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Comparative effects of different nitrogen sources from organic manure and urea fertilizer on growth, crude protein and nutrient uptake of *Amaranthus cruentus*

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Abstract: A two-year field trial was conducted at the Teaching and Research Farm of Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria to evaluate the effects of different organic fertilizer sources and an inorganic fertilizer on growth, crude protein and nutrient uptake of *Amaranthus cruentus*. Sixteen (16) treatments were laid out in a randomized complete block design with 3 replications. Four sources of organic fertilizer (cattle, goat, pig and poultry manures) and an inorganic fertilizer source (urea) were evaluated each at three nitrogen (N) rates (30, 60 and 90 kg N/ha). Plots with no fertilizer application served as the control. Data were subjected to analysis of variance and means compared with Turky's HSD at 5 % level of probability. The results showed that the amendments applied, significantly ($P \leq 0.05$) enhanced growth of *Amaranthus*. Higher rates of pig and poultry manures were as effective as higher rates of urea. Crude protein content of leaf was increased significantly, the highest being in urea at 90 kg N/ha (19.57 %) followed by urea at 60 kg N/ha (17. 98 %) and pig manure at 90 kg N/ha (17.73 %). The amendments applied significantly ($P \leq 0.05$) enhanced the uptake of some major elements compared with the control. The greatest nutrient uptake was obtained in plots amended with pig manure at 90 kg N/ha. The trial has illustrated that pig manure when applied at 90 kg N/ha could substitute urea fertilizer in *Amaranthus* production.
Keywords: *Crude protein, nutrient uptake, organic manure, plant growth, urea fertilizer*

1. Introduction

Amaranthus also called African spinach, bush green, green leaf, *amaranths* in different parts of the world belongs to the family *Amaranthaceae. Amaranthus* species are a group of highly popular vegetables, belonging to many different species. They are the most commonly grown leafy vegetable of the lowland tropics in Asia and Africa. The commonly cultivated *amaranth* in Africa include: *Amaranthus cruentus, A. dubius, A. spinosus, A. blitum, A. thunbergii, A. graecizans* and *A. caudatus*, but only the *A. cruentus* species is most commonly grown in Africa [1].

Amaranthus cruentus is a highly cherished leafy vegetable in Nigeria and has a high nutritional value because of the high levels of essential micro- nutrients like iron (an important element against anemia), manganese and zinc [2]. It contains calcium, magnesium (Mg), carotene and niacin. Vitamin A and C are also present in significant levels. The protein found in young plants of amaranths can be important for people without access to meat or other sources of protein.

Amaranthus cruentus can be sown directly in seed bed with the entire plant harvested some 4 to 5 weeks after sowing [1], or planted in nursery beds before transplanting them to the main field. According to [1], transplanted seedlings are most commonly used for ratoon crops (with successive harvests), whereas direct sowing is the rule for a crop that is harvested by uprooting. The optimal spacing for plants to be harvested by uprooting is 10 x 10 cm, whereas for the one with successive harvests (ratoon crop), the optimum spacing is about 20 × 20 cm [1, 3]. *Amaranthus* requires an ample supply of soil nutrients especially nitrogen for its optimum growth. High levels of nitrogen will delay the onset of flowering, allowing a considerably higher yield [1]. Nitrogen is a vitally important plant nutrient, the supply of which can be controlled by man. It is absorbed by plants in the form of nitrates (NO_3^-) and also in the form of ammonium (NH_4^+). It can also be absorbed in the form of urea ($CO(NH_2)_2$) and even as ammonia (NH_3) [4]. In acid soils plants absorb more nitrate ions, and in slightly alkaline soils they absorb more ammonium ions [4].

The need for nitrogen is evident from the fact that plants require protein for their metabolism. Nitrogen acts as a building material in the formation of protein in plants. It is an integral part of the chlorophyll molecules and also forms important part of various coenzymes [4]. Adequate nitrogen supply is responsible for the dark green colour of the leaves, vigorous growth, branching/tillering, leaf production and enlargement of the surface [5]. It is most important for canopy development. Nitrogen is to a plant what petrol is to a car [6]. When nitrogen supply is restricted or low, the leaves are small, thin and yellow and they mature quickly. Yield as well as protein content is reduced.

