small	NM	0.52ab	0.37d	0.64bc	0.51c
	Large	M	0.48ab	0.63ab	0.77bc	0.85ab
	Large	NM	0.70a	0.72a	0.97a	0.96a
SRP	Small	M	0.42b	0.46bcd	0.60c	0.58bc
	Small	NM	0.35b	0.49bcd	0.65bc	0.58bc
	Large	M	0.57ab	0.57abc	0.74bc	0.67bc
	Large	NM	0.57ab	0.61ab	0.80ab	0.57c
SE (0.05)			**0.03**	**0.03**	**0.04**	**0.04**
ANOVA						
P Sources (P)			ns	ns	ns	ns
Nut size (NS)			**	**	**	**
P x NS			ns	ns	ns	ns
Mycorrhiza (M)			ns	ns	ns	ns
P x M			*	ns	ns	ns
NS x M			ns	ns	**	ns
P x NS x M			ns	ns	ns	ns

For each location, means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test at (p< 0.05), M = with mycorrhiza inoculation, NM = without mycorrhiza inoculation, *, ** significant at 5and 1% respectively, ns = not significant.

The above results are consistent with the findings of Utkhede, *et al* (2008) in which the growth of apple seedlings was enhanced by mychorrhizal inoculation either applied singly or in combination inorganic fertilizer or nitrogen fixing bacteria. The shoot and total dry matter yield of seedlings from large nuts without AM inoculation under SSP application was significantly ($p < 0.05$) higher than the shoot and total dry matter yield of seedlings from small nuts with or without AM inoculation in Uhonmora (Table 3). AM inoculation of seedlings from large nuts under SSP application improved the shoot dry matter by 76.6 % compared to shoot dry matter of seedlings from small nuts with or without AM inoculation in Uhonmora soil. Similarly, the total dry matter yield of cashew seedlings from large nuts improved by 92.8 and 54.7 % for seedlings from small nuts with AM inoculation and small nuts without AM-inoculation in Uhonmora soil respectively. In Ibadan soil, AM inoculation significantly ($p < 0.05$) enhanced the root, shoot and total dry matter yield of seedlings from large nuts when no P was applied. In addition, AM inoculation significantly ($p < 0.05$) increased the root, shoot and total dry matter of cashew seedlings from small nuts compared to its counterpart without AM inoculation in Ibadan (Table 4). Large nuts without AM inoculation also improved the root, shoot and total dry matter of cashew seedlings significantly ($p < 0.05$) when no P was applied. Similarly, under SSP application seedlings from small nuts with or without AM inoculation had significantly ($p < 0.05$) higher root, shoot and total dry matter compared to seedlings from large nuts with or without AM inoculation in Ibadan soil (Table 4). The influence of SSP being superior to SRP may be due to its solubility in water which accounts for its availability in the soil (Haugen and Smith, 1993). When SRP was applied, the root, shoot and total dry matter of cashew seedlings from large nuts were significantly ($p<0.05$) higher with or without AM inoculation compared small nuts (Table 4). The total N, P, K and Mg uptake of cashew seedlings were not significantly affected by the interaction of phosphate fertilizers, cashew nut size and AM inoculation in Uhonmora soil (Table 5). In addition, large nut without AM inoculation had higher ($p < 0.05$) total K and Ca uptake under SSP application compared to small nuts with or without AM inoculation when SSP was applied. Similarly, the total Mg uptake of large nuts without AM inoculation under SSP application was significantly ($p < 0.05$) higher than small nuts under similar condition. In contrast, AM inoculation of small nuts under SRP application significantly ($p < 0.05$) increased the total Mg uptake of cashew seedlings in Uhonmora soil (Table 5). In Ibadan soil, phosphate fertilizer, nut size and AM inoculation significantly ($p<0.05$) enhanced the total N, P, K, Ca and Mg uptake of cashew seedlings. Arbuscular mycorrhizal inoculation of large nuts significantly ($p<0.05$) increased the total N, K and Mg uptake of cashew seedlings when no P was applied compared to large nuts without AM and small nuts with or without AM inoculation under similar situation in Ibadan soil. In addition, small nuts with AM inoculation significantly ($p<0.05$) enhanced the total Mg uptake when no P was applied when compared to its counterpart without AM inoculation under similar condition. Conversely, small nuts without AM inoculation significantly ($p < 0.05$) had higher total N, P, K, Ca and Mg when SSP was applied compared to small nuts with AM inoculation and large nuts with or without AM inoculation in Ibadan soil. However, small nuts inoculated with AM under SSP application enhanced total Ca and Mg uptake of cashew seedlings compared with large nuts with or without AM inoculation when SSP was applied in Ibadan soil (Table 5). The enhancement of plant biomass and nutrient uptake is due to the symbiotic relationship between the root of the cashew and mychorrhizal fungus. The results obtained in this work are in line with the findings of Cabello *et al* (2004) and Caravaca *et al.,* (2004). The total N uptake of seedlings from small nuts with AM inoculation under SSP application was significantly ($p<0.05$) higher than the total N uptake of cashew seedling from large nuts without AM inoculation. Similarly, the total P uptake of cashew seedlings inoculated with AM under SSP application was significantly higher ($p < 0.05$) compared to large nuts with AM inoculation under similar situation in Ibadan soil. AM inoculation of large nuts when SRP was applied significantly ($p<0.05$) enhanced the total N, P, K and Mg uptake of cashew seedlings compared to small nuts with or without AM inoculation and large nuts without AM inoculation in Ibadan soil.

