ECONOMIC POTENTIALS OF OIL PALM PRODUCTS AND WEED CONTROL ON SUSTAINABLE TURMERIC PRODUCTION AND SELECTED SOIL PHYSICAL PROPERTIES IN SOUTHEASTERN NIGERIA

Nwokocha, C.C., Ano, A.O., Njoku, N.R., Korieocha, D.S., Achebe, U., Nwangwu, B.C., Daniel-Ogbonna, C. and Uchechukwu, U.N

National Root Crops Research Institute (NRCRI), Umudike. P.M.B. 7006, Umuahia, Abia State, Nigeria
Corresponding author's email: chrisnwokocha@gmail.com

Abstract
A study was carried out at the Research Farm of National Root Crops Research Institute Umudike, southeastern Nigeria (05^{o}, 29'N, 07^{o} 33'E and 122 m above sea level), in 2015 and 2016 cropping seasons to study the economic potentials of oil palm products and weed control on sustainable turmeric production and some soil physical properties. The experiment was laid out in a split plot treatment arrangement in a randomized complete block design (RCBD) with three replications. Empty palm bunch treatments (0 (12 t/ha straw mulch, 4, 8, and 12 t/ha EPB) occupied the main-plots, while PBA treatments (0 (60N +13P +25K/ha), 4, 8, 12 t/ha PBA) occupied the sub-plots. Application of 0 t/ha EPB (12 t/ha straw) mulch x 12 t/ha PBA gave the highest average plant height, average tiller No/clump, total rhizome No/ha, SHMR and total rhizome yield. This treatment combination also recorded lowest total weed density at 8 and 12 WAP and returned the highest net farm income with a BCR of 16.71. Application of 8 t/ha EPB x 4 t/ha PBA significantly improved soil BD (1.562 g/cm^{3}) and PAW (29.65%). It was concluded that application of 0 t/ha EPB (12 t/ha straw mulch) x 12 t/ha PBA improved the growth and yield parameters of turmeric, controlled total weed density at 8 and 12 WAP and is recommended for turmeric production. When the improvement of soil physical fertility is the only management objective, 8 t/ha EPB x 4 t/ha PBA is recommended in the southeast agro-ecology of Nigeria.

Keywords: *Curcuma longa* Linn, ash, soil physical properties, turmeric and weed density

Introduction

Turmeric (*Curcuma longa* Linn) is an erect perennial plant grown as an annual crop for its rhizome (underground stem bearing roots and shoots) which has a lot of culinary, industrial and pharmacological benefits. Application of dry straw (*Panicum maximum*) mulch at the rate of 12 t/ha immediately after planting (Nwokocha *et al.*,2009a) and supplemental mulch application 8 WAP (Olojede, *et al*., 2012) has been found to be optimum for turmeric production on an *Ultisol* at Umudike It has been reported that turmeric requires 60 kg N, 13 kg P and 25 kg K/ha for optimum rhizome yield at Umudike (Nwokocha *et al*., 2009b).

Empty palm bunches (EPBs) are residues left after palm fruits have been removed from the palm bunches and represents about 23% of total residue in palm oil processing (Udoetok, 2012). Their uses as organic materials in agriculture are under-exploited (Okoli *et al*., 2010). Empty palm bunch is now mainly used as mulch (Hamdan *et al*., 1998) and when placed around young plants, EPB releases potassium to the soil even before decomposition and helps control weeds. Ibeawuchi *et al* (2007) reported the use of EPB as mulch-manure in yam/maize/cassava crop mixture for high yield and weed control especially in yam and cassava planting. However, due to current labour shortage, the transportation and distribution of EPB in the field is getting more expensive necessitating the

incineration of EPB. Farmers are recently becoming aware of the use of palm bunch ash (PBA) in cultivation of root and tuber crops because it is rich in potassium. Udoetok (2012) reported that the appreciable concentrations of anions like nitrate (97.6 mg/kg), phosphate (47.4 mg/kg), sulphate (622 mg/kg), high concentrations of potassium (139.35 mg/kg), calcium (146.15 mg/kg) in PBA, justify its usage as organic fertilizer. High concentrations of calcium, sulphate and a pH of 10.9 confirm that it is a good liming agent. A trial was therefore carried out in 2015 and 2016 at Umudike southeastern Nigeria, to study the effects of EPB and PBA on: growth and rhizome yield of turmeric; soil bulk density (BD) and plant available water (PAW); total weed density; and the economics of EPB and PBA enterprise.

