Nigerian Journal of Soil Science
Journal homepage:www.soilsjournalnigeria.com

EFFECTS OF ARBUSCULAR MYCORRHIZA AND FERTILIZERS ON SOIL CHEMICAL PROPERTIES, GROWTH AND FIBRE YIELD OF KENAF (*Hibiscus cannabinus* LINN.) IN A NUTRIENT DEGRADED SOIL

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ABSTRACT
This study determined effects of fertilizers and Arbuscular Mycorrhizal (AM) inoculation on soil chemical properties, growth and fibre yield of kenaf. The experimental design was split-plot in Randomized Complete Block Design. Mycorrhizal inoculation was the main plot: with mycorrhiza (M+) and without (M-) and twelve fertilizer levels as the sub-plot: 0, NPK 20:10:10 (60 kg N ha^{-1}), purely composted market waste (20, 40, 60, 80 and 100 kg N ha^{-1}), and composted market waste fortified with superphosphate and urea (20, 40, 60, 80 and 100 kg N ha^{-1}) and replicated three times. Residual effect of the treatments was also determined. Data on soil chemical properties, AM Root Colonization (RC), stem diameter, plant height, bast and core yield were collected and analysed using descriptive statistics and ANOVA. Optimum stem diameter, plant height, RC, bast and core yields of 2.3 cm, 269.8 cm, 85.9 %, 3.8 t ha^{-1} and 9.4 t ha^{-1} respectively were obtained at M+ 40 kg N ha^{-1} Composted Market Waste Fortified With Superphosphate and Urea (CMWFWSAU). After harvesting, M- 100 kg N ha^{-1} Purely Composted Market Waste (PCMW) had the highest organic matter: 25.9 g kg^{-1}, total N: 0.8 g kg^{-1}, available P: 6.8 mg kg^{-1}, exchangeable K: 0.4 cmol kg^{-1} and Ca: 9.6 cmol kg^{-1}. For the residual effect, M+ 100 kg N ha^{-1} PCMW had significantly ($p < 0.05$) highest RC (69.0 %), bast (2.7 t ha^{-1}) and core (5.8 t ha^{-1}) yields. Considering the 60 kg N ha^{-1} of fertilizers, PCMW had the highest bast and core yields followed by CMWFWSAU and NPK. The highest soil organic matter was observed in M- 100 kg N ha^{-1} PCMW.
Key words: Arbuscular mycorrhiza, Fertilizers, Kenaf fibre, Soil chemical properties

INTRODUCTION

In a nutrient degraded soil, high and sustainable crop production requires the use of fertilizer. Although high crop yield can be obtained with judicious application of inorganic fertilizer, it is not always easily available to the resource poor farmers because of high cost, logistics and other associated problems. Continuous application of inorganic fertilizer on agricultural land results in acidification of the soils (Yaro *et al.,* 1997). The use of organic fertilizer is also limited by large quantity required to meet crop needs because of its low nutrients content, such large quantity are obviously not obtainable and even if they were, transportation and handling costs would constitute a major constraint. In view of this, complimentary use of low chemical inputs and organic manure (Organo-mineral fertilizer) may be a cost effective economic strategy (Omueti *et al.*, 2000). As a way of reducing total dependence on the use of fertilizer, an integrated fertility management system focusing on biological approach, which is eco-friendly and less expensive, is desirable. Mycorrhiza is a symbiotic association between plant root and specialized soil fungi with evidence that it helps plants in nutrient acquisition of immobile nutrients such as P, N, Zn and Cu in deficient soils (Clark and Zeto, 2000; Hodge 2003; Dare *et al.,* 2008; Ibiremo and Fagbola, 2008).

Kenaf (*Hibiscus cannabinu*s L.) is a member of the Malvaceae family native to east-central Africa (Wilson, 2003). Its economic importance include fibre and food (Bert, 2002; Zhang, 2003), medicine (Cheng, 2001), medium for mushroom cultivation (Cheng, 2001; Liu, 2003), phytoremediation (Bada and Kalejaiye, 2010; Bada and Raji, 2010; Bada and Umunnakwe, 2011), oil and chemical absorbents (Sameshima, 2000).

Therefore, for sustainable kenaf production in a nutrient degraded soil, there is need to study effect of arbuscular mycorrhizal inoculation, NPK (20:10:10), purely composted market waste and composted market waste fortified with superphosphate and urea on the soil chemical properties, growth and fibre yield of kenaf.

MATERIALS AND METHODS

Description of the study area, plot and planting materials

The field experiment was carried out at the Institute of Agricultural Research and Training (IAR&T) Moor Plantation, Ibadan, on Latitude 7 ° 22.5 ′ N and Longitude 3 ° 50.5 ′ E in the Rainforest of South-Western Nigeria. The plot used has been under continuous cultivation with the continuous application of inorganic fertilizer over ten years. Two types of market waste-based fertilizers produced by Pacesetter Organic Fertilizer Company, Ibadan, Nigeria namely: composted market waste fortified with superphosphate and urea (Grade A fertilizer) and purely composted market waste without any additive (Grade B fertilizer). Prior to application, the two fertilizers were taken to the laboratory for proximate analysis. However, N.P.K. 20:10:10 fertilizer at recommended rate of 60 kg N ha^{-1} (Ogunbodede and Adediran, 1996) was also used. Mycorrhizal inoculum (*Glomus mosseae*) consisting of chopped roots of the trapping plant, hyphae, spores and soil was collected from the Soil Microbiology Laboratory, Department of Agronomy, University of Ibadan, Ibadan, Nigeria. Cuba 108 variety of kenaf suitable for different agro-ecological zones in Nigeria (IAR&T, 1997) was collected from IAR&T, Ibadan.

Soil sample collection and analysis

Representative topsoil (0 – 15 cm) samples were collected from Research farm of IAR&T. Sub-samples were taken, air dried and crushed in agate mortar and passed through a 2 mm sieve to determine the physical and chemical properties using standard methods. Arbuscular mycorrhiza infective propagule was also determined using the 'Most Probable Number' (MPN) technique (Porter, 1979).

