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Effects of Fish Pond Effluent and Inorganic Fertilizer on Amaranthus Yield and Soil Chemical Properties in Asaba, Delta State, Nigeria

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Abstract

An experiment was conducted at the Department of Agronomy Experimental Farm, Delta State University, Asaba Campus in 2011 early and late cropping seasons to evaluate the effects of fish pond effluent and inorganic fertilizer on amranthus performance. The study had five levels of fish pond effluent (0, 5, 10, 15 and 20t/ha) and five levels of inorganic fertilizer (0, 100, 150, 200 and 250 kg/ha), laid out in randomized complete block design with four replications. Number of leaves, leaf area, plant girth, leaf fresh weight, stem fresh weight, marketable yield and dry matter yield were measured. Soil samples were taken before and after harvest of late season for soil chemical evaluation. Data were subjected to analysis of variance and means differences were separated with DMRT at 5% level of probability. Results revealed that fish pond effluent and inorganic fertilizer had positive effects onamaranthus. The 250 kg/ha of NPK produced the highest leaf fresh weight, stem fresh weight and marketable yield while 20 t/ha of fish pond effluent had highest dry matter yield at both seasons. Also, 20 t/ha of fish pond effluent had higher effects on soil chemical properties than the NPK fertilizer. It is therefore recommended that 20 t/ha of fish pond effluent be applied in Asaba and its environs.

Keywords: organic waste, soil fertility, soil chemical properties, Amaranthus yield, dry matter

Introduction

Nutrient management is important in sustainable and intensive crop production. Vegetable production in Nigeria (e.g. amaranths) is plagued with an array of challenges such as poor farm inputs, poor cropping system, pests and diseases attack and poor soil fertility (Nwangburaka*et al*., 2012). Among these challenges, poor soil fertility accounted for significantly higher proportion of the problems in crop production (Manyong*et al*., 2002). In this prevailing condition, constant nutrient supply through fertilizer application will be solution or else, soil nutrient decline will be continuous and this will hinder amaranth us production. Vegetable production has become a major aspect of horticulture in view of the value of its products. Amaranth us ranks among the best leafy vegetable in terms of its chemical composition and nutritional value. It contains appreciable amount of crude protein, minerals (calcium and potassium) and vitamins A and C that can contribute substantially to our daily requirement when consumed in reasonable quantity (Rubatzky and Yamaguchi, 1997). Yield of amaranth that range from 4 to 14 t/ha (fresh weight) reported by Campbell and Abboth (1982) could be increased up to 40 t/ha with fertilizer application (NRC, 1984).
Inorganic fertilizer has been used as soil amendment for crop production in the world (Donava and Casey, 2002). This has resulted to increased demand for inorganic fertilizer to ameliorate the lost soil nutrient and improve crop production. The resultant effect was increased production cost which affects food produced in the world most especially Nigeria. In addition,it was revealed that inorganic fertilizer had adverse effects(nutrient imbalance, soil acidity, increased greenhouse effects) on soils (FAO, 2012).

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It also induces cytological defects and chromosomal abnormalities in plant cells (Tabur and Oney, 2009). Application of inorganic fertilizer to sustain crop was found to increase yield only for few years but on long-term basis, it was not effective (Ojeniyi, 2000). It is to be noted that procurement of inorganic fertilizer is beyond the reach of resource poor farmers because of its high cost coupled within accessibility. These challenges leads to the advocacy for the use of organic fertilizer in agriculture. Organic waste is an important source of nutrient for crops especially fruits and vegetables. Huge amount of organic wastes (fish pond effluents, palm oil mill effluents, cassava mill effluent, rubber mill effluent, abattoir waste and crop residues) are generated as by product and are found in most agricultural processing units, posing potential environmental challenges. This condition in addition to scarcity of inorganic fertilizer has necessitated in shift research attention to the utilization of organic wastes which may pose environmental hazard if not converted to agricultural and economic uses (Ayeni, 2010). Incorporating the organic wastes into the soilhelps to build up soil organic matter layer needed for steady supply of plant nutrients (Agboola and Omueti, 1982). The application of organic waste is found to increased soil organic carbon, nitrogen, available phosphorus, exchangeable bases and soil pH (Vanluawe*et al., 2001*). Formulated feeds, and large amount of green and animal manures are applied to fish pond, leading to organic matter accumulating in pond bottoms with time. Regular feeding and fertilization results in accumulation of organic matter, nitrogen and phosphorus in fish pond effluent. Organic matter accumulation rates of 0.87g m^2 d^1 have been reported for intensive polyculture (Schroeder, 1987), while in Tilapia ponds it ranges from 100 to 1500g m^2 d^1 (Avnimelech *et al.,* 1995). Avnimelech (1998), reported that only 25% of N and 20% of P of the feed is recovered in harvested fish and the rest is accumulated in pond effluent. Therefore, application of fish pond effluent will increase soil fertility due to its high nutrient content. Hence, the study aimed at evaluating different levels of the fish pond effluent and NPK15:15:15 fertilizer on the growth and yield of amaranth us and soil chemical properties in Asaba, Delta State, Nigeria.