Materials and Methods

This study was carried out at the Research Farm of National Root Crops Research Institute Umudike, Nigeria (05^{o}, 29'N, 07^{o} 33'E and 122 m above sea level), in 2015 and 2016 cropping seasons. The experiment was laid out in a split plot treatment arrangement in a randomized complete block design (RCBD) with three replications. Empty palm bunch treatments (0 (12 t/ha straw grass), 4, 8, and 12 t/ha EPB) occupied the main-plots, while PBA treatments (0 (60N +13P +25K/ha), 4, 8, 12 t/ha PBA) occupied the sub-plots. Planting was done on beds measuring 2 x 2 m, and at a spacing of 0.50 m between rows and 0.30 m within rows. Herbicide was applied as pre-emergence, while 3 supportive manual weeding were done at 8, 12 and 16 WAP. Fertilizer/PBA treatments were applied at 6 WAP. Growth data were collected on plant height (cm) and tiller number/clump at 12 WAP. Weed composition and density were obtained at 8 and 12 WAP using a quadrant. Soil bulk density (BD) and plant available water (PAW) were measured at 20 WAP. Rhizome yield was determined at harvest (36 WAP). Seed harvest multiplication ratio (SHMR) was calculated by dividing total number of rhizomes harvested/ha by the total number of seed rhizomes planted/ha. Data collected were subjected to analysis of variance for a split plot experiment in RCBD using GenStat Discovery Edition 3 (2007). Significant treatment means were separated using Fischer's Least Significant Difference (F-LSD) at 5% probability level.

For economic analysis, the data were collected using cost route approach. The cost and returns of the enterprise were estimated using the Whole Farm Analysis. Total revenue (returns) was obtained from quantity of turmeric rhizomes harvested. The model is as expressed below, according to Okezie and Ugoechina (2006); Akinpelu *et al*. (2007).

NFI = TR – TC (TVC + TFC) … (1)

R/~~₦~~ investment = NFI/TC … (2)

BCR = TR/TC … (3)

Where: NFI = net farm income; TR = total revenue; TC = total cost; TVC = total variable Cost; TFC = total fixed cost; and BCR = benefit cost ratio

Results and Discussion

Effect of oil palm products on weed control, growth and yield performance of turmeric

Effects of EPB and PBA on BD, PAW, average Plant height, average tiller No/clump, total rhizome No/ha, SHMR and total rhizome yield in 2015 and 2016 (combined analysis) are as shown in Table 1. All mulch treatments significantly ($P < 0.05$) reduced soil BD, except 4 t/ha EPB with a soil BD of 1.780 g/cm^3. This is in agreement with the report of Ogban (2009) who demonstrated that residue mulch at 6 t/ha incorporated in tilled or placed on the surface of tilled and untilled soil improved soil bulk density and soil water content. Similar results were obtained when 10 t/ha cocoa pod waste significantly ($P < 0.05$) reduced soil bulk density from 1.55 – 1.37 g/cm^3 (Onwudike *et al*., 2015). Fertilizer control (0 t/ha PBA) significantly ($P < 0.01$) reduced BD (1.680 g/cm^3), more than other