Experimental design

The experimental design was split-plot in Randomized Complete Block Design. Mycorrhizal inoculation (with and without) was the main plot factor and twelve fertilizer levels: 0, NPK 20:10:10 (60 kg N ha^{-1}), purely composted market waste (20, 40, 60, 80 and 100 kg N ha^{-1}) and composted market waste fortified with superphosphate and urea (20, 40, 60, 80 and 100 kg N ha^{-1}) as the sub-plot factor. Each treatment was replicated three times.

Field preparation and sowing

After ploughing and harrowing, Purely Composted Market Waste (PCMW) and Composted Market Waste Fortified With Superphosphate And Urea (CMWFWSAU) were applied by incorporating into the soil after broadcasting using hoe to a depth of 5cm and sowing was carried out 24 hours after incorporation (Uhlen and Tveitnes, 1995). Inoculation was done with 20 g inoculum of *Glomus mosseae* by placing the crude inoculum directly under the seeds on the field. Kenaf was sown at 50 cm between and 20 cm within rows at the rate of 4-6 seeds per hole. After germination, the plants were thinned to one per stand. Each sub-plot measured 2 m × 0.8 m consisting of five rows and five columns making 25 plants per plot. NPK fertilizer was applied third week after sowing by side placement.

Data collection

Stem diameter (using Venier caliper) and plant height (using metre rule) were taken at

Table 1: Soil physical and chemical properties before planting on the field

Soil properties	Value
Sand (g kg^{-1})	780
Silt (g kg^{-1})	170
Clay (g kg^{-1})	50
Textural class	Sandy loam
pH (H_2O)	6.2
Organic matter (g kg^{-1})	13.1
Total N (g/kg)	1.2
Available P (mg kg^{-1})	2.71
K (cmol kg^{-1})	0.18
Ca (cmol kg^{-1})	1.61
Na (cmol kg^{-1})	0.52
Mg (cmol/kg)	2.01
Exch. acidity (cmol/kg)	0.1
ECEC (cmol/kg)	4.42
Base saturation (%)	97.32

sixth week after sowing and continued at two weeks interval until harvest (25 % flowering). Mycorrhizal colonization was quantified by the grid – line intersect method (Giovannetti and Mosse, 1980). After retting, bast and core yields were determined.

Table 2: Influence of mycorrhiza inoculation and fertilizers on the stem diameter (cm) of kenaf

Mycorrhiza inoculation	Fertilizers application	6	8	10	12	14
With	0	0.43	0.65	0.76	1.00	1.02
	NPK	0.91	1.08	1.51	1.90	1.97
	PCMW20	0.63	0.71	0.92	1.20	1.23
	PCMW40	0.80	0.89	1.25	1.50	1.65
	PCMW60	0.75	0.88	1.20	1.50	1.57
	PCMW80	0.73	0.82	1.10	1.43	1.48
	PCMW100	0.75	0.83	1.12	1.45	1.49
	CMWFWSAU20	0.65	0.79	1.06	1.32	1.36
	CMWFWSAU40	1.10	1.22	1.80	2.20	2.27
	CMWFWSAU60	0.98	1.10	1.54	2.01	2.02
	CMWFWSAU80	0.83	0.95	1.31	1.70	1.75
	CMWFWSAU100	0.85	0.99	1.35	1.78	1.83
Without	0	0.40	0.44	0.50	0.94	0.97
	NPK	0.87	1.05	1.41	1.81	1.82
	PCMW20	0.55	0.65	0.83	1.00	1.03
	PCMW40	0.70	0.79	1.07	1.42	1.45
	PCMW60	0.75	0.85	1.18	1.45	1.56
	PCMW80	0.72	0.82	1.08	1.42	1.47
	PCMW100	0.73	0.83	1.10	1.43	1.49
	CMWFWSAU20	0.65	0.72	0.93	1.20	1.26
	CMWFWSAU40	0.81	0.90	1.30	1.65	1.68
	CMWFWSAU60	0.89	1.07	1.51	1.86	1.97
	CMWFWSAU80	0.81	0.95	1.31	1.70	1.73
	CMWFWSAU100	0.83	0.98	1.35	1.73	1.76
SE						
Mycorrhiza (M)		0.0028	0.0034	0.0032	0.0031	0.0101
Fertilizers (F)		0.0069	0.0084	0.0077	0.0076	0.0248
Interaction M x F		0.0097	0.0119	0.0109	0.0108	0.0351
ANOVA						
M		***	***	***	***	***
F		***	***	***	***	***
Interaction M x F		***	***	***	***	***

6, 8, 10, 12 and 14 = Weeks after planting
NPK60 = 60 kg N ha^{-1} of NPK (20:10:10) fertilizer
PCMW20, PCMW40, PCMW60, PCMW80 and PCMW100 = 20, 40, 60, 80 and 100 kg N ha^{-1} of Purely Composted Market Waste.
CMWFWSAU20, CMWFWSAU40, CMWFWSAU60, CMWFWSAU80 and CMWFWSAU100 = 20, 40, 60, 80 and 100 kg N ha^{-1} of Composted Market Waste Fortified With Superphosphate And Urea
S.E. = Standard Error
*** represent level of significance at $p < 0.001$

Residual effects of arbuscular mycorrhiza and fertilizers

Field preparation and sowing

After harvesting, neither fertilizers nor mycorrhiza was applied. Sowing and other farm operations were carried out as done on the field experiment. Growth and yield parameters were determined. Arbuscular mycorrhizal colonization and soil chemical properties were determined as described earlier.

Statistical analyses

Data were analysed using descriptive statistics and analysis of variance (ANOVA). Test of significance of the means by the standard error.

RESULTS

Soil characteristics before sowing

The soil was sandy loam in texture, with a pH of 6.2 and low in nutrients like N, P and K (Table 1).