Urea is the major nitrogen (N) fertilizer accounting for over 80 % of the total N used. Researchers have shown that animals retain only 10 % of the food mass they ingest as they excrete large amounts of metabolic wastes and incompletely digested organic matter [7]. This implies that organic manure is very rich in organic matter and nutrients. Generally, about three-fourths of the nitrogen, four-fifths of the phosphorus, and nine-tenths of the potassium ingested is voided by the animals and appears in the manures [8]. For this reason, animal manures are valuable sources of both macro- and micronutrients.

Various experiments ([1], [9], [10] have shown that well-decomposed (fermented) manure of whatever type is the best for *amaranth* cultivation. A rate of 6 t/ha of organic manures has been recommended by [11] as optimum for enhancing the *Amaranthus* seed N, ash and crude protein quality on a lowly fertile soils in the humid tropics. The responds of *amaranths* cultivated in Africa to organic manure application at the rate of 2- 4 t/ha have been reported by [1].

Except for nitrogen, the availability of most nutrients in manures is fairly consistent. Nitrogen can occur in several forms, each of which can be lost when subjected to different management or environmental conditions [12]. Nitrogen in animal manure comes from uric acid, ammonia salts, and organic (fecal) matter. The predominant form is uric acid, which readily transform to ammonia (NH_3), a gaseous form of nitrogen that can evaporate if not mixed into the soil. When it is thoroughly mixed, the ammonia changes to ammonium (NH_4), this can be temporarily held on clay particles and organic matter [12]. Thus soil mixing can reduce nitrogen losses and increase the amount available to plants. Therefore, to minimize nitrogen losses, manure should be applied as near as possible to planting time or to the crop growth stage during which nitrogen is most needed [12], [13], [14].

This study investigates the effects of different nitrogen sources and rates on growth, leaf crude protein content and nutrient uptake of *Amaranthus cruentus* production in the Rainforest zone of Umudike, Nigeria.

2. Materials and methods

2.1 Description of the Study Area

This experiment was conducted during the dry season at the Research Farm of Michael Okpara University of Agriculture, Umudike, Abia State in Nigeria. Umudike is located in the humid forest zone of Nigeria and lies within latitude ^{0}50 29' N and longitude 070 33' E, with an altitude of 122 m above sea level. The study area by the virtue of its latitudinal location falls within the humid tropics and hence enjoys humid tropical environment marked by two distinct seasons namely the rainy season and the dry season. Umudike is characterized by tropical wet (March to October) and dry (November to February) seasons. Annual rainfall in Umudike ranges from 1900 mm to 2650 mm, bimodally distributed with peaks in the months of July and September [15]. There is usually a short dry spell in August which is referred to as 'August break'. The minimum and maximum temperatures ranged from 19 to 240 ^{C} and 28 to 340 ^{C} respectively. The minimum and maximum monthly relative humidity ranges from 39 to 81% and 52 to 87% respectively in the area. The soil is loamy sand, strongly acidic in reaction with low nutrient reserve [16] and classified as an Ultisol [17].

2.2 Soil sampling and processing

About 10 auger points' soil samples were taken from the experimental site before experiment using soil auger at a depth of 0-15 cm. The soil samples were mixed thoroughly to make a composite sample before commencement of experiment for laboratory analysis. The soil sample was air-dried, ground and sieved with 2 mm sieve to remove materials greater than 2 mm in diameter before analysis.

2.3 Experimental design and treatments

There were 16 treatments (TABLE 1) laid out in a randomized complete block design with 3 replications. Four sources of organic fertilizer (cattle, goat, pig and poultry manures) and an inorganic fertilizer source (urea) were evaluated each at three nitrogen (N) rates (30, 60 and 90 kg N/ha). Plots with no fertilizer application served as the control. The organic manures were collected from the animal farm unit of the university. The manures were dried to hinder decomposition and later analyzed following standard procedures [18]. The chemical compositions of the manures are as shown in Table 2. The specific weight of manure or fertilizer to apply per N rate was calculated on the basis of the N content of the material (TABLES 1 and 2). The *Amaranthus* seeds were obtained from the National Root Crops Research Institute (NRCRI), Umudike.