Table 4: Dry matter of cashew seedlings as influenced by phosphorus sources, nut size and mycorrhiza inoculation in soils from two locations under greenhouse conditions at 4 MAP

P sources	Nut Size	Mycorrhiza Inoculation	Dry Matter (g $plant^{-1}$)		
			Root	Shoot	Total
Uhonmora					
Control	Small	M	1.83a	4.63ab	6.46ab
	Small	NM	1.26a	4.55ab	5.81ab
	Large	M	1.56a	3.83b	5.39b
	Large	NM	1.40a	3.35b	4.75b
SSP	Small	M	1.77a	3.76b	5.53b
	Small	NM	1.10a	3.76b	4.86b
	Large	M	1.95a	6.64ab	8.59ab
	Large	NM	2.10a	8.75a	10.85a
SRP	Small	M	1.54a	4.14ab	5.68b
	Small	NM	1.75a	5.98ab	7.73ab
	Large	M	1.00a	5.45ab	6.45ab
	Large	NM	1.21a	4.35ab	5.56ab
SE (0.05)			0.29	0.45	0.51
ANOVA					
P Sources (P)			ns	ns	ns
Nut size (NS)			ns	ns	ns
P x NS			ns	*	ns
Mycorrhiza (M)			ns	ns	ns
P x M			ns	ns	ns
NS x M			ns	ns	ns
P x NS x M			ns	ns	ns
Ibadan					
Control	Small	M	2.54c	7.28c	9.82c
	Small	NM	2.10d	6.03d	8.13d
	Large	M	3.35a	9.57a	12.92a
	Large	NM	2.88bc	8.24bc	11.12bc
SSP	Small	M	2.55c	7.29c	9.84c
	Small	NM	3.32a	9.49a	12.81a
	Large	M	1.79d	5.12d	6.91d
	Large	NM	1.71d	4.90d	6.61d
SRP	Small	M	1.29e	3.70e	4.99e
	Small	NM	1.11e	3.16e	4.27e
	Large	M	3.11ab	8.88ab	11.99ab
	Large	NM	2.98ab	8.53ab	11.51ab
SE (0.05)			0.23	0.64	0.86
ANOVA					
P Sources (P)			**	**	**
Nut size (NS)			**	**	**
P x NS			**	**	**
Mycorrhiza (M)			ns	ns	ns
P x M			**	**	**
NS x M			ns	ns	ns
P x NS x M			**	**	**

For each location, means in column followed by the same letter(s) are not significantly different according to Duncan'sMultiple Range Test ($p < 0.05$). M = with mycorrhizal inoculation, NM = no mycorrhizal inoculation, *, ** =significant at 5 and 1% respectively, ns = not significant.