Influence of AM inoculation and fertilizers on the growth of kenaf

Mycorrhizal inoculation and fertilizer application rates significantly affected the stem diameter (Table 2) of kenaf. Inoculated kenaf at 0 fertilizer level had higher stem diameter than the non-inoculated counterpart at 0 fertilizer level from 8 to 14 WAP by percentage range of 5.2 – 7.5 % (Table 2). Increase in the levels of PCMW and CMWFWSAU without mycorrhizal inoculation significantly ($p < 0.001$) increased stem diameter from 20 to 60 kg N ha^{-1} of both PCMW and CMWFWSAU from 6 to 14 WAP. Among the 60 kg N ha^{-1} of the fertilizers applied without mycorrhizal inoculation, CMWFWSAU had significantly ($p < 0.001$) higher stem diameter than the PCMW (from 6 to 14 WAP) and NPK (from 10 to 14 WAP) fertilizer. On the effect of mycorrhizal inoculation and fertilizers application on stem diameter, significant ($p < 0.001$) differences were observed between inoculated kenaf with fertilizers application and non-inoculated kenaf with fertilizers application at 60 kg N ha^{-1} of NPK, 20 and 40 kg N ha^{-1} of PCMW and 40 kg N ha^{-1} of CMWFWSAU from 6 to 14 WAP.

Increase in the levels of PCMW and CMWFWSAU with mycorrhizal inoculation significantly ($p < 0.001$) increased stem diameter from 20 to 40 kg N ha^{-1}. Significantly ($p < 0.001$) higher stem diameter was observed in the inoculated kenaf at 40 kg N ha^{-1} of CMWFWSAU compared to other fertilizer levels with and without mycorrhizal inoculation.

Mycorrhizal inoculation without fertilizer application significantly ($p < 0.001$) increased plant height compared to the non-inoculated throughout the growth period (Table 3). At 14 WAP, increase in the levels of PCMW and CMWFWSAU without mycorrhizal inoculation significantly ($p < 0.001$) increased plant height. Among 60 kg N ha^{-1} of the fertilizers applied without mycorrhizal inoculation, CMWFWSAU had significantly ($p < 0.001$) higher plant height than PCMW. Inoculated kenaf with fertilizers application was higher than the non-inoculated with fertilizers application at 14 WAP with percentage increase ranging from 1.3 to 31.0 %. At 14 WAP, increase in the levels of PCMW and CMWFWSAU with mycorrhizal inoculation significantly ($p < 0.01$) increased plant height. Significantly ($p < 0.01$) higher plant height was observed in the inoculated kenaf at 40 kg N ha^{-1} of CMWFWSAU.

Table 3: Influence of mycorrhiza inoculation and fertilizers on the plant height (cm) of kenaf

Mycorrhiza inoculation	Fertilizers application	6	8	10	12	14
With	0	42.47	79.57	89.60	150.10	162.70
	NPK	78.27	125.17	170.17	217.27	233.20
	PCMW20	44.37	86.90	109.37	158.50	168.10
	PCMW40	60.17	110.60	150.57	200.27	215.87
	PCMW60	59.80	110.30	150.10	196.30	210.90
	PCMW80	52.87	102.60	141.60	173.10	191.97
	PCMW100	55.97	104.30	147.27	188.50	204.43
	CMWFWSAU20	45.50	95.90	121.70	164.97	181.87
	CMWFWSAU40	83.67	137.27	200.37	240.77	269.77
	CMWFWSAU60	80.27	133.77	180.27	219.57	237.83
	CMWFWSAU80	68.27	118.67	160.00	207.67	219.40
	CMWFWSAU100	75.27	121.87	160.40	210.40	225.93
Without	0	23.60	38.00	68.80	131.90	138.17
	NPK	75.67	122.87	161.30	210.47	226.77
	PCMW20	43.17	80.80	101.00	157.67	165.93
	PCMW40	48.30	100.27	134.60	171.07	182.67
	PCMW60	58.07	108.60	150.00	190.50	206.63
	PCMW80	51.77	101.90	140.20	171.60	183.37
	PCMW100	53.30	103.87	141.97	180.70	199.77
	CMWFWSAU20	45.00	89.67	120.77	162.37	176.57
	CMWFWSAU40	62.07	114.37	151.00	200.30	205.90
	CMWFWSAU60	75.67	122.87	164.87	212.67	229.94
	CMWFWSAU80	66.97	118.00	153.30	205.67	218.93
	CMWFWSAU100	70.17	120.47	160.17	210.17	223.60
SE						
Mycorrhiza (M)		0.4831	0.6332	0.5734	2.0200	1.6201
Fertilizers (F)		1.1834	1.5510	1.4045	4.9479	3.9685
Interaction M x F		1.6736	2.1935	1.9863	6.9974	5.6123
ANOVA						
M		***	***	***	***	***
F		***	***	***	***	***
Interaction M x F		***	***	***	*	**

6, 8, 10, 12 and 14 = Weeks after planting
NPK60 = 60 kg N ha^{-1} of NPK (20:10:10) fertilizer
PCMW20, PCMW40, PCMW60, PCMW80 and PCMW100 = 20, 40, 60, 80 and 100 kg N ha^{-1}of Purely Composted Market Waste.
CMWFWSAU20, CMWFWSAU40, CMWFWSAU60, CMWFWSAU80 and CMWFWSAU100 = 20, 40, 60, 80 and 100 kg N ha^{-1} of Composted Market Waste Fortified With Superphosphate And Urea
S.E. = Standard Error
*, ** and *** represent level of significance at $p < 0.05$, 0.01 and 0.001 respectively

Effects of arbuscular mycorrhiza and fertilizers on the yield and root colonization of kenaf

Bast, core and root colonization of kenaf were affected significantly ($p < 0.001$) by mycorrhizal inoculation and fertilizer application rates (Table 4). Bast yield of inoculated kenaf without fertilizer application was 38.3 % higher than the bast yield of the non-inoculated without fertilizer application. At 60 kg N ha^{-1} of the fertilizers without mycorrhizal inoculation, bast yield of the CMWFWSAU was 12.7 % higher than the bast yield of NPK fertilizer. At all levels of fertilizers application with and without mycorrhizal inoculation, significantly ($p < 0.001$) higher bast yield was observed in the inoculated kenaf at 40 kg N ha^{-1} of CMWFWSAU.