Materials and Methods

The research was carried out in early (May/June) and late cropping seasons (September/October) of 2011, at the Department of Agronomy Experimental Farm, Delta State University, Asaba Campus. The site is situated in rainforest zone of Nigeria, at longitude 6^0 14′E and latitude 6^0 14′N. The rainfall pattern was bi-modal with a definite cycle of rainy season from March to October and dry season from November to February. The site was continuously cropped to arable crops (cassava, maize and yam) without record of fertilizer usage. The predominant weeds found on the site were siam weed (*Chromolaenaodorata*) and guinea grass (*Aspiliaafricana*). Soil sample was collected for pre-planting soil analysis (particle size distribution and chemical properties). The fish pond effluent used was collected from Fishery Unit, Faculty of Agriculture Teaching and Research Farm. While the inorganic fertilizer was obtained from Agricultural Development Project (ADP), Ibusa, Delta State. The fish pond effluent was applied at0, 5, 10, 15 and 20 t ha^{-1}while NPK 15: 15:15 was applied at 0, 100, 150, 200 and 250 kg ha^{-1}in four replications. The fish pond effluent was incorporated into the soil with hoe and spade during seed bed preparation, a day before transplanting while the NPK fertilizer was applied a week after transplanting. The amaranth us seeds obtained from local vegetable producer at Agbor, Delta State were sowed and the seedlings were transplanted two weeks after into already prepared bed at one per hole. The experiment was laid out in a randomized complete block design (RCBD), while the field lay-out measured 35 m by 19 m (665 m^2), demarcated into four replicates (35 m by 4 m each) with nine subplots, of3 m by 4 m, spaced 1 m apart. While planting space of 25 cm by 50 cm was used. Sixteen plants with 100 by 200 cm quadrant in each bed were measured for growth and yield parameters. The data collections on growth parameters started three weeks after transplanting and subsequently on weekly basis while yield parameters were assessed after harvest. Soil samples were taken after harvest of the late season for post-harvest soil chemical analysis. The parameters considered were: plant height (cm), number of leaves, plant girth (cm), leaf area (cm^2),leaf fresh weight (t/ha), stem fresh weight (t/ha), dry matter yield and vitamin C content, while the soil parameters were: soil pH, organic matter, total nitrogen, available phosphorus, potassium, calcium, magnesium and sodium.

The soil samples were air dried at room temperature and sieved with 2mm sieve before analyses. The soil pH was on a ratio of 1:2 soil/water suspensions (IITA, 1979). Organic carbon was determined with Walkley Black Method. Exchangeable bases- K, Ca. Mg and Na were extracted by ammonium acetate extraction. The Ca and Mg were determined by Atomic Absorption Spectrophotometer (AAS) while K and Na were read with Flame Photometer. The available P was extracted using Bray-1 extracting solution and further reading was carried out Color metrically. Total N was determined with Kjeldhal distillation method. The data obtained were statistically analyzed using the Analysis of Variance. Duncan Multiple Range Test (DMRT) at 5% level of probability was used to separate differences among treatment means.

Results

Particle size Distribution and Chemical Analysis before Planting

The nutrient content of soil before pre-planting was shown on Table 1. The soil was sandy loam, slightly alkaline and low in total N, and available P. The total N of 0.41 gkg^{-1} was less than the critical level of 1.5 kg^{-1}, while the available P of 6.81 mg kg^{-1} was less than the critical level.

Post Planting Soil Chemical Analysis

Table 2 shows the effects of different levels of fish pond effluent and NPK 15:15:15 fertilizer on soil chemical properties after late season harvest. The levels of NPK 15:15:15 reduces soil pH than the control while application of fish pond effluent increased the soil pH. Application of 15t/ha of fish pond effluent had the highest organic carbon, and was followed by 20 t/ha of fish pond effluent whereas the least was control. Also, 20 t/ha fish pond effluent had the highest total nitrogen, while the least was the control. Increase level of fish pond effluent and NPK 15:15:15 led to increase of available phosphorus. Control treatment had the least available phosphorus, while 20 t/ha of fish pond effluent had the highest available phosphorus. The NPK15:15:15 at 200 and 250 kg/ha and 20 t/ha fish pond effluent had equal value of potassium while the control had the least. Application of 10 t/ha of fish pond effluent and 100 kg/ha of NPK15:15:15 had equal value of calcium followed by 20 t/ha fish pond effluent whereas the control had the least. Fish pond effluent at 20 t/ha had the highest magnesium followed by 15 t/ha of fish pond effluent and 200 kg/ha of NPK15:15:15. Application of 20 t/ha fish pond effluent gave highest sodium in soil closely followed by application of 15 t/ha fish pond effluent and 200 kg/ha NPK15:15:15.