2.4 Field studies

The experimental area was mechanically ploughed and harrowed. The field was manually marked out with pegs and flat beds measuring 3 m x 1.5 m were made manually using spade. An alley of 1.2 m was left between blocks and 0.6 m between plots. The organic manure treatments were spread and incorporated into the soil [19] on specified plots at specified rate of application. The soil was kept moist and left for two weeks before planting. Urea fertilizer treatment was applied to specified plots two weeks after planting using the band placement method. Banding of the urea fertilizer was about 3.75 cm away from the plant on one side of the seed row and about 5 cm deep.

The *Amaranthus* seeds were mixed with dried river sand before sowing so as to ensure the seeds were not planted too close together for proper management of the seed rate desired. The mixture was 70% sand and 30% *Amaranthus* seeds. These were evenly distributed directly on drills at a distance of 10 cm between each row.

TABLE 1: Treatments and quantity per hectare

Treatments	Specific weights (kg/ha) of N
Control	Absolutely no
Cattle manure at 30 kg N/ha	2255.56
Cattle manure at 60 kg N/ha	4511.33
Cattle manure at 90 kg N/ha	6766.89
Goat manure at 30 kg N/ha	1224.44
Goat manure at 60 kg N/ha	2448.89
Goat manure at 90 kg N/ha	3673.56
Pig manure at 30 kg N/ha	1045.33
Pig manure at 60 kg N/ha	2090.67
Pig manure at 90 kg N/ha	3136.00
Poultry manure at 30 kg N/ha	1158.22
Poultry manure at 60 kg N/ha	2316.67
Poultry manure at 90 kg N/ha	3474.89
Urea fertilizer at 30 kg N/ha	66.67
Urea fertilizer at 60 kg N/ha	133.33
Urea fertilizer at 90 kg N/ha	200.00

TABLE 2: Chemical composition of treatments

Parameter	**Value**				
	Cattle manure	Goat manure	Pig manure	Poultry manure	Urea
pH (H_2O)	9.6	9.4	8.3	8.9	-
Org. C (%)	15.42	27.42	30.29	28.04	-
Org. matter (%)	26.58	47.27	52.22	48.34	-
Total N (%)	1.33	2.45	2.87	2.59	46
C: N ratio	11.59	11.19	10.55	10.82	-
Total P (%)	0.07	0.11	0..21	0.19	-
Total K (%)	0.90	1.39	1.80	1.50	-
Ca (%)	1.70	1.70	4.00	4.00	-
Mg (%)	0.70	0.90	1.80	2.00	-

The seedlings were later thinned to one plant per stand few days after emergence at a spacing of 10 cm between plants. Therefore, the planting distance was 10 cm × 10 cm giving plant population of 450 plants per bed equivalent to 1,000,000 plants per hectare (10,000 m^2). The plots were kept weed free throughout the crop growing period by hand pulling because of the closeness of the plants. Plots were irrigated manually using watering cans before planting and immediately after planting to ensure germination and enhance sprouting. Watering was done 2 times a day (morning and evening) at the initial stage of development and this was reduced to ones (evening only) every day till the end of the experiment. During this time there was a good canopy development that shaded the ground and reduced soil moisture loss.

Agronomic parameters measured included plant height and number of leaves per plant from randomly selected ten tagged plants per plot. Plant height was measured with a meter rule as the height from the base of the crop (ground level) to the tip of the plant, while the number of leaves was taken to be the fully opened leaves per plant. These measurements commenced 3 weeks after planting (WAP) and continued at weekly interval until the end of the experiment (5 WAP). At the end of the experiment, the ten tagged plants were uprooted, rinsed and labeled for onward analysis in the laboratory.