Core yield of inoculated kenaf without fertilizer application was higher than non-inoculated counterpart without fertilizer application by 10.4 % (Table 4). Increase in the levels of PCMW and CMWFWSAU without mycorrhizal inoculation significantly ($p < 0.001$) increased core yield from 20 to 60 kg N ha^{-1}. After 60 kg N ha^{-1} of the two fertilizers, core yield started decreasing by 21.9 and 21.3 % in PCMW and CMWFWSAU respectively. When compared core yield with reference to fertilizers application without mycorrhizal inoculation, 60 kg N ha^{-1} of NPK and CMWFWSAU had significantly ($p < 0.001$) higher core yield than PCMW. Core yield of the

Table 4: Influence of mycorrhiza inoculation and fertilizers on the colonization, bast and core yield (t ha^{-1}) of kenaf

Mycorrhiza inoculation	Fertilizers application	Bast	Core	Mycorrhizal colonization (%)
With	0	0.83	1.80	19.63
	NPK60	2.43	6.80	75.93
	PCMW20	1.33	2.77	23.93
	PCMW40	1.73	5.10	47.73
	PCMW60	1.67	4.90	39.47
	PCMW80	1.53	4.27	32.27
	PCMW100	1.63	4.63	31.80
	CMWFWSAU20	1.43	3.50	25.87
	CMWFWSAU40	3.78	9.37	85.93
	CMWFWSAU60	3.07	8.05	79.13
	CMWFWSAU80	1.83	5.80	62.60
	CMWFWSAU100	1.93	6.20	67.50
Without	0	0.60	1.63	16.87
	NPK60	2.13	6.37	65.20
	PCMW20	1.20	2.63	22.63
	PCMW40	1.33	3.60	26.93
	PCMW60	1.47	4.67	37.00
	PCMW80	1.37	3.83	28.50
	PCMW100	1.40	4.50	29.30
	CMWFWSAU20	1.27	3.40	25.03
	CMWFWSAU40	1.57	5.47	57.13
	CMWFWSAU60	2.40	6.97	72.60
	CMWFWSAU80	1.70	5.60	60.13
	CMWFWSAU100	1.80	5.70	64.03
	S.E.			
	Mycorrhiza (M)	0.05	0.09	0.50
	Fertilizers (F)	0.12	0.23	1.23
	Interaction			
	M × F	0.16	0.33	1.74
	ANOVA			
	M	***	***	***
	F	***	***	***
	Interaction			
	M × F	***	***	***

NPK60 = 60 kg N ha^{-1} of NPK (20:10:10) fertilizer
PCMW20, PCMW40, PCMW60, PCMW80 and PCMW100 = 20, 40, 60, 80 and 100 kg N ha^{-1}of Purely Composted Market Waste.
CMWFWSAU20, CMWFWSAU40, CMWFWSAU60, CMWFWSAU80 and CMWFWSAU100 = 20, 40, 60, 80 and 100 kg N ha^{-1} of Composted Market Waste Fortified With Superphosphate And Urea
S.E. = Standard Error,

*** represent level of significance at $p < 0.001$

60 kg N ha^{-1} of CMWFWSAU was higher than that of NPK by 9.4 %. Increase in the levels of PCMW and CMWFWSAU with mycorrhizal inoculation significantly ($p < 0.001$) increased the core yield from 20 to 40 kg N ha^{-1}. Thereafter, core yield decreased by 19.4 and 61.6 % in PCMW and CMWFWSAU respectively. Inoculated kenaf at 40 kg N ha^{-1} of CMWFWSAU had significantly ($p < 0.001$) higher core yield compared to other fertilizer levels with and without mycorrhizal inoculation.

Mycorrhizal colonization of inoculated kenaf at 0 fertilizer level was higher than the non-inoculated counterpart at the same fertilizer level by 16.4 % (Table 4). Increase in the levels of PCMW and CMWFWSAU without mycorrhizal inoculation significantly ($p < 0.001$) increased mycorrhizal colonization from 20 to 60

Table 5: Selected soil chemical properties after harvesting kenaf

Mycorrhiza inoculation	Fertilizers application	pH	Organic matter (g kg^{-1})	N (g kg^{-1})	P (mg kg^{-1})	K	Ca	Mg	Na
						(cmol kg^{-1})			
With	Control	5.90	10.40	0.40	2.93	0.14	2.92	0.26	0.02
	NPK	5.73	11.40	0.40	3.40	0.16	4.07	0.29	0.02
	PCMW20	6.23	15.90	0.50	4.13	0.20	5.52	0.27	0.03
	PCMW40	6.33	17.80	0.50	4.31	0.23	6.12	0.29	0.02
	PCMW60	6.37	18.70	0.50	5.55	0.30	6.47	0.34	0.02
	PCMW80	6.43	24.00	0.70	6.02	0.35	7.72	0.37	0.02
	PCMW100	6.40	24.90	0.70	6.35	0.39	9.42	0.39	0.03
	CMWFWSAU20	6.20	15.10	0.40	4.11	0.18	5.47	0.25	0.03
	CMWFWSAU40	6.30	16.30	0.40	4.31	0.24	5.67	0.27	0.02
	CMWFWSAU60	6.40	17.30	0.40	4.61	0.28	6.32	0.30	0.02
	CMWFWSAU80	6.43	21.20	0.60	4.69	0.32	6.37	0.33	0.02
	CMWFWSAU100	6.37	21.80	0.60	5.03	0.37	6.42	0.34	0.02
Without	Control	6.00	11.40	0.40	3.10	0.16	5.07	0.26	0.03
	NPK	5.90	12.40	0.40	3.81	0.19	5.92	0.27	0.03
	PCMW20	6.33	16.90	0.50	4.37	0.26	6.04	0.26	0.03
	PCMW40	6.33	18.70	0.50	5.23	0.32	7.07	0.26	0.03
	PCMW60	6.47	19.70	0.60	6.30	0.38	8.17	0.31	0.03
	PCMW80	6.50	24.60	0.70	6.35	0.40	8.27	0.34	0.03
	PCMW100	6.50	25.90	0.80	6.75	0.41	9.62	0.37	0.03
	CMWFWSAU20	6.33	15.90	0.40	4.20	0.21	5.97	0.25	0.03
	CMWFWSAU40	6.40	17.40	0.50	4.94	0.26	6.97	0.25	0.03
	CMWFWSAU60	6.40	18.30	0.50	5.34	0.31	7.12	0.29	0.03
	CMWFWSAU80	6.43	22.30	0.70	5.46	0.34	7.47	0.30	0.03
	CMWFWSAU100	6.43	22.90	0.70	6.19	0.39	8.17	0.34	0.03
	SE								
	Mycorrhiza (M)	0.022	0.002	0.002	0.001	0.002	0.001	0.003	0.002
	Fertilizers (F)	0.054	0.005	0.004	0.003	0.005	0.002	0.007	0.005
	Interaction								
	M x F	0.076	0.006	0.006	0.005	0.008	0.003	0.01	0.006
	ANOVA								
	M	ns	***	ns	***	***	***	ns	ns
	F	***	***	***	***	***	***	***	ns
	Interaction								
	M x F	ns	*	ns	***	***	***	*	ns

