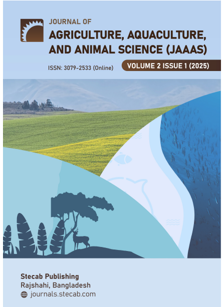

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Research Article

Effects of Fish Pond Sediment on Yield and Productivity of Two Varieties of Amaranths (*Amaranthus spp.*)

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About Article

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ABSTRACT

The rising costs of inorganic fertilizers have rendered them inaccessible to many farmers, resulting in reduced crop yields. An affordable alternative for enhancing soil fertility is the use of organic materials such as fish pond sediments. These sediments are nutrient-rich and have the potential to enhance soil quality, promote crop growth, and increase yields. This study examined the effect of fish pond sediments on the yield and productivity of two amaranth varieties. The research was conducted at the University of Ilorin Teaching and Research Farm. A 2x6 factorial experiment was employed using a Randomized Complete Block Design. The experiment included six sediment application rates: a control (no sediments) and sediment rates of 5, 10, 15, 20, and 25 Mg/ha, applied to two amaranth varieties (green leaf with Accession IDs NHAM 0116-1-2 and NHAM 0112-1-4). Yield and productivity parameters were assessed after 10 weeks. The findings revealed that fish pond sediment application significantly enhanced the yield of both amaranth varieties. The highest yield (51.36 Mg/ha), Chlorophyll A (1.64 mg/dm^2), chlorophyll B (1.76 mg/dm^2), and crude fibre content (12.18%) were recorded at the sediment application rate of 25 Mg/ha. The results demonstrate that fish pond sediments are a viable nutrient source for improving soil fertility and boosting the growth and yield of amaranths.

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1. INTRODUCTION

Amaranths (*Amaranthus spp.*) are a group of leafy vegetables that are widely consumed in many parts of the world. They are known for their high nutritional value, containing vitamins, minerals, and antioxidants that are important for human health (Lima *et al*., 2009). Amaranths are also popular among farmers due to their short growing period and high yields, making them an important crop for food security.

They are used for producing nutritious grain and foliage, and as colourful ornamentals (Brenner *et al*., 2000). In recent times, there has been a growing demand for this crop as a vegetable, particularly in urban areas where people are less engaged in primary agricultural activities (Law-Ogbomo *et al*., 2009). This increased demand has elevated amaranth to a significant status within our markets, with its production serving as a crucial economic activity for rural women. However, soils in Sub-Saharan Africa are inherently infertile, characterized by consistently low levels of soil organic matter (Shiyam & Binang, 2013). As a result, many farmers have turned to inorganic fertilizers.

The reliance on inorganic fertilizers has been driven by their ability to deliver substantial increases in crop production, albeit over the short term. This reliance was reinforced by the ease of handling and the concentrated nutrient content of inorganic fertilizers. Nevertheless, studies have unveiled the detrimental consequences (nutrient imbalance and soil acidity) associated with the prolonged use of inorganic fertilizers on soils. FAO (2012) as well as causing greenhouse gases effect by nitrogen oxides (NO, N_2O, NO_2) emission which leads to depletion of ozone layer among others due to chlorofluorocarbon build up thus causing phyto-toxicity which readily accumulate in tissue of living organism and as a result causing harm in human health (Alloway, 2013). It has been found out that inorganic fertilizer especially high nitrate contained nitrogenous ones have detrimental effect on human health when applied to soil. In addition, greater amount of this nitrogenous fertilizer is not always completely absorbed by plants thereby interfering with both surface and underground water leading to water table pollution. Furthermore, it has been discovered that it can induce cytological abnormalities and chromosomal irregularities in plant cells (Tabur & Oney, 2009). It's essential to highlight that the high cost of inorganic fertilizers places them out of reach for impoverished farmers. These challenges have spurred the promotion of organic fertilizers in agriculture.