2.5 Laboratory studies

The soil sample was subjected to chemical analysis using standard procedures as described by [18]. The ten uprooted plants per plot were oven-dried at 65 ^{0}C to constant weight [20] and then milled for laboratory analysis. The animal manures and plant samples were subjected to chemical analysis using standard procedures as described by [18]. The nitrogen (N) in the samples was determined by the macro-kjeldahl method. The total N values were converted into crude protein by multiplying by a factor, 6.25. Separate samples were digested using the nitric-perchloric acid mixtures; phosphorus (P) was evaluated using phosphor-vanadomolybdate colorimetry, potassium (K) and sodium (Na) by flame photometer while calcium (Ca) and magnesium (Mg) were determnined by the EDTA titration method.

2.6 Data Analysis

Data collected were subjected to analysis of variance (ANOVA) using the general linear models (GLM) procedures of the Statistical Analysis System Programme [21] to determine treatment effects and means compared with Turky's HSD at 5 % level of probability.

3. Results and discussion

3.1 Properties of the soil used for the experiment

The soil used for the study was loamy sand in texture (sand= 831 g/kg, silt = 72 g/kg, clay = 97 g/kg) and strongly acid (4.76). The values of organic carbon (11.5 g/kg), total nitrogen (1.18 g/kg), available phosphorus (12.00 mg/kg) and potassium (0.10 cmol/kg) of the experimental soil were below the critical minimum for Nigerian soils [22]. The low levels of nutrients obtained in the experimental soils signify the need for additional nutrient supply.

3.2 Effects of different nitrogen sources and rates on growth parameters of *Amaranthus*

TABLE 3 presents data on the effect of different nitrogen sources and rates on the plant height of *Amaranthus* at different growth stages. At 3 WAP, there was no significant ($P > 0.05$) difference in growth between the control plots (without amendment) and those amended with the lowest rate of goat manure, pig manure and urea (30 and 90 kg N/ha). The tallest plants were obtained in plots amended with cattle manure and there was no significant difference in height between these plants and those of pig manure (60 kg N/ha) and poultry manure (90 kg N/ha). However, at 4 WAP, application of manure or urea fertilizer significantly ($P < 0.05$) enhanced growth compared with the control. The tallest plants were obtained in plots amended with higher rates of urea, pig manure and poultry manure each at 90 kg N/ha. Apart from goat manure at 30 and 90 kg N/ha, all the rates of manure and urea fertilizer significantly

TABLE 3: Effects of different nitrogen sources and rates on plant height of *Amaranthus*

Treatments	Plant height (cm)		
	3WAP	4WAP	5WAP
Control	9.33f	18.40i	29.77d
Cattle manure at 30 kg N/ha	14.27abcd	27.29gh	44.73bc
Cattle manure at 60 kg N/ha	16.58a	31.40ef	57.13ab
Cattle manure at 90 kg N/ha	15.13abc	33.43de	58.67a
Goat manure at 30 kg N/ha	10.25f	24.34h	38.93cd
Goat manure at 60 kg N/ha	11.20ef	29.19fg	41.30c
Goat manure at 90 kg N/ha	12.87cde	33.13de	39.67cd
Pig manure at 30 kg N/ha	10.30f	27.11gh	46.40bc
Pig manure at 60 kg N/ha	14.27abcd	35.43cd	55.80ab
Pig manure at 90 kg N/ha	13.87bcde	49.01a	64.47a
Poultry manure at 30 kg N/ha	12.87cde	25.43h	41.87c
Poultry manure at 60 kg N/ha	12.67de	41.11b	53.80ab
Poultry manure at 90 kg N/ha	15.83ab	48.01a	57.13ab
Urea fertilizer at 30 kg N/ha	11.40ef	27.31gh	53.33ab
Urea fertilizer at 60 kg N/ha	13.27cde	49.05a	55.93ab
Urea fertilizer at 90 kg N/ha	11.30ef	49.31a	61.60a

enhanced growth of *Amaranthus* compared with control plots at 5 WAP. The tallest plants were obtained in plots amended with pig manure, cattle manure and urea each at 90 kg N/ha and there were no significant differences among these nitrogen sources.

