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Comparative effects of different nitrogen sources and rates on soil properties and yield 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 the soil properties and yield 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 pH value of the soil was significantly increased in plots amended with higher rates of organic manure. Higher rates of amendments significantly ($P \leq 0.05$) increased total N, organic carbon, exchangeable K, Na and base saturation contents of the soil relative to the control plots. Among all the treatments, plots amended with pig manure at 90 kg N/ha had the best soil chemical properties. Amendment of soil with organic manure and urea significantly ($P \leq 0.05$) enhanced fresh and dry matter yield of *Amaranthus* with the highest values of 48.18 t/ha and 7.66 t/ha obtained in plots amended with 90 kg N/ha of pig manure, respectively. It is therefore recommended that pig manure at 90 kg N/ha be used in the cultivation of *Amaranthus* in Umudike and soil in similar agro ecology.
Keywords: *Amaranthus, organic manure, soil properties, urea fertilizer, rates of application*

1. Introduction

Tropical soils are highly susceptible to degradation under continuous cultivation. Amelioration of soil fertility problem in the tropics through inorganic fertilizer application is faced with much criticism with respect to environmental and health concerns. Good quality soil is important for sustainable crop production especially under continuous cultivation. The use of organic manures for the production of leafy vegetables has been reported to be effective [1], [2]. Manures can sustain crop yield under continuous cultivation. They have the capacity for gradual release of nutrients to the soil thereby improving the fertility of degraded soil [1]. Generally, adequate soil nitrogen, phosphorus and potassium are essential nutrients which can be supplied by organic and inorganic fertilizer sources.

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 [3]. 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. Leafy vegetables such as *Amaranthus* require more nitrogen for its optimum growth. High levels of nitrogen will delay the onset of flowering, allowing a considerably higher yield [4]. 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) [5]. In acid soils plants absorb more nitrate ions, and in slightly alkaline soils they absorb more ammonium ions [5]. *Amaranthus cruentus* can be sown directly in seed bed with the entire plant harvested some 4 to 5 weeks after sowing [4], or planted in nursery beds before transplanting them to the main field. According to [4], 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 [4], [6].

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 [7]. There is usually a short dry spell in August which is referred to as ‘August break’. The minimum and maximum temperatures range from 19 to 24^{0}C and 28 to 34^{0} 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 [1] and classified as an Ultisol [8].

2.2 Soil sampling and processing

Soil samples were taken from the experimental site before and after experiment using soil auger at a depth of 0-15 cm. About 6-8 sample points were taken from each block, mixed thoroughly to make a composite sample before commencement of experiment, while one composite soil sample was taken per plot after the experiment for laboratory analysis. The soil samples were air-dried, ground and sieved with 2 mm sieve to remove materials greater than 2 mm in diameter before using them for analysis.

2.3 Experimental design and treatments

Sixteen (16) treatments (Table 1) were laid out in a randomized complete block design with 3 replications each. 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 [9]. 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 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.

Harvesting was done at 5 WAP by uprooting the entire plant from an area of 100 cm × 100 cm per plot and the fresh yield determined after rinsing the roots free of sand. For dry matter determination, ten tagged plants were uprooted, rinsed, and oven-dried at 65 ^{0}C to constant weight [10] and the weight determined using digital balance. The data on fresh and dry yield were converted into t/ha using the formula below:

$$\text{Yield (t/ha)} = \frac{WT \times 10^{-2}}{PA} \quad (1)$$

Where *WT* = weight of *Amaranthus* (g), *PA* = plot area (m^2), 10^{-2} = conversion factor because 1 ha = 10^4 m^2 and 1 t = 10^6 g or 10^3 kg.

2.5 Laboratory studies

The animal manures and soil samples were subjected to laboratory analysis using standard procedures as described by [9]. Particle size distribution was determined by the Bouyoucous hydrometer method, using sodium hexametaphosphate as a dispersant. Soil pH was determined in 1:2.5 soil: water ratio with a pH meter. Organic carbon was determined by Walkley and Black Dichromate Oxidation Method. Total nitrogen (N) was determined by the micro-kjeldahl method. Available phosphorus (P) was extracted by the Bray 1 extraction method, and the content of P was determined colorimetrically using a Technico AAII auto analyser (Technico, Oakland, Calif). Exchangeable bases (K, Na, Ca, Mg) were extracted with 0.1N ammonium acetate, K and Na were read with a flame photometer while Ca and Mg were determined through the EDTA titration method. Exchangeable acidity was determined by leaching the soils with 1N KCl and titrating aliquots with 0.01 NaOH. Effective cation exchange capacity (ECEC) was calculated as the sum of Ca, Mg, K and Na and exchangeable acidity. Base saturation was calculated by dividing the sum of exchangeable bases by ECEC and multiplying by 100.