NPK60 = 60 kg N ha^{-1} of NPK (20:10:10) fertilizer
PCMW20, PCMW40, PCMW60, PCMW80 and PCMW100 = 20, 40, 60, 80 and 100 kg N $ha^{-1}$of Purely Composted Market Waste.
CMWFWSAU20, CMWFWSAU40, CMWFWSAU60, CMWFWSAU80 and CMWFWSAU100 = 20, 40, 60, 80 and 100 kg N ha^{-1} of Composted Market Waste Fortified With Superphosphate And Urea
S.E. = Standard Error, ns = not significant,
* and *** represent level of significance at $p < 0.05$ and 0.001

kg N ha^{-1}. Declining in percentage mycorrhizal colonization started at 80 kg N ha^{-1} of the two fertilizers. Significantly ($p < 0.001$) higher mycorrhizal colonization was observed at 60 kg N ha^{-1} of CMWFWSAU compared to other fertilizer levels without mycorrhizal inoculation. Increase in the levels of PCMW and CMWFWSAU with mycorrhizal inoculation significantly ($p < 0.001$) increased mycorrhizal colonization from 20 to 40 kg N ha^{-1} of both PCMW and CMWFWSAU. Inoculated kenaf at 40 kg N ha^{-1} of CMWFWSAU had significantly ($p < 0.001$) higher mycorrhizal colonization compared to other fertilizer levels with and without mycorrhizal inoculation.

Soil chemical properties after harvesting kenaf

Soil chemical properties were significantly affected by mycorrhizal inoculation and fertilizer application rates (Table 5). Soil of the inoculated kenaf without fertilizer application had significantly ($p < 0.001$) lower organic matter, phosphorus (P), potassium (K) and calcium (Ca) than the soil of non-inoculated kenaf without fertilizer application. Fertilizers application without mycorrhizal inoculation significantly ($p < 0.001$) increased soil pH (except 60 kg N ha^{-1} of NPK), organic matter, N (except 60 kg N ha^{-1} of NPK), P, K, Ca and magnesium (Mg) (except 60 kg N ha^{-1} of NPK, 20 and 40 kg N ha^{-1} of both PCMW and CMWFWSAU). Among the 60 kg N ha^{-1} of the fertilizers applied without mycorrhizal inoculation, PCMW had significantly ($p < 0.001$) higher soil organic matter, N, P, K and Ca followed by the CMWFWSAU and NPK fertilizers. Soil of the inoculated kenaf with fertilizers application had significantly lower soil organic matter ($p < 0.05$), P ($p < 0.001$), K ($p < 0.001$) (except 40, 80 and 100 kg N ha^{-1} of CMWFWSAU) and Ca ($p < 0.001$) compared to the soil of the non-inoculated kenaf with fertilizers application. Increase in the levels of PCMW and CMWFWSAU with mycorrhizal inoculation significantly increased soil organic matter ($p < 0.05$), P ($p < 0.001$), K ($p < 0.001$) and Ca ($p < 0.001$) from 20 to 100 kg N ha^{-1}. Considering the fertilizers application with and without mycorrhizal inoculation, soil of the non-inoculated kenaf at 100 kg N ha^{-1} of PCMW had significantly higher soil organic matter ($p < 0.05$), P ($p < 0.001$) and Ca ($p < 0.001$).

Residual effects of AM inoculation and fertilizers on the growth of kenaf

Stem diameter (Table 6) was significantly affected by the residual effects of mycorrhizal inoculation and fertilizers application. Stem diameter of inoculated kenaf without fertilizer application was higher than non-inoculated counterpart at 0 fertilizer application throughout the growth period by percentage range of 1.2 – 10.9 % (Table 6). Increase in the levels of PCMW and CMWFWSAU without mycorrhizal inoculation resulted in the significant ($p < 0.001$) increase in stem diameter from 20 to 80 kg N ha^{-1} of both PCMW and CMWFWSAU at 14 WAP. On the residual effect of mycorrhizal inoculation and fertilizers application, significant ($p < 0.001$) differences were observed between inoculated and non-inoculated kenaf at 60 and 100 kg N ha^{-1} of PCMW; and at 60 kg N ha^{-1} of CMWFWSAU. Inoculated kenaf at 100 kg N ha^{-1} of PCMW had significantly ($p < 0.001$) higher stem diameter compared to other fertilizer levels with and without mycorrhizal inoculation.

Inoculated kenaf without fertilizer application had higher plant height than non-inoculated kenaf at 0 fertilizer level with percentage range of 2.4 to 18.8 % from 6 to 14 WAP (Table 7).

Table 6: Residual effect of mycorrhizal inoculation and fertilizers on the stem diameter (cm) of kenaf

Mycorrhiza inoculation	Fertilizers application	6	8	10	12	14
With	0	0.60	0.86	0.98	1.02	1.04
	NPK	0.72	0.88	1.00	1.03	1.06
	PCMW20	0.73	0.95	1.04	1.10	1.13
	PCMW40	0.75	1.00	1.10	1.13	1.13
	PCMW60	0.82	1.08	1.21	1.30	1.34
	PCMW80	0.93	1.15	1.30	1.33	1.39
	PCMW100	1.09	1.32	1.39	1.48	1.55
	CMWFWSAU20	0.73	0.90	1.02	1.06	1.09
	CMWFWSAU40	0.75	1.00	1.05	1.12	1.17
	CMWFWSAU60	0.81	1.06	1.20	1.27	1.32
	CMWFWSAU80	0.85	1.13	1.29	1.32	1.37
	CMWFWSAU100	0.96	1.32	1.35	1.38	1.44
Without	0	0.55	0.85	0.90	0.92	0.95
	NPK	0.65	0.87	1.00	1.02	1.06
	PCMW20	0.73	0.93	1.03	1.06	1.11
	PCMW40	0.75	1.00	1.05	1.10	1.14
	PCMW60	0.79	1.02	1.12	1.22	1.26
	PCMW80	0.85	1.10	1.26	1.31	1.37
	PCMW100	0.95	1.23	1.32	1.35	1.41
	CMWFWSAU20	0.72	0.90	1.02	1.05	1.08
	CMWFWSAU40	0.74	0.95	1.05	1.10	1.13
	CMWFWSAU60	0.75	1.00	1.10	1.15	1.18
	CMWFWSAU80	0.83	1.10	1.23	1.31	1.36
	CMWFWSAU100	0.93	1.16	1.30	1.33	1.40
SE						
Mycorrhiza (M)		0.0019	0.0018	0.0024	0.0014	0.0050
Fertilizers (F)		0.0048	0.0045	0.0059	0.0033	0.0122
Interaction M x F		0.0067	0.0064	0.0084	0.0047	0.0172
ANOVA						
M		***	***	***	***	***
F		***	***	***	***	***
Interaction M x F		***	***	***	***	***