The highest plant height obtained from manure and urea fertilizer may be probably due to favourable nutrient mineralization of these fertilizers. The control plants produced the shortest plants as they had to rely only on the native soil fertility which from the result of chemical analysis was deficient in nutrients. Similar results have been reported by [23] who reported positive response of *Amaranthus* to added nutrients when compared with plants without additional nutrients. The highest plant height observed in this study from plants treated with higher rates of treatments agreed with the works of [24] and [25] who reported that higher rate of manure increased the plant height of *Amaranthus*.

At 3 WAP, application of manure and urea fertilizer at all rates with the exception of pig and poultry manure at 30 kg N/ha, significantly ($P < 0.05$) increased leaf production of *Amaranthus* compared with control plots (TABLE 4). The highest number of leaves was obtained in plots amended with urea at 60 kg N/ha, poultry manure and pig manure at 90 kg N/ha. There was no significant difference ($P > 0.05$) in the number of leaves produced between urea at 30 kg N/ha and goat manure (90 kg N/ha), cattle manure (90 kg N/ha), pig manure (60 kg N/ha) and poultry manure (60 kg N/ha). At 4 WAP, the trend almost followed that of 3 WAP. However, at the lowest rate of manure application, only goat manure amended plots produced significantly higher number of leaves compared with the control plots. Leaf production was significantly ($P < 0.05$) higher in plots treated with 60 kg N/ha of urea than any other fertilizer rate. This was closely followed by plots amended with 90 kg N/ha of either pig manure or poultry manure. There was no significant difference in leaf production at 5 WAP between the control plots and all rates of goat manure as well as the lowest rate of all other manure (TABLE 4). The highest number of leaves was obtained from plots amended with urea (60 and 90 kg N/ha) and pig manure (90 kg N/ha). There no significant $P > 0.05$) differences among these treatments. Differences in the number of leaves do affect the overall performance of *Amaranthus* as the leaves serve as photosynthetic organ of the plant. This is in line with what has been pointed out by [5] that adequate nitrogen supply is responsible for vigorous growth and leaf production of plants. Similar result was obtained by [24] who observed highest number of leaves of *Amaranthus* at higher rate of manure application.

3.3 Effects of different nitrogen sources and rates on crude protein content and nutrient uptake in *Amaranthus*

The result of crude protein content in *Amaranthus* plant as influenced by different rates of manure and urea fertilizer are presented in TABLE 5. Plots amended with cattle manure at 30 kg N/ha produced plants that had the same content of crude protein with the unamended plots. However, other rates of fertilizer application produced plants that had significantly higher crude protein content than the control plots. The highest crude protein content was obtained in plants amended with the highest rate of urea closely followed by urea at 60 kg N/ha and pig manure at 90 kg N/ha. This is in line with the result obtained by [16] as treatments applied led to significant increase in crude protein content of fluted pumpkin when compared with untreated plants.

TABLE 4: Effects of different nitrogen sources and rates on number of leaves per *Amaranthus* plant

Treatments	Number of leaves per plant		
	3WAP	4WAP	5WAP
Control	12.59i	22.49h	34.18h
Cattle manure at 30 kg N/ha	13.57efgh	22.77gh	34.80gh
Cattle manure at 60 kg N/ha	14.27bcde	23.90def	37.93ef
Cattle manure at 90 kg N/ha	14.43bcd	24.42d	39.77cd
Goat manure at 30 kg N/ha	13.37fgh	23.34efg	34.30h
Goat manure at 60 kg N/ha	13.93cdef	24.13de	35.23gh
Goat manure at 90 kg N/ha	13.83defg	24.20d	35.37gh
Pig manure at 30 kg N/ha	12.97hi	23.17fgh	35.70gh
Pig manure at 60 kg N/ha	13.80defg	25.57c	41.17c
Pig manure at 90 kg N/ha	14.83ab	26.48b	43.37ab
Poultry manure at 30 kg N/ha	13.17ghi	22.77gh	34.47h
Poultry manure at 60 kg N/ha	13.67efgh	24.53d	38.40de
Poultry manure at 90 kg N/ha	15.17a	25.90bc	39.53cde
Urea fertilizer at 30 kg N/ha	13.90cdefg	24.15d	36.43fg
Urea fertilizer at 60 kg N/ha	15.17a	27.75a	43.72ab
Urea fertilizer at 90 kg N/ha	14.57abc	25.47c	44.60a