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 [11] 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

TABLE 3 shows the initial status of the soil used for the experiment. The results of the analysis (sand= 83.1 %, silt = 7.2 %, clay = 9.7 %) showed that the soil was loamy sand in texture with silt content below 10 %. This agrees with the report of [12], [13], who noted that the silt content of the soils of eastern Nigeria is very low. They classified the soil of the study area with loamy sand texture as an Ultisol. The soil was strongly acid (4.76) in reaction. The high acidic level of the soil may be due to high intensity rainfall in the area, which leaches basic cations down the profile. 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 [14]; this may be due to low soil organic matter. Low organic matter in the soil lowers the soil water holding capacity [15] which in turn increases the soil temperature [16]. Organic matter increases the amount of soil water and the proportion of available water for plant growth [17], the ultimate consequence of low soil organic matter being declining soil fertility and increased soil loss through erosion. The low nitrogen level could be attributed to high rate of mineralization and subsequent high rate of leaching that accompanies the heavy rains associated with the forest zone of Southeastern Nigeria

[18]. The low levels of nutrients obtained in the experimental soils indicate low fertility status and may be attributed to high temperature, high rainfall and leaching losses which characterize the tropical areas [19]. The low fertility status could also be attributed to continuous cropping which necessitates the need for additional nutrient supply.

TABLE 3: Pre-cropping soil properties in the experimental site

Soil Property	Value
Sand (%)	83.1
Silt (%)	7.2
Clay (%)	9.7
Texture	Loamy sand
pH (H_2O)	4.76
pH ($CaCl_2$)	4.08
Org. C (g/kg)	11.5
Total N (g/kg)	1.18
C:N ratio	9.75
Available P (mg/kg)	12.00
Exchangeable Ca (cmol/kg)	2.60
Exchangeable Mg (cmol/kg)	1.20
Exchangeable K (cmol/kg)	0.10
Exchangeable Na (cmol/kg)	0.06
Exchangeable Acidity (cmol/kg)	1.36
ECEC (cmol/kg)	5.32
Base saturation (%)	74.4

3.2 Effects of different nitrogen sources and rates on soil properties

The results of the chemical properties of the soil after harvest as influenced by the different rates of application of either organic or inorganic fertilizer are presented in TABLE 4. The pH (H_2O) of the soil was increased significantly ($P < 0.05$) with fertilizer application compared with the untreated plots (control) excepting plots amended with urea at 30 and 90 kg N/ha. However, for soil pH ($CaCl_2$), only soil amended with pig manure (60 - 90 kg N/ha), poultry manure (90 kg N/ha) and cattle manure (60 - 90 kg N/ha) had a significant increase in pH compared with the control. The highest soil pH value was obtained in cattle manure (90 kg N/ha) amended plots. This view was also reported by [20], who observed that soil pH was more greatly increased with the application of municipal wastes, poultry and pig manures, especially at the higher rates of treatment. It was also reported by [21], that application of manures significantly increased soil pH. Other researchers [22], [23], [24], [25] also reported increases in soil pH as application rates of manure were increased. The mechanism responsible for the increase in soil pH was due to ion exchange reactions which occur when terminal OH^- of Al or Fe^{2+} hydroxyl oxides are replaced by organic anions which are decomposition products of the manure such as malate, citrate and tartrate [26]. The ability of organic manure to increase soil pH was due to the presence of basic cations contained in them.

The total N content of the soil was significantly ($P < 0.05$) increased with fertilizer application with the exception of pig manure and urea each at 30 kg N/ha compared with the control plots. However, the highest total N value was obtained in plots amended with pig manure at 90 kg N/ha closely followed by plots amended with the highest rate of poultry manure and urea. With the exception of goat manure at 30 kg N/ha, application of either fertilizer type significantly increased organic carbon content of the soil. The highest content of organic carbon was obtained in plots amended with pig manure (60- 90 kg N/ha), cattle and poultry manure at 90 kg N/ha. A build-up of the soil organic carbon by addition of organic manures has also been confirmed by several studies [10], [27], [24]. Application of organic and inorganic fertilizer did not significantly ($P > 0.05$) increase the available P content of the soil compared with the control excepting those plots treated with pig manure (60 – 90 kg N/ha), cattle and poultry manure at 90 kg N/ha. Plots amended with pig manure at 90 kg N/ha had the highest amount of available P.