Table 5: Total nutrient uptake of cashew seedlings as influenced by phosphorus sources, nut size and mycorrhizal inoculation in soils from two locations under greenhouse conditions at 4 MAP

P Source	Nut Size	Mycorrhizal Inoculation	Total Nutrient Uptake at 4 MAP (mg/plant)				
			N	P	K	Ca	Mg
Uhonmora							
Control	Small	M	163.67a	7.58ab	59.30ab	42.28b	22.85ab
	Small	NM	127.79a	7.13ab	47.07b	48.01b	22.90ab
	Large	M	126.08a	6.60ab	34.53b	25.58b	15.50b
	Large	NM	113.98a	9.06ab	30.97b	42.14b	14.65b
SSP	Small	M	104.47a	5.16b	39.91b	35.22b	19.89ab
	Small	NM	103.87a	4.48b	45.41b	30.78b	14.12b
	Large	M	162.99a	9.70ab	58.35ab	42.43b	26.67ab
	Large	NM	169.52a	11.52ab	96.32a	84.41a	37.88a
SRP	Small	M	138.79a	7.11ab	44.93b	31.69b	37.88a
	Small	NM	122.69a	14.36a	55.42ab	63.49ab	15.60b
	Large	M	160.13a	9.79ab	71.00ab	50.47b	30.16ab
	Large	NM	131.09a	7.56ab	54.46ab	40.54b	30.80ab
SE (0.05)			6.79	0.79	5.11	4.63	2.50
ANOVA							
P Sources (P)			ns	ns	ns	ns	ns
Nut size (NS)			ns	ns	ns	ns	ns
P x NS			ns	ns	*	*	ns
Mycorrhiza (M)			ns	ns	ns	ns	ns
P x M			ns	ns	ns	ns	ns
NS x M			ns	ns	ns	ns	ns
P x NS x M			ns	ns	ns	*	ns
Ibadan							
Control	Small	M	151.28cd	9.91cd	66.96b	69.91def	27.78cd
	Small	NM	151.70cd	10.61c	59.02bc	52.06gh	22.79ef
	Large	M	238.36a	11.01bc	87.97a	66.29ef	34.75b
	Large	NM	191.11b	10.55c	64.78b	73.93de	26.46de
SSP	Small	M	159.77cd	6.89e	53.21cd	81.52cd	32.20bc
	Small	NM	248.97a	13.53a	79.03a	106.76a	45.05a
	Large	M	135.95de	5.51f	49.77cd	48.75h	18.09f
	Large	NM	113.26e	3.80g	47.30d	60.71fg	21.74ef
SRP	Small	M	80.79f	4.26fg	25.64e	41.83h	12.40g
	Small	NM	71.17f	5.33f	28.38e	28.13i	11.53g
	Large	M	241.16	12.30ab	82.50a	92.51bc	43.35a
	Large	NM	177.75bc	8.95d	64.47b	93.94b	25.50de
SE (0.05)			17.18	0.95	9.66	6.72	3.09
ANOVA							
P Sources (P)			**	**	**	**	**
Nut size (NS)			**	Ns	**	**	**
P x NS			**	**	**	**	**
Mycorrhiza (M)			ns	ns	ns	ns	**
P x M			**	**	**	*	**
NS x M			**	**	**	ns	**
P x NS x M			*	**	*	**	*

For each location, means in columns followed by the same letter(s) are not significantly different according toDuncan's Multiple Range Test at (p<0.05), M = with mycorrhiza inoculation, NM = without mycorrhiza inoculation, *, ** significant at 5 and 1% respectively, ns = not significant.