6, 8, 10, 12 and 14 = Weeks after planting
NPK60 = 60 kg N ha^{-1} of NPK (20:10:10) fertilizer
PCMW20, PCMW40, PCMW60, PCMW80 and PCMW100 = 20, 40, 60, 80 and 100 kg N ha^{-1}of Purely Composted Market Waste.
CMWFWSAU20, CMWFWSAU40, CMWFWSAU60, CMWFWSAU80 and CMWFWSAU100 = 20, 40, 60, 80 and 100 kg N ha^{-1} of Composted Market Waste Fortified With Superphosphate And Urea
S.E. = Standard Error

*** represent level of significance at $p < 0.001$

Increase in the levels of PCMW and CMWFWSAU without mycorrhizal inoculation increased plant height of kenaf from 20 to 100 kg N ha^{-1}. On the residual effect of mycorrhizal inoculation and fertilizers application, significantly ($p < 0.05$) higher plant height was observed in the inoculated kenaf at 100 kg N ha^{-1} of PCMW 14WAP compared to other treatments.

Residual effects of arbuscular mycorrhiza and fertilizers on the yield and mycorrhizal colonization of kenaf

Bast yield of inoculated kenaf without fertilizer application was higher than the bast yield of the non-inoculated without fertilizer application by 23.3 % (Table 8). Increase in the levels of PCMW and CMWFWSAU without mycorrhizal inoculation significantly ($p < 0.001$) increased bast yield at 100 kg N ha^{-1} of both PCMW and CMWFWSAU. Considering 60 kg N ha^{-1} of the fertilizers applied without mycorrhizal inoculation, PCMW had the highest bast yield followed by the CMWFWSAU and NPK fertilizer. Of all the fertilizers application with and without mycorrhizal inoculation, inoculated kenaf at 100 kg N ha^{-1} of PCMW had the highest bast yield.

Core yield of inoculated kenaf without fertilizer application was 16.3 % higher than the

Table7: Residual effect of mycorrhiza inoculation and fertilizers on the plant height (cm) of kenaf

Mycorrhiza inoculation	Fertilizers application	6	8	10	12	14
With	0	49.40	76.10	110.10	128.10	139.70
	NPK	51.67	79.87	112.10	135.10	147.10
	PCMW20	53.60	87.17	117.18	147.10	157.37
	PCMW40	60.17	90.10	126.17	151.17	165.43
	PCMW60	61.17	93.10	131.17	166.17	178.43
	PCMW80	70.17	101.17	140.10	180.17	196.37
	PCMW100	82.97	115.17	181.17	217.17	235.43
	CMWFWSAU20	53.10	82.17	115.17	142.10	154.70
	CMWFWSAU40	59.70	89.17	126.10	150.17	163.43
	CMWFWSAU60	61.17	91.17	130.10	165.10	177.77
	CMWFWSAU80	63.97	100.17	135.17	180.10	187.43
	CMWFWSAU100	78.40	115.17	173.17	204.17	220.10
Without	0	41.60	70.10	107.10	125.10	131.37
	NPK	50.53	77.10	111.10	130.10	145.37
	PCMW20	53.37	83.10	117.10	145.10	156.03
	PCMW40	54.90	88.60	125.17	150.10	159.17
	PCMW60	60.27	90.67	128.17	157.17	168.37
	PCMW80	63.30	98.17	134.10	174.17	183.43
	PCMW100	76.17	110.10	145.17	190.17	208.43
	CMWFWSAU20	52.40	81.10	115.10	136.10	147.37
	CMWFWSAU40	54.30	88.53	121.10	147.17	158.77
	CMWFWSAU60	60.17	90.60	127.17	157.10	166.37
	CMWFWSAU80	63.30	95.10	134.10	168.17	179.03
	CMWFWSAU100	73.47	105.17	140.17	183.17	199.10
SE						
Mycorrhiza (M)		0.5724	0.6484	0.5746	0.7616	1.7012
Fertilizers (F)		1.4022	1.5883	1.4076	1.8655	4.1670
Interaction M x F		1.9830	2.2463	1.9906	2.6382	5.8930
ANOVA						
M		***	***	***	***	***
F		***	***	***	***	***
Interaction M x F		**	***	***	***	*

6, 8, 10, 12 and 14 = Weeks after planting

NPK60 = 60 kg N ha^{-1} of NPK (20:10:10) fertilizer

PCMW20, PCMW40, PCMW60, PCMW80 and PCMW100 = 20, 40, 60, 80 and 100 kg N $ha^{-1}$of Purely Composted Market Waste.