For calcium, with the exception of pig manure and poultry manure (90 kg N/ha) as well as cattle manure at 30 kg N/ha and 90 kg N/ha, application of either fertilizer type did not cause significant ($P > 0.05$) increase in calcium content compared with the soil with no fertilizer application. Magnesium content of the soil almost followed the trend of calcium. However, urea applied at 30 - 60 kg N/ha significantly increased the content of Mg compared

TABLE 4: Effects of different nitrogen sources and rates on soil properties

Treatments	pH (H2O)	pH ($CaCl_2$)	Total N (g/kg)	Org. C (g/kg)	Av. P (mg/kg)	Exchangeable cations (cmol/kg)				EA (cmol/kg)	ECEC (cmol/kg)	BS (%)
						Ca	Mg	Na	K			
Control	4.82g	4.32d	1.18i	11.15h	16.60efgh	3.08de	1.68fg	0.05d	0.088hi	1.36a	6.31de	77.52f
C30	5.22de	4.34d	1.26h	14.93fg	13.30cdef	3.60bc	1.73fg	0.06c	0.093gh	1.15c	6.69cd	82.08cde
C60	5.51abc	4.63c	1.40ef	17.63bcd	13.57cde	3.20cde	2.00cdef	0.06c	0.097f	1.14c	6.30de	84.98bcd
C90	5.64a	4.85a	1.45de	18.63abc	16.67ab	3.63bc	2.53ab	0.07b	0.111bc	1.10cd	7.29ab	86.93ab
G30	5.04ef	4.33d	1.32g	13.33gh	10.33h	3.10de	1.73fg	0.06c	0.095fg	1.15c	6.27de	79.22ef
G60	5.27d	4.33d	1.42ef	16.13def	10.70gh	3.10de	1.73fg	0.06c	0.097f	1.15c	6.10e	81.78cde
G90	5.31cd	4.40d	1.44de	15.63defg	12.20defgh	3.43bcde	1.93defg	0.06c	0.103d	1.12c	6.54cde	84.77bcd
Pi30	5.24de	4.36d	1.20i	16.17cdef	13.60cde	3.23cde	1.87defg	0.06c	0.098ef	1.14c	6.42cde	82.07cde
Pi60	5.31cd	4.68bc	1.49d	19.73ab	15.40bc	3.53bcd	2.13cde	0.07b	0.114ab	1.10cd	6.87bc	85.20bc
Pi90	5.52ab	4.79ab	1.90a	20.93a	18.25a	4.27a	2.60a	0.08a	0.117a	0.99e	7.72a	89.00a
Po30	5.20de	4.35d	1.38f	14.63fg	12.37defgh	3.50bcd	1.60g	0.06c	0.097f	1.16c	6.44cde	81.37de
Po60	5.26d	4.44d	1.45de	16.50cdef	12.60defg	3.40bcde	2.20bcd	0.07b	0.110c	1.12c	6.90bc	82.67cde
Po90	5.31cd	4.63c	1.68b	17.33bcde	14.50bcd	3.70b	2.33abc	0.07b	0.112bc	1.04de	7.26ab	85.23bc
U30	4.98fg	4.34d	1.18i	14.33fg	11.03fgh	3.23cde	2.13cde	0.06c	0.085i	1.15c	6.56cde	84.30bc
U60	5.13def	4.36d	1.61c	15.53defg	12.60defg	3.23cde	2.13cde	0.06c	0.101de	1.12c	6.56cde	84.30bc
U90	4.99fg	4.32d	1.72b	15.87defg	12.43defgh	3.03e	1.80efg	0.06c	0.097f	1.25b	6.09e	82.10cde

Means having the same letter within a column are not significantly different by Turky's HSD at $P<0.05$
C = cattle manure, G = goat manure, Pi = pig manure, Po = poultry manure, U = urea fertilizer
30, 60, 90 = rates of application based on N content.

with the control. Fertilizer application significantly increased the sodium content of the soil relative to the control. However, the highest value was obtained in plots amended with 90 kg N/ha of pig manure. Apart from urea and cattle manure at 30 kg N/ha, all rates of fertilizer application significantly increased K content of the soil compared with the control. The highest K content was obtained in soil amended with pig manure at 90 kg N/ha. This is in line with what was reported by several researchers [27], [28], that organic manures are generally superior to inorganic fertilizer in improving the soil availability of K, Ca, Mg and Na. The results showed general improvement on the exchangeable cations of the soil under study. These observations are in agreement with the findings of [29], who reported that increasing rates of poultry manure resulted in increasing values of exchangeable cations (bases).