Table 6: Soil chemical properties as influenced by P-fertilizers on AM inoculated cashew seedlings from different nut sizes in soils from two locations under greenhouse conditions at 4 MAP

P Source	Nut Size	Mycorrhizal Inoculation	Soil Test Values				
			pH	Avail. P (mg/kg)	Inorg. P (mg/kg)	Org. P (mg/kg)	Total P (mg/kg)
Uhonmora							
Control	Small	M	5.84ab	14.17a	138.81ab	127.30b	266.10b
	Small	NM	6.10a	13.20a	127.14de	143.30b	270.40b
	Large	M	6.08a	15.65a	125.38e	120.30b	245.70b
	Large	NM	6.14a	12.11a	134.14bcd	134.70b	268.80b
SSP	Small	M	5.74b	13.11a	143.78a	122.90b	266.70b
	Small	NM	5.72b	13.88a	136.50abc	113.00b	249.50b
	Large	M	5.66b	13.88a	136.10abc	121.70b	257.70b
	Large	NM	5.75b	13.88a	142.67ab	122.40b	265.07b
SRP	Small	M	5.74b	11.71a	129.09cde	192.70a	321.79a
	Small	NM	5.68b	11.37a	122.32e	129.50b	251.80b
	Large	M	5.95ab	15.50a	138.64ab	110.50b	249.40b
	Large	NM	6.08a	12.57a	141.51ab	116.20b	257.70b
SE (0.05)			0.05	0.39	13.50	17.12	5.78
ANOVA							
P Sources (P)			ns	ns	*	ns	ns
Nut size (NS)			ns	**	**	*	ns
P x NS			ns	ns	ns	*	ns
Mycorrhiza (M)			ns	ns	ns	ns	ns
P x M			ns	ns	ns	ns	ns
NS x M			**	ns	*	ns	ns
P x NS x M			*	ns	*	ns	ns
Ibadan							
Control	Small	M	6.50ab	20.52a	49.14a	113.14b	162.28a
	Small	NM	6.63a	14.47abc	42.02ab	138.96a	180.98a
	Large	M	6.56a	9.47bc	30.65c	142.43a	173.08a
	Large	NM	6.32b	10.10bc	40.28ab	83.13c	123.42b
SSP	Small	M	6.46b	11.05bc	16.42d	138.67a	155.09a
	Small	NM	6.57a	10.55bc	45.16ab	131.70ab	176.86a
	Large	M	6.57a	8.45c	31.03c	128.66ab	159.69a
	Large	NM	6.55a	14.21abc	27.90c	128.17ab	156.07a
SRP	Small	M	6.59a	14.05abc	39.10ab	140.09a	179.19a
	Small	NM	6.47ab	9.16c	51.43a	132.91ab	184.34a
	Large	M	6.58a	12.07bc	39.44ab	142.55a	181.99a
	Large	NM	6.49ab	16.77ab	34.18c	139.76a	173.94a
SE (0.05)			0.02	1.03	2.83	4.90	5.00
ANOVA							
SP Sources (P)			*	ns	ns	**	**
Nut size (NS)			*	ns	ns	ns	ns
P x NS			ns	ns	ns	ns	ns
Mycorrhiza (M)			ns	ns	ns	*	ns
P x M			ns	ns	ns	ns	ns
NS x M			*	ns	ns	**	*
P x NS x M			ns	*	*	**	*

For each location, means in columns followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test at ($p<0.05$), M = with mycorrhiza inoculation, NM = without mycorrhiza inoculation, *, ** significant at 5 and 1% respectively, ns = not significant.