Effects of Different Levels of Fish Pond Effluent and NPK15:15:15 on the growth of Amaranth us in Both Seasons

Table 3 showed the effects of different levels of fish pond effluent and NPK15:15:15 on the growth of amaranth us at 7weeks after transplanting (WAT). There were significant differences and growth of amaranth us which increases with corresponding increase in levels of fertilizer application and WAT. Plant height at 7 WAT was significantly highest (68.7 cm) with application of250 kg/ha NPK15:15:1 at the early season and 20 t/ha (72.3 cm) of fish pond effluent at the late season At the early season, 250 kg of NPK15:15:15 had highest number of leaves, followed by 150 kg of NPK15:15:15 while the control was the least. Then in late season, 15 t/ha of fish pond effluent had highest number of leaves followed by 250 of NPK15:15:15 and 15 t/ha of fish pond effluent while control had the least. The 250 kg of NPK15:15:15 had highest leaf area at early season, at the late season, 20 t/ha of fish pond effluent had highest leaf area. The plant girth also increased with increase of WAT and application level. At early season, 250 kg of NPK15:15:15 had highest plant girth at 7 WAT. During the late season, 20 t/ha of fish pond effluent had the highest plant girth while control had the least plant girth.

Effects of Different levels of Fish Pond Effluent and NPK15:15:15 on yield and Yield Quality of Amaranths in both Seasons

Amaranths yield increased significantly with increase in both fertilizer levels and cropping seasons (Table 4). The 250 kg of NPK15:15:15 produced highest leaf fresh weight, stem fresh weight and marketable yield while control had the least in both early and late seasons respectively. Table 5 also shows effects of different levels of fish pond effluent and NPK15:15:15 fertilizer on amaranthus dry matter yield after harvest at both seasons. The 20 t/ha of the fish pond effluent produced significantly higher dry matter yields at both seasons while the control had the least. The late season dry matter yields were generally higher than the early season. The vitamin C content of the amaranthus increases significantly with increase in fertilizer application and season of cropping (Table 5). At the early season, 250 kg of NPK15:15:15 treated amaranth us had highest vitamin C content (32.4) while the control was 11.31 mg/100g. In late season, 20 t/ha of fish pond effluent treated amaranth us had the highest vitamin C content while control was also the least (11.31 mg/100g). The values of vitamins recorded was slightly higher in the late season cropping than early season.

Discussion

Initial soil analysis of the site showed sandy loam and acidic with low organic matter, total N, available P, exchangeable bases and high base saturation. The soil pH is within the range reported by Kamprath, (1970) for proper amaranth us growth.

The low soil organic matter content suggested the need for improvement to support vegetable production. The decreased soil organic matter and plant nutrients are key factors responsible for the observed declining trend in cropping system (Reddy and Krishnainh, 1999). This declining soil fertility was a major characteristics of tropical soils (Ogunwale *et al*., 2002). The soil poor fertility was attributed to continuous cropping which makes the soil highly vulnerable to soil degradation (Anikwe*etal*., 1999). The low pH in the control, NPK and increases pH in the fish pond effluent explained acidifying effects of the NPK fertilizer and neutralizing effects of fish pond effluent. The fish pond effluent has been found to improving soil pH due to the relative exchangeable Ca, Mg and K it contained (Olayinka and Adebayo, 1985). Application of NPK fertilizer increase soil acidity slightly over the control, this slight increase could be attributed to application of the NPK fertilizer, indicating that mineral fertilizer cannot be used to improved soil acidity (Onwudike, 2010). In all the fish pond effluent treatments, soil organic matter increased with the application level. This increase could be attributed to the effects of the fish pond effluent applied. Similar result have been reported by Oguike*et al*. (2006). This suggested that, more humus are accumulated in soil with higher application of fish pond effluent. Application of NPK15:15:15 could not improve soil organic matter which may be inability of NPK fertilizer to form humus in soil. This further proved that mineral fertilizer cannot be used to maintain soil organic matter. Total nitrogen was generally low, this could be attributed to slow decomposition rate of the fish pond effluent. As a result, most of the soil nitrogen may have still be retained in the organic form (Vanlauwe*et al.,* 1998). This finding was in line with result of Oguike*et al.* (2006). The NPK fertilizer has no effects on total nitrogen and this could be due to high rate of nutrients released which probably could have led to loss of elements. The levels of fish pond effluent significantly increased available phosphorus and also, had higher available P than the NPK and control. This could be attributed to effects of fish pond effluent which increased P solubility of soluble carbon compounds competing with P for sorption. Also, mineralization of organic P could have released P into the soil solution, contributing to the observed high available P from application of manure (Mohammadi*etal*., 2009). Water soluble K improved significantly with the incorporation of fish pond effluent. According to Vermal*etal*., (2002), hydrogen ions released from organic material are exchanged with K on exchange site or set free the fixed clay micelle. Calcium and Mg equally increased with enhanced application level and were also higher than the control.