Plots not amended with fertilizer had significantly the highest exchangeable acidity (EA) value. This was followed by those treated with urea at 90 kg N/ha. The least EA value was obtained in plots amended with the highest rate of pig manure. The effective cation exchange capacity (ECEC) of the soil was not significantly increased ($P > 0.05$) with application of either organic or inorganic fertilizer with the exception of plots amended with cattle manure (90 kg N/ha), poultry and pig manure (60 - 90 kg N/ha) compared with the control plots. The highest ECEC value was obtained in plots amended with pig manure at 90 kg N/ha. There was a significant increase in base saturation of the soil with application of either fertilizer type with the exception of plots amended with goat manure at 30 kg N/ha relative to the control plots. Plots amended with pig manure at 90 kg N/ha had the highest base saturation value. The improvement in most of the soil chemical properties by the amendments applied, especially the organic fertilizer, is in line with the findings of [30], [31] who reported that manure increased soil organic matter, N, P, exchangeable K, Ca and Mg.

3.3 Effects of different nitrogen sources and rates on fresh and dry matter yield of *Amaranthus*

Results of fresh and dry matter yield of *Amaranthus* are presented in TABLE 5. Apart from the lowest rate of goat and poultry manure, application of fertilizer at all rates significantly ($P < 0.05$) increased fresh yield of *Amaranthus*. The highest fresh yield (48.18 t/ha) was obtained from plots amended with pig manure at 90 kg N/ha and this was statistically similar to fresh yield obtained from plots amended with urea at 60 kg N/ha (43.67 t/ha) and urea at 90 kg N/ha (43.96 t/ha). For the dry matter yield, there was a significant increase in dry matter accumulation in plots amended with either organic or inorganic fertilizer at all rates with the exception of goat manure at 30 kg N/ha compared to the control plots. The highest dry matter yield (7.66 t/ha) was obtained in plots amended with pig manure at 90 kg N/ha closely followed by poultry manure at 90 kg N/ha (6.46 t/ha). There were no significant differences in dry matter yield among cattle manure (90 kg N/ha), poultry and pig manure each at 60 kg N/ha and urea (60 and 90 kg N/ha) treated plots.

Generally, the fresh yields obtained from almost all the treatments except the absolute control were higher than the 25 t/ha reported as the optimum yields by [32], and the maximum yield of 30 t/ha reported by [4] (2000) but fall within the range obtained by [33]. This shows that *Amaranthus* responded positively to the amendments applied. The highest dry matter yields obtained from the pig manure treatment concurs with those obtained by [10].

TABLE 5: Effect of different nitrogen sources and rates on fresh and dry matter yield of *Amaranthus*

Treatments	Fresh yield	Dry matter yield
Control	18.78h	2.80i
Cattle manure at 30 kg N/ha	24.92fg	4.28fg
Cattle manure at 60 kg N/ha	29.60def	4.65ef
Cattle manure at 90 kg N/ha	34.82cd	5.35cd
Goat manure at 30 kg N/ha	19.34h	3.38hi
Goat manure at 60 kg N/ha	22.78gh	3.52h
Goat manure at 90 kg N/ha	26.03efg	4.35efg
Pig manure at 30 kg N/ha	30.11def	4.24fg
Pig manure at 60 kg N/ha	39.91bc	5.68c
Pig manure at 90 kg N/ha	48.18a	7.66a
Poultry manure at 30 kg N/ha	23.24gh	3.78gh
Poultry manure at 60 kg N/ha	30.34de	5.00de
Poultry manure at 90 kg N/ha	42.53b	6.46b
Urea fertilizer at 30 kg N/ha	30.19def	3.76gh
Urea fertilizer at 60 kg N/ha	43.67ab	5.52cd
Urea fertilizer at 90 kg N/ha	43.96ab	5.35cd

4. Conclusion

This study showed that the organic and inorganic fertilizers applied improved the soil properties and yield of *Amaranthus* relative to control with the best performances obtained at higher rates of application of amendments, especially pig manure. Pig manure at 90 kg N/ha was as effective as urea fertilizer at 60 and 90 kg N/ha. Based on the role played by organic manure in soil fertility maintenance, and also on the increasing awareness by consumers in western and tropical countries on illnesses such as diabetics, hypertension, cancer and obesity associated with consumption of food produced from using chemical fertilizers, pig manure could be a very attractive fertilizer alternative particularly for annual crops with short growth cycle such as *Amaranthus*. It is therefore reasonable to recommend the use of pig manure at 90 kg N/ha in the cultivation of *Amaranthus cruentus* in an acidic Ultisol.

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