TABLE 5: Effects of different nitrogen sources and rates on crude protein content and nutrient uptake of *Amaranthus* plant

Treatments	Crude protein (%)	Nutrient uptake (kg/ha)				
		N	P	K	Ca	Mg
Control	8.63k	38.15i	21.23j	44.24k	56.84i	11.66h
Cattle manure at 30 kg N/ha	9.21jk	64.25h	32.66fgh	73.39gh	91.41efgh	18.88efg
Cattle manure at 60 kg N/ha	10.16j	85.92fg	34.39fg	80.90defg	101.93ef	22.59def
Cattle manure at 90 kg N/ha	12.52h	105.85de	44.53cd	102.45c	125.54cd	26.89cd
Goat manure at 30 kg N/ha	11.32i	56.68h	26.00ij	55.66jk	74.48hi	15.26gh
Goat manure at 60 kg N/ha	12.76gh	68.25gh	29.12ghi	60.77ij	78.64gh	16.67fgh
Goat manure at 90 kg N/ha	14.61ef	97.98ef	36.27ef	78.06efgh	107.42de	19.79efg
Pig manure at 30 kg N/ha	14.93e	100.40def	36.43ef	73.91fgh	97.04efg	24.44cde
Pig manure at 60 kg N/ha	16.75cd	149.31c	50.37bc	115.16b	173.69b	35.22b
Pig manure at 90 kg N/ha	17.73bc	214.79a	70.86a	171.71a	256.28a	47.30a
Poultry manure at 30 kg N/ha	12.01hi	68.68gh	29.54ghi	68.19hi	81.01gh	18.84efg
Poultry manure at 60 kg N/ha	13.74fg	117.09d	42.00de	91.02cd	138.78c	27.74cd
Poultry manure at 90 kg N/ha	14.64ef	163.28bc	55.73b	120.45b	183.09b	47.36a
Urea fertilizer at 30 kg N/ha	16.65d	101.24def	28.25hi	56.69ij	82.44fgh	20.70efg
Urea fertilizer at 60 kg N/ha	17.98b	160.03bc	41.47de	87.31de	168.11b	29.62bc
Urea fertilizer at 90 kg N/ha	19.57a	169.02b	44.77cd	85.77def	166.61b	29.57bc

Manure and urea fertilizer application significantly ($P < 0.05$) enhanced N- uptake compared with the control. The least uptake of nutrients in control plots as observed in this study agreed with reports of [26], [16] and [27] who observed that nutrient content of fertilizer determines the uptake of such nutrient by plants. N-uptake increased with an increase in the rate of fertilizer application. The highest amount of N-uptake occurred in plots amended with pig manure at 90 kg N/ha closely followed by the highest rate of urea and poultry manure. With the exception of goat manure at 30 kg N/ha, application of fertilizer significantly enhanced P-uptake. The highest level of P-uptake was obtained in plots amended with pig manure at 90 kg N/ha followed by poultry manure at 90 kg N/ha. The uptake of K and Ca followed the trend of that of P-uptake. However, Ca-uptake in urea (60 and 90 kg N/ha) amended plots was statistically similar to plots amended with poultry manure at 90 kg N/ha and pig manure at 60 kg N/ha. For Mg-uptake, plots amended with goat manure up to 60 kg N/ha were similar statistically with the control plots. The greatest Mg-uptake occurred in plots amended with the highest rate of poultry and pig manure. A similar result of increases in nutrient uptake of *Amaranthus* as application rates of amendment increases was reported by [27] in Benin city of Nigeria. Significant increases in nutrient uptake of *Amaranthus* as a result of applying manure and NPK fertilizer in an Ultisol of South East Nigeria have also been reported by [26].