PBA treatments, except 4 t/ha PBA (1.683 g/cm^3). Soil compaction is unlikely to be affected by inorganic fertilizer inputs. According to Malik *et al*. (2014) highest value of soil bulk density was obtained from treatment with recommended dose of NPK fertilizers, when compared with values obtained from organic fertilizer plots. It may be suggested that tillage operations and roots proliferation in response to improved nutrients availability following inorganic fertilizer application coupled with increased microbial activities in the presence of NPK fertilizer caused the significant reduction in soil bulk density obtained in fertilizer control plots. Ezekiel *et al.* (2009a) reported that PBA at 2.5 t/ha is an effective soil amendment for increasing the root growth and yield of cassava in Omoku, southeast Nigeria. Interaction effect showed that 8 t/ha EPB x 4 t/ha PBA improved soil BD (1.562 g/cm^3) most. Application of 8 t/ha EPB waste optimally improved PAW (23.06%). Onwudike *et al*. (2015) significantly increased soil moisture content using 10 t/ha rice mill waste by 19% in 2011 and 25% in 2013. Application of 4 t/ha PBA and the interaction effect of 8 t/ha EPB x 4 t/ha PBA resulted in significantly highest amount of PAW (22.48 and 29.65%, respectively).

Significantly ($P < 0.01$) highest values of average plant height (59.83 cm), total rhizome No/ha (1977000/ha) and SHMR (30) were recorded on plots that received 12 t/ha EPB. This is in tandem with the reports of Mbagwu (1991) and Eneje and Uzoukwu (2012). Application of 12 t/ha PBA recorded highest values of average tiller No/clump (4.2), total rhizome No/ha (1989000/ha) and SHMR (30). Several researchers have reported that plant derived wastes, such as PBA, significantly improved root yield and nutrients uptake by cassava (Ezekiel *et al.*, 2009b; Ojeniyi *et al.*, 2009; Ojeniyi and Igbomrore, 2004). Interaction effects showed that 0 t/ha EPB x 12 t/ha PBA treatments combinations gave best results in average plant height (60.81 cm), average tiller No/clump (5.2) total rhizome No/ha (2,400,000/ha) and SHMR (36). This performance may be attributed to the effect of 12 t/ha straw mulch and its supplemental straw mulch application at 8 WAP after augmenting with 12 t/ha PBA. This treatment combination provided enough mulch cover and organic fertilizer for the plant. Highest amount of total rhizome yield due to EPB application was obtained using 12 t/ha straw mulch (13.62 t/ha), which did not differ significantly ($P < 0.01$) with the yield due to application of 12 t/ha EPB (13.48 t/ha). Application of 4 t/ha PBA produced the highest total rhizome yield (12.91 t/ha) which did not differ significantly ($P < 0.01$) with the yield due to application of 12 t/ha PBA (12.40 t/ha). Kayode *et al.* (2012) had reported that application of 4 t/ha plant derived ash increased significantly the tuber weight of yam by 44%. Lowest rhizome yield of 11.08 t/ha was recorded in plots treated with inorganic fertilizer. These results give credence to recommendation of Udoetok (2012) to the effect that PBA should be used as organic fertilizer in view of its appreciable nitrate level (97.6 mg/kg) and high concentrations of potassium (139.35 mg/kg) and calcium (146.15 mg/kg). Effect of EPB x PBA interaction on rhizome yield of turmeric at Umudike showed that application of 0 t/ha EPB x 12 t/ha PBA recorded the highest yield (15.79 t/ha), which did not differ significantly ($P < 0.01$) with yield obtained from 12 t/ha EPB x 4 t/ha PBA interaction plots (14.70 t/ha).

Table 1: Effect of empty palm bunch and palm bunch ash on bulk density (BD), plant available water (PAW), plant height, average tiller No/clump at 12 WAP, total rhizome No/ha, SHMR and total rhizome yield in 2015 and 2016 (2 years combined analysis).