Large nuts with AM inoculation under SRP application consistently and significantly ($P<0.05$) enhanced the total N, P, K and Mg uptake of cashew seedlings in comparison with large nuts without AM inoculation and small nuts with or without AM inoculation in Ibadan soil. However, large nuts without AM inoculation under SRP application significantly ($p<0.05$) improved the total uptake of N, P, K and Ca compared to small nuts with or without AM inoculation under similar situation in Ibadan soil. AM inoculation increased the total Ca uptake of small nuts by 48.7 % which is significantly ($p<0.05$) higher than its counterpart without AM inoculation in Ibadan soil. Ogoke *et al.,* (2004) found that grain dry-weight of soybeans was significantly increased by P application at sites where initial soil test P was 6.2 $mgkg^{-1}$ but where initial soil test P was high, the application of P depressed grain yield. Nevertheless, the performance of SSP in terms of dry matter accumulation and nutrient uptake in Uhonmora and Ibadan soils was significantly higher than that of SRP due to its higher solubility. This result is consistent with findings of Haugen and Smith, (1993) who reported that plants receiving SSP were significantly larger than plants receiving only basic nutrients after six weeks. Direct application of rock phosphate as fertilizers, have not produced conclusive results. Ghosh, (1999) found that application of finely ground rock phosphate was as effective as SSP, whereas in some other reports by Haugen and Smith, (1993), showed that rock phosphate performed less than SSP. The interaction of phosphate fertilizers, cashew nut sizes and AM inoculation was not significant on soil available P, organic P, total P in Uhonmora (Table 6). However, soil pH and inorganic P were significantly ($p< 0.05$) affected by the treatment combinations. In particular, under AM inoculation and small nuts, inorganic P of the soil was increased compared to small nuts without AM inoculation and large nuts with AM inoculation when no P was applied in Uhonmora soil. Similarly, large nuts without AM inoculation significantly ($p< 0.05$) enhanced the accumulation of inorganic P compared to its counterpart with AM inoculation when no P was applied in Ibadan soil (Table 6). In Uhonmora small nuts inoculated with AM significantly enhanced the accumulation of organic and total P compared to small nuts without AM and large nuts with or without AM inoculation under SRP application in Uhonmora soil. Similarly, large nuts without AM inoculation under SRP application also significantly ($p < 0.05$) increased the soil pH compared to small nuts with or without AM under similar situation. The P-fractions (organic and total P) of Uhonmora soil when SRP was applied to large nuts without AM increased by 5.2 % and 3.3 % respectively. The influence of P fertilizers, AM inoculation and nut sizes was significant ($p< 0.05$) on soil available P, inorganic P, organic P and total P but not on soil pH in Ibadan soil (Table 6). On a specific note, small nuts without AM inoculation under no P application significantly ($p< 0.05$) increased the soil pH compared to large nut with AM under SSP application in Ibadan soil. However, AM inoculation of small nuts without P application significantly ($p< 0.05$) increased soil available P and inorganic P compared to AM inoculated large nuts when no P was applied in Ibadan soil (Table 6). Large nuts inoculated with AM increased significantly ($p< 0.05$) the soil pH and total P by 3.8 % and 40.6 % respectively when no P was applied in Ibadan soil. Similarly, small nuts without AM inoculation under SSP application significantly ($p< 0.05$) increased the pH and inorganic P in Ibadan soil. The total soil P content in Ibadan was increased by 14.0 % as result of SSP application to un-inoculated cashew seedlings. Similarly, the available P of Ibadan soil when SRP was applied to large nuts without AM inoculation significantly ($p< 0.05$) improved compared to small nuts without AM under similar treatments. The inorganic P of Ibadan soil also improved by 50.5 % when SRP was applied to small nuts without AM inoculation compared to large nuts without AM inoculation. Plant height was significantly correlated ($r = 0.35^*$) with AM infection in the root of cashew in Uhonmora soil. However, in Ibadan soil, they indicated low correlation ($r = 0.12$) (Table 7). Similarly, stem diameter had significant correlation with plant height in Ibadan ($r = 0.60^{**}$) and Uhonmora ($r = 0.45^{**}$). In the same vein, total dry matter and total nutrient uptake (P, K, Ca and Mg) were significantly correlated with total nitrogen uptake of cashew seedlings in the two soils (Table 7).

Table 7: Relationship among plant and soil variables of cashew as affected by cashew nut size phosphate fertilizers and AM inoculation under greenhouse conditions in Ibadan (above diagonal) and Uhonmora (below diagonal)