CMWFWSAU20, CMWFWSAU40, CMWFWSAU60, CMWFWSAU80 and CMWFWSAU100 = 20, 40, 60, 80 and 100 kg N ha^{-1} of Composted Market Waste Fortified With Superphosphate And Urea

S.E. = Standard Error

*, ** and *** represent level of significance at $p < 0.05$, 0.01 and 0.001 respectively

Table 8: Residual effects of arbuscular mycorrhiza and fertilizers on the mycorrhizal colonization, bast and core yield (t ha^{-1}) of kenaf

Mycorrhiza inoculation	Fertilizers application	Bast	Core	Mycorrhizal colonization (%)
With	0	0.53	1.43	15.13
	NPK60	0.87	2.23	16.63
	PCMW20	1.13	2.77	21.13
	PCMW40	1.23	3.43	26.20
	PCMW60	1.33	3.67	41.17
	PCMW80	1.60	4.10	52.57
	PCMW100	2.68	5.79	68.80
	CMWFWSAU20	0.97	2.83	18.47
	CMWFWSAU40	1.17	3.50	23.83
	CMWFWSAU60	1.30	3.63	37.93
	CMWFWSAU80	1.43	3.87	48.80
	CMWFWSAU100	2.10	4.87	61.03
Without	0	0.43	1.23	13.80
	NPK60	0.80	2.20	15.40
	PCMW20	0.97	2.60	19.43
	PCMW40	1.10	3.37	23.03
	PCMW60	1.20	3.33	31.20
	PCMW80	1.30	3.80	44.60
	PCMW100	1.87	4.30	58.17
	CMWFWSAU20	0.90	2.73	17.10
	CMWFWSAU40	1.03	3.10	22.07
	CMWFWSAU60	1.13	3.53	28.07
	CMWFWSAU80	1.20	3.50	42.70
	CMWFWSAU100	1.76	4.07	54.80
	S.E.			
	Mycorrhiza (M)	0.04	0.08	0.47
	Fertilizers (F)	0.10	0.19	1.15
	Interaction			
	M × F	0.14	0.26	1.63
	ANOVA			
	M	***	**	***
	F	***	***	***
	Interaction			
	M × F	ns	ns	*

NPK60 = 60 kg N ha^{-1} of NPK (20:10:10) fertilizer
PCMW20, PCMW40, PCMW60, PCMW80 and PCMW100 = 20, 40, 60, 80 and 100 kg N ha^{-1}of Purely Composted Market Waste.
CMWFWSAU20, CMWFWSAU40, CMWFWSAU60, CMWFWSAU80 and CMWFWSAU100 = 20, 40, 60, 80 and 100 kg N ha^{-1} of Composted Market Waste Fortified With Superphosphate And Urea
S.E. = Standard Error, ns = not significant
*, ** and *** represent level of significance at $p < 0.05$, 0.01 and 0.001

core yield of non-inoculated kenaf at the same fertilizer level (Table 8). Among the 60 kg N ha^{-1} of the fertilizers applied without mycorrhizal inoculation, PCMW and CMWFWSAU had significantly ($p < 0.001$) higher core yield compared to NPK fertilizer; and the core yield of CMWFWSAU was 6.0 % higher than that of PCMW. Highest core yield was observed in the inoculated kenaf at 100 kg N ha^{-1} of PCMW.

Mycorrhizal colonization of inoculated kenaf without fertilizer application was higher than that of non-inoculated kenaf at 0 fertilizer level by 9.6 % (Table 8). Increase in the level of PCMW and CMWFWSAU without mycorrhizal inoculation significantly ($p < 0.001$) increased mycorrhizal colonization from 60 to 100 kg N ha^{-1} of both PCMW and CMWFWSAU. At 60 kg N ha^{-1} of the fertilizers applied, PCMW and CMWFWSAU had significantly ($p < 0.001$) higher mycorrhizal colonization compared to the NPK fertilizer. Inoculated kenaf with fertilizers application had significantly ($p < 0.05$) higher mycorrhizal colonization than non-inoculated kenaf with fertilizers application at 60, 80 and 100 kg N ha^{-1} of both PCMW and CMWFWSAU.

Increase in the levels of PCMW and CMWFWSAU with mycorrhizal inoculation significantly ($p < 0.05$) increased percentage mycorrhizal colonization at 60, 80 and 100 kg N ha^{-1} of both PCMW and CMWFWSAU. Significantly ($p < 0.05$) higher mycorrhizal colonization was observed in the inoculated kenaf at 100 kg N ha^{-1} of PCMW compared to other fertilizer levels with and without mycorrhizal inoculation.

Residual effects of arbuscular mycorrhiza and fertilizers on soil chemical properties after harvesting kenaf

Increase in the levels of PCMW and CMWFWSAU without mycorrhizal inoculation significantly ($p < 0.001$) increased soil organic matter, P (at 40 and 60 kg N ha^{-1} of PCMW; and also at 80 kg N ha^{-1} of CMWFWSAU) and Ca (Table 9). Among the 60 kg N ha^{-1} of the fertilizers applied without mycorrhizal inoculation, PCMW had significantly ($p < 0.001$) higher soil organic matter, N, P and Ca followed by the CMWFWSAU and NPK fertilizer. Fertilizers application with mycorrhizal inoculation had significantly lower soil organic matter ($p < 0.001$) (except 80 kg N ha^{-1} of PCMW), N ($p < 0.05$) (except 60 kg N ha^{-1} of PCMW, 20, 40 and 60 kg N ha^{-1} of CMWFWSAU), P ($p < 0.01$) (at 40, 60, and 100 kg N ha^{-1} of PCMW, 80 and 100 kg N ha^{-1} of CMWFWSAU) and Ca ($p < 0.001$) than the non-inoculated, with fertilizers application. When compared the fertilizers application with and without mycorrhizal inoculation, soil of the non-inoculated kenaf at 100 kg N ha^{-1} of PCMW had significantly ($p < 0.001$) higher soil organic matter and Ca compared to other fertilizer levels with and without mycorrhizal inoculation.

DISCUSSION

Inoculated kenaf at 40 kg N ha^{-1} of Composted Market Waste Fortified With Superphosphate and Urea (CMWFWSAU) that had significantly ($p < 0.05$) higher percentage AM colonization also had significantly ($p < 0.05$) higher stem diameter, plant height, bast and core yield. Dare *et al.* (2008) reported that inoculation with AM is highly beneficial to the yield and nutrient uptake of yam. Comparing the 60 kg N ha^{-1} of the fertilizers applied with and without inoculation, CMWFWSAU had highest AM colonization, bast and core yield followed by the NPK and Purely Composted Market Waste (PCMW). This might be due to nutrient availability in the soil throughout the crop growing period in case of CMWFWSAU and unlike NPK fertilizer which provide large doses of nutrients at early stage of plant growth which plant may not be able to effectively utilize and PCMW which release nutrients slowly in a continuous way. Combination of organic and inorganic fertilizers performs better on crop yield than when each of them is solely used (Sridhar and Adeoye, 2003).