	BD (g/cm^3)	PAW (%)	Av.Plant height (cm)	Av.Tiller No/clump	Total rhizome No/ha ('000)	SHMR	Total rhizome yield (t/ha)
EPB (t/ha)							
0 (12 t/ha straw grass)	**1.738**	20.07	55.59	4.0	1718	26	**13.62**
4	1.780	19.96	54.31	3.6	1608	24	10.17
8	**1.650**	**23.06**	56.74	3.8	1529	23	11.15
12	**1.710**	18.73	**59.83**	3.9	**1977**	**30**	**13.42**
LSD (0.05)	0.09*	2.48*	2.82**	NS	157**		0.78**
PBA (t/ha)							
0 (N60+P13+K25 kg/ha)	**1.680**	20.49	57.69	**3.9**	1402	21	11.08
4	**1.683**	**22.48**	55.04	3.6	1670	25	**12.85**
8	1.775	19.82	57.54	3.7	1770	27	12.03
12	1.740	19.02	56.20	**4.2**	**1989**	**30**	**12.40**
LSD (0.05)	0.06**	1.89**	NS	0.3**	99**		0.55**
EPB x PBA interaction							
0 EPB x 0 PBA	1.762	23.61	56.86	3.3	1027	15	11.08
0 EPB x 4 PBA	1.759	19.11	49.10	3.1	1450	22	14.01
0 EPB x 8 PBA	1.718	18.88	56.57	4.4	1995	30	13.61
0 EPB x 12 PBA	1.712	18.67	**60.81**	**5.2**	**2400**	**36**	**15.79**
4 EPB x 0 PBA	1.649	19.21	55.09	4.2	1384	21	8.17
4 EPB x 4 PBA	1.836	18.79	52.45	3.1	1562	23	11.44
4 EPB x 8 PBA	1.733	24.20	55.34	3.1	1740	26	10.89
4 EPB x 12 PBA	1.902	17.65	54.35	4.1	1744	26	10.17
8 EPB x 0 PBA	1.570	22.79	60.78	4.3	1535	23	11.13
8 EPB x 4 PBA	**1.562**	**29.65**	56.38	3.9	1378	21	11.49
8 EPB x 8 PBA	1.774	18.64	56.89	3.3	1418	21	9.68
8 EPB x 12 PBA	1.694	21.15	52.94	3.6	1785	27	12.30
12 EPB x 0 PBA	1.739	16.33	59.02	3.6	1663	25	13.96
12 EPB x 4 PBA	1.573	22.39	**62.23**	4.1	2291	34	**14.70**
12 EPB x 8 PBA	1.877	17.56	61.36	3.8	1926	29	13.92
12 EPB x 12 PBA	1.652	18.63	56.71	4.0	2028	30	11.34
LSD (0.05)	0.13**	3.99**	4.96**	0.7**	225**		1.19**

*, ** = Significant at 5 and 1% probability levels, respectively; NS = Not significant at 5% probability level. SHMR = Seed harvest multiplication ratio.

Weed Control

Weed composition and density due to application of EPB and PBA are as shown in Table 2. Simple effect of EPB mulch showed that grasses more than other weed species were suppressed by mulching at both 8 and 12 WAP, with values ranging from 0.7 – 1.8 No/m^2 and 0.8 – 1.9 No/m^2, respectively. Application of 12 t/ha EPB resulted in lowest total weed density of 9.1 No/m^2 at 8 WAP. However, at 12 WAP, application of 0 t/ha EPB (12 t/ha straw mulch + supplemental mulching at 8 WAP) recorded the least total weed number of 43.9 No/m^2. The ability of 0 t/ha EPB mulch to reduce total weed incidence at 12 WAP may be attributed to supplemental straw mulch application at 8 WAP. Application of 4 t/ha PBA significantly and optimally reduced total weed density (8.3 No/m^2) at 8 WAP. Ibeawuchi *et al* (2007) reported the use of EPB as mulch-manure in weed control, especially in yam and cassava planting. Interaction effect of EPB x PBA showed that application of 0 t/ha EPB x 12

t/ha reduced significantly ($P < 0.01$) total weed density at 8 WAP (6.7 No/m^2) and at 12 WAP (36.3 No/m^2). Similar results were obtained with 12 t/ha EPB x 12 t/ha PBA. These results confirm that EPB as mulch manure may be used to control weed incidence in turmeric production at Umudike.