Variables		1	2	3	4	5	6	7	8	9	10	11	12
Mycorrhizal Infection	(1)		0.18	0.22	0.15	0.06	0.20	-0.01	0.13	0.11	-0.07	-0.15	-0.15
Total N Uptake	(2)	0.02		0.87**	0.95**	0.82*	0.92**	0.12	-0.09	0.95**	-0.00	0.08	0.02
Total P Uptake	(3)	-0.00	0.78**		0.87**	0.70**	0.82**	-0.11	-0.38*	0.86**	0.09	-0.05	0.15
Total K Uptake	(4)	0.16	0.94**	0.78*		0.76**	0.88**	0.18	-0.06	0.95**	-0.01	-0.05	0.01
Total Ca Uptake	(5)	0.10	0.83**	0.86**	0.91**		0.87**	-0.06	-0.13	0.87**	-0.05	0.10	0.18
Total Mg Uptake	(6)	0.14	0.89**	0.88**	0.93**	0.93**		-0.02	-0.08	0.89**	0.04	0.06	-0.00
Height	(7)	0.35**	0.13	0.13	0.23	0.26	0.24		0.60**	0.14	-0.28	-0.12	-0.28
Stem Diameter	(8)	0.27	0.20	0.17	0.23	0.22	0.26	0.45**		-0.14	-0.37*	-0.27	0.51**
Total Diameter	(9)	0.08	0.95**	0.78**	0.91**	0.92**	0.24	0.25			0.07	0.07	0.15
Total soil P	(10)	0.01	0.05	-0.00	-0.00	-0.05	-0.07	-0.00	-0.09	-0.00		-0.03	0.13
Total Acidity	(11)	-0.16	0.28	0.19	0.30	0.27	0.18	-0.07	-0.19	0.24	-0.11		0.05
MBAR	(12)	0.02	0.07	0.00	0.14	0.13	0.09	0.09	-0.12	0.09	-0.26	0.45**	

*** Significant at 5 and 1% respectively.

Total dry matter had significant ($p<0.05$) correlations with total P, K and Ca uptake of cashew seedlings in Ibadan and Uhonmora soils. However, total dry matter yield had low correlation ($r = 0.24$) with total Mg uptake by cashew seedlings in Uhonmora soil but in Ibadan the correlation was highly significant ($p<0.05$) (r=0.89**). Total Mg uptake had significant correlation with total P, K and Ca uptake in both Ibadan and Uhonmora soils. Similarly, total K uptake by cashew seedlings was significantly correlated to Ca uptake in both locations. Total nutrient uptake (N, P, K, Ca and Mg), stem diameter, total dry matter and total soil P had low correlation with AM infection of cashew roots in both soils of Ibadan and Uhonmora. In addition, total acidity and molar basic aluminum ratio (MBAR) were negatively related to the AM colonization of cashew roots in Ibadan soil. However, in Uhonmora soil, only total acidity was negatively related ($r = -0.16$) to root colonization by AM (Table 7). In Uhonmora soil, MBAR correlated significantly (r = 0.45**) with total exchangeable acidity. Conversely, in Ibadan soil, it had very low correlation ($r = 0.05$). Total acidity in the soils of Ibadan and Uhonmora correlated negatively with cashew height and stem diameter. Similarly, MBAR correlated negatively with stem diameter in Ibadan soil (r = -0.51**) and in Uhonmora soil ($r = -0.12$).

CONCLUSIONS

The interaction effect of nut size and AM inoculation was significant ($p<0.05$) on the growth (height and stem diameter) of cashew seedlings at 2, 3 and 4 MAP in Ibadan soil and 1-4 MAP in Uhonmora soil. Phosphate fertilizers treated-cashew seedlings from large nuts inoculated with AM had higher height and stem diameter than those from small nuts under similar treatments. The dry matter of cashew seedlings was significantly improved by large nut size in Ibadan soil only while it only improved the dry matter yield by 20.3 % in Uhonmora soil. Sokoto rock phosphate had comparable influence with SSP on the growth of cashew in the greenhouse studies. Hence, when SSP is not available, Nigerian Sokoto rock phosphate is a viable option for cashew production. In addition, cashew large nut size gave initial seedling growth advantage over that of small sized nuts only at the juvenile stage but as the plants age the influence fizzles out. Inoculation of cashew with exotic AM may not be necessary because cashew easily forms association with native mycorrhizaea in the soil and thus making the external addition of AM to increase the cost of input to cashew production.

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