4. Conclusion

This study showed that *Amaranthus* responded positively to applied nutrients with the best performance obtained at higher rates of application of treatments. Pig manure at 90 kg N/ha was as effective as urea fertilizer. However, there was no significant increases in *Amaranthus* performance between urea fertilizer applied at either 60 kg N/ha or at 90 kg N/ha making the 60 kg N/ha of urea fertilizer more economical. For manure, the higher rate (90 kg N/ha), especially pig manure gave the best in all the growth parameters. Given its superior responses, pig manure at 90 kg N/ha could be a very attractive organic fertilizer alternative to inorganic fertilizer particularly for annual crops with short growth cycle such as *Amaranthus*. It is therefore recommended that pig manure at 90 kg N/ha be used in the cultivation of *Amaranthus cruentus* in Umudike and soil in similar agro ecology.

References

[1] R. R. Schippers, 2000. *African indigenous vegetables. An overview of the cultivated species*.Chatham, UK: Natural Resources Institute / ACP-EU Technical Centre for Agricultural and Rural Cooperation, 214.

[2] A. P. Mnkeni, P. Masika and M. Maphaha, 2007. Nutritional quality of vegetable and seed from different

accessions of *Amaranthus* in South Africa, *Water SA*, 33(3): 377-380.

[3] S. A. Ayuba, E .S. Attah and E. A. T. Ali, 2001. Growth response of *Amaranthus* (*Amaranthus cruentus L*) to application of urea and organic manure under irrigation, *Proceedings of the 27th Annual conference of the Soil Science Society of Nigeria*, 226- 230.

[4] S. L. Tisdale and W. L. Nelson, 1975. *Soil fertility and fertilizers,* 3rd ed. Macmillan publishing, New york, pp 694.

[5] G. C. Lowrison, *Fertilizer Technology*, 1989. Ellis Horwood Ltd, England, pp 543.

[6] H. L. S. Tandon, 1991. *Fertilizer recommendation for horticultural crops. A Guidebook,* 2nd ed. Fertilizer Development and Consultation Organization, New Delhi, India, pp 148.

[7] O. Odeyemi, I. A. Amuzu and S. Muazu, 1994. Development of technology for biogas and fertilizer production from liquid and solid wastes. In: Organic Fertilizer in the Nigerian Agriculture : Present and Future. *Proceedings of a National Organic Fertilizer Seminar*, Kaduna, 7 – 20.

[8] N. C. Brady and R. R. Weil, 1999. *The Nature and Properties of Soils*, 12th Edition (Prentice Hall, New Jersey, pp 881.

[9] I. Odiete, S. O. Ojeniyi, O. M. Akinola and A. A. Anchor, 1999. Effect of goat dung manure on soil chemical properties and yield components of okra, *Amaranthus* and maize, *Proceedings of the 25th Annual Conference of Soil Science Society of Nigeria (SSSN)*, Benin, 174 – 178.

[10] O. B. Iren, D. O. Asawalam, V. E. Osodeke and N. M. John, 2011a. Effects of Animal Manures and Urea Fertilizer as Nitrogen Sources for *Amaranthus* Growth and Yield in a Rainforest Ultisol in Nigeria. *World Journal of Applied Science and Technology (WOJAST)*, 3 (1): 73-78.

[11] E. I. Moyin-Jesu, 2007. Use of selected agro-industrial biomass for enhancing seed nitrogen, ash and crude protein quality of *Amaranthus viridis*, *L. Emir. J. Food Agric.*, 19 (1): 13-21.

[12] J. P. Zublena, J. C. Barker and T. A. Carter, 1996. Poultry manure as a fertilizer source. In: Water quality and waste management, *North Carolina Cooperative Extension Service*, 439- 456.