Table 2: Effect of empty palm bunch (EPB) and palm bunch ash (PBA) on the weed composition and density (No/ m^2) of a turmeric farm in 2015 and 2016 (2 years combined analysis)

	8 WAP				12 WAP			
Treatments	**BL**	**GR**	**SDG**	**TWD**	**BL**	**GR**	**SDG**	**TWD**
EPB (t/ha)								
0 (12 t/ha straw grass)	10.0	**0.9**	**2.0**	13.0	**28.6**	**0.8**	**14.5**	**43.9**
4	**7.7**	1.8	3.2	12.7	49.2	1.9	23.5	74.5
8	**8.0**	**1.0**	**1.7**	10.7	49.3	**1.3**	19.0	69.5
12	**6.9**	**0.7**	**1.5**	**9.1**	36.8	**0.9**	**13.2**	50.9
LSD (0.05)	1.5**	0.7*	1.0*	1.5*	3.5**	0.7*	2.5**	2.8**
PBA (t/ha)								
0 (N60+P13+K25 kg/ha)	13.5	1.6	2.8	18.0	42.0	1.04	17.6	60.7
4	**5.3**	1.2	**1.8**	**8.3**	**39.1**	1.21	18.0	58.3
8	**6.0**	**0.6**	**1.3**	**7.8**	**36.0**	0.96	20.0	57.0
12	7.8	**1.0**	2.6	11.3	46.6	1.71	**14.5**	62.8
LSD (0.05)	1.1**	0.6**	0.7**	1.1**	5.3**	NS	1.4**	NS
EPB x PBA interaction								
0 EPB x 0 PBA	26.0	1.8	3.2	31.0	**29.8**	0.7	15.5	46.0
0 EPB x 4 PBA	**3.5**	0.8	2.5	**6.8**	**27.8**	0.3	14.8	**43.0**
0 EPB x 8 PBA	6.0	0.3	**0.2**	**6.5**	**29.8**	0.7	19.8	50.3
0 EPB x 12 PBA	**4.5**	0.7	2.3	**7.5**	**26.8**	1.5	**8.0**	**36.3**
4 EPB x 0 PBA	9.0	2.0	4.5	15.5	38.3	1.3	22.3	62.0
4 EPB x 4 PBA	**2.8**	2.5	1.7	**7.0**	41.7	2.3	24.3	68.3
4 EPB x 8 PBA	8.0	0.8	1.7	10.5	37.3	1.0	29.8	68.2
4 EPB x 12 PBA	11.0	1.8	5.0	17.8	79.3	2.8	17.3	99.5
8 EPB x 0 PBA	9.5	1.7	1.7	12.8	53.5	0.8	15.0	69.3
8 EPB x 4 PBA	8.2	0.8	**1.5**	10.5	46.3	1.2	19.0	66.5
8 EPB x 8 PBA	**3.7**	0.7	1.8	**6.2**	42.7	1.7	19.0	63.3
8 EPB x 12 PBA	10.5	1.0	1.8	13.3	54.5	1.7	22.8	79.0
12 EPB x 0 PBA	9.7	1.0	2.0	12.7	46.5	1.3	17.7	65.5
12 EPB x 4 PBA	6.8	0.7	1.5	9.0	40.7	1.0	13.8	55.5
12 EPB x 8 PBA	6.2	0.5	1.5	**8.2**	**34.3**	0.5	**11.3**	46.2
12 EPB x 12 PBA	**5.0**	0.5	1.2	**6.7**	**25.7**	0.8	**9.8**	**36.3**
LSD (0.05)	2.3**	NS	1.5**	2.4**	9.7**	NS	3.4**	8.8**

*, ** = Significant at 5 and 1% probability levels, respectively; NS = Not significant at 5% probability level;
BL = Broad leaves; GR = Grasses; SDG = Sedges; TWD = Total weed density.

Economics of oil palm products for sustainable turmeric production.

The results of economics of EPB and PBA enterprise on turmeric production for 2015 and 2016 seasons (combined analysis) were summarized in Table 3. The simple effect of EPB showed that application of straw mulch at 12 t/ha with supplemental application at 8 WAP (0 t/ha EPB) has the greatest comparative advantage because the net return per hectare is N6,400,889.00. This means that income derived using straw mulch is 1565% higher than the cost (Table 3). Effect of PBA showed that application of 4 t/ha PBA returned the greatest profit per hectare of N6,029,620.00, while maintaining a return per naira investment of N15.29. The results due to EPB x PBA interaction revealed that 0 t/ha EPB x 12 t/ha PBA gave the highest net farm income per hectare of N7,421,696.00, and a BCR of 16.71.