Increased vegetative growth with fish pond effluent application could be related to its high nutrient content. The growth and yield response obtained in this study compared favourably with the work of Ado (1995). The untreated plants were shorter as they depends on the intrinsic soil fertility that was low (Table 1). This position was earlier reported by Egharevba and Ogbe (2002). The height of the plant is an important growth character directly linked with the productive potential of plants. An optimum plant height is claimed to be positively correlated with productivity of plants (Saeed *et al.,* 2007*).* Changes in the number of leaves are bound to affect the overall performance of Amaranthuscruentus as the leaves serve as photosynthetic organ of the plant (Ayodele, 1983). This confirmed the finding of Adediran and Banjoko (2002), who reported that the application of manure enhances growth and yield of crop. Increasing levels of fish pond effluent resulted in high growth rate and increased yield. This result is in agreement with earlier work done by Danbaba (2003) who reported that high level of liquid organic fertilizer increased growth and development of sweet potato. In that study, crops which received liquid organic fertilizer at the rates of 12 and 24 l/ha gave superior vegetative growth and development than lower levels. The fish pond effluent contains both major and micro nutrient in adequate amounts for increased vegetative growth of crop. The higher yield obtained in NPK15:15:15 treated plots at the early season could be attributed to the immediate nutrients release while the higher residual nutrient build-up in the fish pond effluent treated plot which resulted in higher yield in late season could be due to the long term effects of fish pond effluent (Kolade *et al.,* 2006). Vitamin C content that was higher with fish pond effluent application in late season agreed with previous report that increase in organic matter content leads to an increase in soil microbial population (Nakhro and Dkhar, 2010), while high microbial population had been reported to improve the antioxidant capability of the soil which according to Skwarylo-Bednarz and Krzepilko (2008) could lead to increase vitamin C content. The contribution of fish pond effluent to residual pool of nutrients in soil releases the nutrients slowly thereby preventing quick leaching or loss of nutrients (Makinde*et al., 2010*). This could have also resulted in increase yield and vitamin C content reported in this study. **In conclusion,** treatment of amaranth us with fish pond effluent and inorganic fertilizer improved the growth and yield significantly. The 250 kg/ha of inorganic fertilizer produced the highest leaf fresh weight, stem fresh weight and marketable yield while 20 t/ha of fish pond effluent had the highest dry matter yield at both seasons. There were higher response of soil chemical properties to fish pond effluent than the inorganic fertilizer.

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Table 1: Soil Physical and Chemical Properties before Incubation

Parameter	Nutrient Status
pH (H_2O) 1:2	6.53
Organic carbon (gkg^{-1})	7.11
Total nitrogen (gkg^{-1})	0.42
Available P ($mgkg^{-1}$)	6.81
Exchangeable bases ($cmolkg^{-1}$)	
K	0.57
Mg	0.46
Ca	0.48
Na	0.61
Exch. Acidity	0.07
CEC	2. 19
Particle Size (gkg^{-1})	
Sand	848
Silt	98
Clay	54
Textural Class	**Sandy loam**