[13] I. Hoffman, D. Gerling, U.S. Kyiogwon and A. Mane-Bieldfeldt, 2001. Farmer's management strategies to maintain soil fertility in a remote area in northwest Nigeria, *Agriculture,Ecosystem and Environment*, 86: 263-275.

[14] K. D. Smiciklas, A. S. Moore and J. C. Adams, 2008. Fertilizer nitrogen practices and nitrate levels in surface water within an Illinois watershed, *Journal of Natural Resources and Life Sciences Education*, 37: 14-19.

[15] O. B. Iren and V. E. Osodeke, 2006. Estimation of Water Requirements of Early and Late Season Pepper (Capsicum annum) in Umudike, South-Eastern Nigeria, *Global Journal of Agricultural Sciences*, 5 (2): 95-99.

[16] O. B. Iren, N. M. John and E. A. Imuk, 2012. Effects of sole and combined applications of organic manures and urea on growth, crude protein and nutrient uptake of fluted pumpkin (*Telfairia occidentalis*, Hook f.), *Journal of Agriculture, Forestry and Environment*, 2 (1): 78 – 85.

[17] Soil Survey Staff, 1999. Soil Taxonomy: A basic system of soil classification for making and interpreting soil surveys (2nd ed.), Natural Resources Conservation Service, USDA, Washington DC, USA.

[18] E. J. Udo, T. O. Ibia, J. A. Ogunwale, A. O. Ano and I. E. Esu, 2009. *Manual of soil, plant and water analyses*, Sibon books Ltd. Lagos.

[19] O. B. Iren, D. O. Asawalam and V. E. Osodeke, 2011b. Effects of Time and Method of Pig Manure Application on Growth Parameters and Yield of *Amaranthus cruentus* in a Rainforest *Ultisol* in Nigeria, *Production Agriculture and Technology (PAT) Journal*, Nasarawa State University, Keffi, 7 (1): 103-116.

[20] A. P. Maerere, G. G. Kimbi and D. L. M. Nonga, 2001. Comparative effectiveness of animal manures on soil chemical properties, yield and root growth of *Amaranthus* (*Amaranthus Cruentus* L.), *African Journal of Science and Technology*, 1(4): 14-21.

[21] SAS (Statistical Analysis System), 1989. *Statistical Analysis System User's guide: Statistics,* SAS Institute.

[22] E. A. Aduayi, V. O. Chude, B. A. Adebusuya and S. O. Olayiwola, 2002. *Fertilizer Use and Management Practices for Crops in Nigeria*, Federal Fertilizer Department, Federal Ministry of Agriculture and Rural Development, Abuja, pp 188.

[23] O. A. Abayomi and O. J. Adebayo, 2014. Effect of Fertilizer Types on the Growth and Yield *Amaranthus caudatus* in Ilorin, Southern Guinea, Savanna Zone of Nigeria, *Advances in Agriculture*, Article ID 947062, 5 pages, doi:10.1155/2014/947062.

[24] S. O. Akparobi, 2009. Effect of farmyard manures on the growth and yield of *Amaranthus cruentus*, *Agricultural Tropica et Subtropica*, 41 (1): 7 – 10.

[25] K. O. Sanni, J. M. Adesina, B. S. Ewulu, S. O. Ojeniyi and F. E. Mazi, 2013. Comparative effect of

variable rates of pig and poultry manure on the agronomic performances of *Amaranthus hybridus* in humid rainforest, South Western Nigeria, *Nigerian Journal of Soil Science*, 23 (1): 42 – 47.

[26] O. I. Nwachukwu, A. E. Nyong and U. D. Opara, 2013. Effect of manures and ash on soil properties, yield and nutrient uptake of *Amaranthus* in an Ultisol of South East Nigeria, *Nigerian Journal of Soil Science*, 22 (2): 70 – 78.

[27] E. O. Jumbo, S. U. Remison and K. E. Law-Ogbomo, 2012. Influence of palm oil mill effluent and NPK on nutrient availability to *Amaranthus cruentus*, *Nigerian Journal of Soil Science*, 22 (2): 88-96.