Table 3: Economics of turmeric (*Curcuma longa* Linn) production using empty palm bunch (EPB) and palm bunch ash (PBA) at Umudike

Treatment	Total Rev.(₦'000)	TC (₦)	NFI (₦)	R/₦	BCR
EPB (t/ha)					
MC	6,810	409,111	6,400,889	15.65	**16.65**
4	5,084	414,920	4,669,080	11.25	12.25
8	5,576	434,280	5,141,720	11.84	12.84
12	6,709	453,640	6,255,360	13.79	14.79
PBA (t/ha)					
Fert. C	5,542	383,111	5,157,889	13.45	14.45
4	6,424	394,380	6,029,620	15.29	**16.29**
8	6,013	442,780	5,569,720	12.58	13.58
12	6,201	491,180	5,709,320	11.62	12.62
EPB x PBA interaction[#] (t/ha)					
MC x Fert. C	5,542	364,735	5,172,765	14.18	15.18
0 EPB x 4 PBA	7,004	375,504	6,628,496	17.65	**18.65**
0 EPB x 8 PBA	6,804	423,904	6,380,096	15.05	16.05
0 EPB x 12 PBA	**7,894**	472,304	**7,421,696**	15.71	16.71
4 EPB x 4 PBA	5,721	381,312	5,339,688	14.00	15.00
8 EPB x 0 PBA	5,567	389,903	5,176,597	13.28	14.28
8 EPB x 4 PBA	5,746	400,672	5,345,328	13.34	14.34
12 EPB x 0 PBA	6,979	409,263	6,569,737	16.05	17.05
12 EPB x 4 PBA	7,350	420,032	6,929,968	16.50	**17.50**
12 EPB x 8 PBA	6,961	468,432	6,492,068	13.86	14.86

= Best treatment combinations with R/₦ > ₦13.00; M C = Mulch Control (Application of 12 t/ha straw at planting + supplemental mulching 8 WAP); Fert. C = Fert. Control (Application of 60 kg N + 13 kg P + 25 kg K/ha).

Conclusion

It was concluded that application of 8 t/ha EPB x 4 t/ha PBA reduced soil BD and increased PAW and is recommended for the improvement of soil physical fertility. Application of 0 t/ha EPB (straw) x 12 t/ha PBA gave the highest average plant height, average tiller No/clump, total rhizome No/ha, SHMR and total rhizome yield. This treatment combination also recorded lowest total weed density at 8 and 12 WAP and returned the highest net farm income with a BCR of 16.71 and is therefore recommended for turmeric production in the southeast agro-ecology of Nigeria.

References

Akinpelu, A.O., Mbanaso, E.O., Olojede, A.O., Obasi, C. and Amaefule, A. (2007). Economics of turmeric (*Curcuma longa* Linn) production under low altitude agro-ecology: A case study of NRCRI, Umudike, Abia State. *NRCRI Annual Report 2007.* Pp 88-92.

Eneje, R.C. and Uzoukwu, I. (2012). Effect of rice mill waste and poultry manure on some chemical properties and growth and yield of maize. *Nigerian Journal of Soil Science.* 22(1): 59 – 64.

Ezekiel, P.O., Ojeniyi, S.O., Asawalam, D.O. and Ano, A.O. (2009a). Effect of oil palm bunch ash on soil NPK and root yield of sweet and bitter cassava. *Nigerian Journal of Soil Science.* 19(1): 1 – 5.

Ezekiel, P.O., Ojeniyi, S.O., Asawalam, D.O. and Ano, A.O. (2009b). Root growth, dry root yield and NPK content of cassava as influenced by oil palm bunch ash on Ultisols of South-east Nigeria. *Nigerian Journal of Soil Science.* 19(1): 6 – 10.

GenStat Discovery Edition 3 (2007). GenStat Procedure Library Release 7.2 DE (PC/Windows) Copyright 2007, Lawes Agricultural Trust (Rothamsted Experimental Station).

Hamdan, A.B., Tarmizi, A.M. and Mohammed, D Tayeb (1998). Empty fruit bunch mulching and nitrogen fertilizer amendment: The resultant effect on oil palm performance and soil properties. *PROM Bull.* Palm oil Res. Inst. Malaysia 37.