Table 2: Post Soil Chemical Analysis

Treatments Kg NPK ha^{-1}	pH (H_2O 1:2)	Organic C (gkg^{-1})	Total N. (gkg^{-1})	Available P. ($mgkg^{-1}$)	Exchangeable bases ($cmolkg^{-1}$) K	Ca	Mg	Na
Control	6.40	5.79	0.68	5.76	0.60	0.52	0.50	0.58
5 FPE/ha	6.66	8.21	0.73	8.02	0.63	0.54	0.52	0.73
10 FPE/ha	6.71	9.24	0.75	8.34	0.64	0.65	0.67	0.77
15 FPE/ha	7.10	10.51	0.78	10.23	0.78	0.54	0.69	0.82
20 FPE/ha	7.30	10.23	0.87	11.34	0.87	0.58	0.78	0.88
100 NPK/ha	6.26	8.24	0.64	6.31	0.64	0.65	0.61	0.74
150 NPK/ha	6.25	8.25	0.65	6.33	0.72	0.54	0.64	0.78
200 NPK/ha	6.22	8.33	0.66	6.34	0.78	0.56	0.69	0.82
250 NPK/ha	6.22	8.51	0.67	7.00	0.78	0.55	0.60	0.80

Table 3: Effects of Different Levels of fish Pond Effluent and NPK15:15:15 Fertilizer on Amaranthus Plant Height (cm), Number of Leaves, Leaf area (cm^2) and Plant Girth (cm)

Fertilizer rate	Plant height (cm)	Number of leaves	Leaf area (cm^2)	Plant girth (cm)
Early season				
Control	47.3	39.4	323.4	2.4
5 FPE/ha	48.1	40.1	363.4	2.6
10 FPE/ha	54.1	42.3	366.7	3.0
15 FPE/ha	63.1	43.0	350.0	3.3
20 FPE/ha	64.3	45.0	377.7	3.9
100 NPK/ha	64.3	55.1	381.0	3.8
150 NPK/ha	65.3	59.0	378.0	3.9
200 NPK/ha	65.5	64.0	388.0	4.0
250 NPK/ha	68.7	65.1	400.1	4.1
LSD	11.2	11.2	22.0	0.9
	s	s	s	s
Late season				
Control	39.3	34.0	293.4	2.1
5 FPE/ha	64.8	58.6	382.4	4.3
10 FPE/ha	66.9	63.4	378.3	4.4
15 FPE/ha	68.9	71.6	355.8	4.7
20 FPE/ha	72.3	58.4	411.8	4.9
100 NPK/ha	60.1	58.8	309.4	3.8
150 NPK/ha	62.3	61.0	311.4	4.0
200 NPK/ha	65.0	62.3	381.7	4.1
250 NPK/ha	66.0	63.0	392.0	4.3
LSD	12.3	15.3	55.3	1.1
	s	s	s	s

Note
S = significant

Table 4: Effects of Different Levels of Fish Pond Effluent and NPK15:15:15 Fertilizer on Amaranthus Leaf Fresh Weight, Stem Fresh Weight per Plant and Yield per Hectare

Fertilizer rate	leaf fresh weight	stem fresh weight	Market yield	dry matter yield
Early season				
Control	198.1	242..3	501.3	21.3
5 FPE/ha	245.0	270.4	561.6	24.3
10 FPE/ha	301.3	351.5	580.3	29.4
15 FPE/ha	360.3	429.1	643.8	33.7
20 FPE/ha	481.4	512.3	689.3	41.2
100 NPK/ha	405.4	421.5	578.3	26.3
150 NPK/ha	423.5	440.6	598.4	27.1
200 NPK/ha	491.3	521.8	698.5	35.3
250 NPK/ha	523.6	568.9	703.6	40.3
LSD	22.3	25.4	25.3	4.3
	s	s	s	S
Late season				
Control	171.3	204.4	480.5	18.3
5 FPE/ha	250.4	281.5	570.3	31.4
10 FPE/ha	313.7	563.9	589.4	38.1
15 FPE/ha	381.8	441.4	663.3	41.3
20 FPE/ha	503.4	532.4	721.8	51.8
100 NPK/ha	406.9	428.4	582.2	28.4
150 NPK/ha	430.4	448.5	611.3	31.8
200 NPK/ha	503.6	533.1	623.4	37.4
250 NPK/ha	514.1	541.4	724.5	41.4
LSD	34.4	38.1	44.3	6.3
	s	s	s	s

Note
S = significant

Table 5: Effects of Different Levels of Fish Pond Effluent and NPK15:15:15 Fertilizer on Vitaminc Content of Amaranthus at the Early Season

Fertilizer rate	Early season (mg/100g)	Late season (mg/100g)
Control	11.31	10.03
5 FPE/ha	14.22	17.53
10 FPE/ha	16.23	21.41
15 FPE/ha	18.41	30.34
20 FPE/ha	24.13	38.40
100 NPK/ha	18.34	19.91
150 NPK/ha	24.87	25.33
200 NPK/ha	26.44	29.43
250 NPK/ha	32.40	31.87
LSD values	9.34	8.38
	s	s

Note
S = significant