On the residual effect, at 60 kg N ha^{-1} of the fertilizers, PCMW had the highest growth and yield parameters followed by the CMWFWSAU and NPK fertilizer. This might be due to the ability of the two fertilizers to supply organic material to the soil. Soils with an abundance of organic matter remain loose and airy, hold a

Table 9: Residual effects of arbuscular mycorrhiza and fertilizers on soil chemical properties after harvesting kenaf

Mycorrhiza inoculation	Fertilizers application	pH	Organic matter (g kg^{-1})	N (g kg^{-1})	P (mg kg^{-1})	K	Ca	Mg	Na
						(cmol kg^{-1})			
With	0	5.60	7.20	0.20	1.83	0.12	1.32	0.15	0.02
	NPK	5.43	8.70	0.20	2.05	0.14	3.08	0.22	0.01
	PCMW20	6.16	10.90	0.30	2.42	0.18	4.09	0.17	0.02
	PCMW40	6.20	11.90	0.30	2.52	0.20	4.72	0.26	0.02
	PCMW60	6.23	12.30	0.40	3.13	0.28	5.17	0.27	0.02
	PCMW80	6.30	15.00	0.40	3.29	0.32	6.52	0.28	0.02
	PCMW100	6.30	15.30	0.50	3.54	0.37	8.32	0.28	0.02
	CMWFWSAU20	6.13	10.50	0.30	2.41	0.15	3.97	0.15	0.02
	CMWFWSAU40	6.20	11.40	0.30	2.48	0.22	4.28	0.17	0.02
	CMWFWSAU60	6.23	11.70	0.30	2.73	0.25	5.11	0.20	0.02
	CMWFWSAU80	6.30	13.60	0.40	3.11	0.31	5.22	0.27	0.02
	CMWFWSAU100	6.33	13.90	0.40	3.45	0.33	5.37	0.28	0.02
Without	0	5.80	8.70	0.30	1.97	0.14	3.57	0.16	0.02
	NPK	5.77	9.20	0.30	2.26	0.17	4.82	0.17	0.02
	PCMW20	6.23	11.40	0.40	2.54	0.23	4.30	0.16	0.02
	PCMW40	6.26	12.30	0.40	2.97	0.30	5.57	0.18	0.02
	PCMW60	6.33	12.80	0.40	3.50	0.35	6.77	0.27	0.02
	PCMW80	6.33	14.40	0.50	3.53	0.36	6.97	0.30	0.02
	PCMW100	6.43	16.10	0.60	3.87	0.39	8.49	0.32	0.02
	CMWFWSAU20	6.17	10.70	0.30	2.48	0.18	4.57	0.16	0.02
	CMWFWSAU40	6.23	11.70	0.30	2.77	0.24	5.67	0.18	0.02
	CMWFWSAU60	6.23	12.10	0.30	3.01	0.28	5.92	0.26	0.02
	CMWFWSAU80	6.33	14.20	0.50	3.63	0.32	6.37	0.30	0.02
	CMWFWSAU100	6.37	15.40	0.50	3.83	0.38	7.14	0.31	0.02
	SE								
	Mycorrhiza (M)	0.026	0.002	0.001	0.034	0.045	0.002	0.001	0.002
	Fertilizers (F)	0.063	0.005	0.003	0.082	0.109	0.006	0.002	0.005
	Interaction								
	M x F	0.090	0.007	0.004	0.117	0.155	0.008	0.002	0.006
	ANOVA								
	M	ns	***	**	*	***	ns	*	***
	F	***	***	***	***	***	***	ns	***
	Interaction								
	M x F	ns	***	*	**	***	***	ns	***

NPK60 = 60 kg N ha^{-1} of NPK (20:10:10) fertilizer
PCMW20, PCMW40, PCMW60, PCMW80 and PCMW100 = 20, 40, 60, 80 and 100 kg N ha^{-1}of Purely Composted Market Waste.
CMWFWSAU20, CMWFWSAU40, CMWFWSAU60, CMWFWSAU80 and CMWFWSAU100 = 20, 40, 60, 80 and 100 kg N ha^{-1} of Composted Market Waste Fortified With Superphosphate And Urea
S.E. = Standard Error, ns = not significant

*, ** and *** represent level of significance at $p < 0.05$, 0.01 and 0.001

greater amount of moisture and nutrients, promote the growth of beneficial soil organisms and provide a healthier plant root system (EP, 2011). Soil chemical properties (such as pH, organic matter, total nitrogen, available phosphorus, potassium and calcium) increased from 20 kg N ha^{-1} to 100 kg N ha^{-1} of both PCMW and CMWFWSAU. The market wastes in PCMW and CMWFWSAU might serve as liming material to the soil which might be responsible for the increase in the soil chemical properties. Adetunji (2005) suggested that for soil quality maintenance, liming of acid soils should be done to a pH that gives optimum fertilizer efficiency, nutrient uptake, and aluminum saturation. Soils that receive significant amounts of organic material tend to maintain (buffer) soil pH values for longer period (Adetunji and Okeleye, 2001).

The application of compost is a proven way of improving soil properties by supplying organic matter and micronutrients (Sridhar and Adeoye, 2003). Adetunji (2005) also stated that organic matter is probably the most vital indicator of soil quality and influences the physical, chemical and biological indicators of soil quality and soil nitrogen is inextricably tied to the soil organic matter content because the bulk of soil nitrogen is in organic combination.

CONCLUSIONANDRECOMMENDATIONS

The higher the percentage root colonization, the higher were the growth and yield parameters with inoculated kenaf greater than the non-inoculated. Inoculated kenaf at 40 kg N ha^{-1} of composted market waste fortified with Superphosphate and Urea had significantly higher mycorrhizal colonization, bast and core yield compared to the recommended 60 kg N ha^{-1} of NPK (20: 10: 10). Composted market waste base fertilizer improved soil chemical properties such as organic matter, pH, nitrogen, phosphorus and potassium compared to the NPK fertilizer.

Conversion of waste to fertilizer and management of indigenous mycorrhiza will reduce the application of chemical fertilizers and ensure optimum quantitative yield of kenaf.

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