Ibeawuchi, L.I., Etuk, E.B. and Obiefuna, J.C. (2007). Palm Bunch Refuse (PBR) Mulch- Manure in Yam/Maize/Cassava Crop Mixture In: *Proceedings of the third National Conference On Organic Agriculture*. UDU Sokoto. Nigeria. 11 – 15th Nov. 2007.

Kayode, B.O., Ojeniyi, S.O. and Odedina, S.A. (2012). Soil properties and response of yam to ash application at Akure, Nigeria. *NJSS*, 22(1): 186 – 189.

Malik, S.S., Chauhan, R.C., Laura, J.S., Kapoor, T., Abhilashi, R. and Sharma, N. (2014). Influence of organic and synthetic fertilizers on soil physical properties. *Interational Journal of current Microbiology and Applied Sciences.* Vol. 3 (8): 802 – 810. *http://www.ijcmas.com.*

Mbagwu, J.S.C. (1991). Mulching an Ultisol in southern Nigeria: Effects on physical properties and maize and cowpea yields. *J. Sci Food Agric.* 57: 517 – 526.

Nwokocha, C. C., Olojede, A.O., Ano, A.O., Onyekwere, I.N. and Ukaoma, A.A. (2009a).Planting depth and mulch effects on the yield of turmeric grown in an Arenic Hapludult. *Proceedings of the 43rd Annual Conference of the Agricultural Society of Nigeria.* Held at National Universities Commission Auditorium, and RMRDC Abuja. Pp 851 – 855.

Nwokocha, C. C., Olojede, A.O., Ano, A.O., Chukwu, G.O. and Korieocha, D.S. (2009b). NPK requirements for turmeric production on an Arenic Hapludult in southeastern Nigeria. *Proceedings of the 33rd Annual Conference of the Soil Science Society of Nigeria.* Held at University of Ado-Ekiti 2009. Pp 166-171.

Ogban, P.I. (2009). Effect of tillage and mulching systems on soil properties in Southwest Nigeria. *Nigerian Journal of Soil Science.* 19: 81 – 92.

Ojeniyi, S.O. and Igbomrore, H. (2004). Comparative effect of mulches on soil and leaf nutrient content and cassava yield. *Nigerian Journal of Soil Science.* 14: 93 – 97.

Ojeniyi, S.O., Owolabi, O., Akinola, O.M. and Odedina, S.A. (2009). Field study of the effect of organo-mineral fertilizer on maize growth, yield, soil and plant nutrient composition in Ilesa, Southwest Nigeria. *Nigeria Journal of Soil Science.* 19: 11 – 16.

Okezie, C.A. and Ugoechina, C.C. (2006). Economics of cashew (*Anacardium occidentale*) harvesting in Ezeagu, Enugu State, Nigeria. In: *Proceedings of the 40th Annual Conference of the Agricultural Society of Nigeria, Umudike, Abia State.* Oct. 16-20, 2006: 79-81.

Okoli, N.A., Obiefuna, J.C., Ibeawuchi, L.I. and Alagba, A.R. (2010). Potentials of palm bunch products in sustainable crop production in Nigeria. *Proceedings of the 44th Annual Conference of Agricultural Society of Nigeria "LAUTECH 2010".* Pp 862 – 864.

Olojede, A.O., Nwokocha, C.c. and Obasi, C.P. (2012). Best time of supplemental mulch application for turmeric production under a rainforest agro-ecology of Nigeria. 2012 NRCRI Annual Report. Pp 65 and 66.

Onwudike, S.U., Asawalam, D.O. and Ano, A.O. (2015). Comparative evaluation of burnt and un-burnt agro-wastes on soil physic-chemical properties, growth and yield of cocoyam (*Colocasia esculenta*) in a humid environment. *Special NJSS* Vol. 25, Pp 46 – 61.

Udoetok, I.A. (2012). Characterization of ash made from oil palm empty fruit bunches. *International Journal of Environmental Sciences*, Vol. 3. No 1: 518-524.