An effective method for improving soil fertility is the use of organic amendments such as fish pond sediments. These sediments are abundant in macronutrients and essential micronutrients vital for plant growth. Organic waste serves as a crucial source of nutrients, particularly for crops like fruits and vegetables. A considerable volume of organic waste, stemming from various sources such as fish pond effluents, palm oil mill effluents, cassava mill effluent, rubber mill effluent, abattoir waste, and crop residues, which are typically produced as byproducts in various agricultural processing facilities. This accumulation of organic waste presents potential ecological challenges. Given the shortage of inorganic fertilizers, research efforts have shifted towards exploring the utilization of these organic waste materials. However, it's essential to note that if not properly converted for agricultural and economic purposes, these organic wastes may pose environmental hazards (Ayeni, 2010).

Fish pond sediments are the accumulated solid materials that settles at the bottom of fish ponds over time. These sediments are composed of fish excreta, uneaten fish feed, dead aquatic plants and animals, and other materials (Kokou & Fountoulaki, 2018). As a result, they have the potential to serve as valuable fertilizer supplements and soil conditioners, thereby improving the soil environment for crop cultivation (Mizanur *et al*., 2004). There is a paucity of research on the effects of fish pond sediments especially on leafy vegetables like Amaranth. This research investigates the effects of fish pond sediments on yield and productivity of two varieties of Amaranths.

2. LITERATURE REVIEW

Previous research, including studies by Berg (2002), Drózdz *et al.* (2020), Pueppke *et al.* (2020), Ahmed and Turchini (2021), and Farrant *et al.* (2021), highlighted the benefits of nutrient reuse and recycling in integrated aquaculture and agricultural systems. These practices enhance food production efficiency, reduce nutrient pollution, and improve farmers' living standards through higher incomes and better environmental health. A study by Adediran and Banjoko (2002) found that the application of fish pond sediment to soil increased the growth and yield of amaranth by up to 50%. The study also found that fish pond sediment improved the quality of amaranth leaves, increasing their protein and vitamin C content. Another study by Makinde *et al.* (2010), found that the application of fish pond sediment to soil increased the yield of amaranth by up to 20%. The study also found that fish pond sediment improved the shelf life of amaranth leaves.

Thanh *et al.* (2023) demonstrated that combining chemical fertilizers with 25% or 50% organic fertilizers significantly boosted growth performance indices in Malabar spinach and Amaranthus cruentus, leading to optimal vegetable yields. Similarly, Thanh *et al.* (2015), Haque *et al.* (2016), and Da *et al.* (2015) explored the use of Pangasius catfish pond sediments as organic fertilizer, finding them effective for cultivating vegetables such as water spinach, cucumber, mustard greens, and fodder grass.

Eymontt *et al.* (2017) found that the application of fish pond sediments to soil increased amaranth yield by up to 15%. Amaranth leaf area and biomass by up to 20% due to the application of fish pond sediments. This increase in growth to the improved soil water and nutrient holding capacity provided by the fish pond sediments. Dróżdż *et al.* (2020) found that the application of fish pond sediments to soil increased amaranth protein content by up to 10%. They attributed this increase in protein content to the improved soil fertility and nutrient availability by the fish pond sediments.

Ojobor and Tobih (2015) investigated the effects of fish pond effluent and inorganic fertilizer on amaranth performance at the Delta State University Agronomy Experimental Farm, Asaba Campus. Their findings showed that while 250 kg/ha of NPK fertilizer produced the highest leaf and stem fresh weights as well as marketable yield, 20 t/ha of fish pond effluent resulted in the highest dry matter yield across seasons. Additionally, the fish pond effluent had a greater impact on improving soil chemical properties compared to NPK fertilizer, leading to the recommendation of applying 20 t/ha of fish pond effluent in Asaba and similar regions for enhanced crop and soil outcomes.

3. METHODOLOGY

The study was at the University of Ilorin Teaching and Research Farm, located in the southern Guinea savannah of Nigeria. The site, characterized by Alfisols with coarse-textured and low organic matter soils, faced significant degradation and erosion (Jimoh, 2011; Ogunwale *et al*., 2002). The experiment, carried out under rain-fed conditions, employed a 2 x 6 factorial design with a Randomized Complete Block Design (RCBD) replicated three times. Treatments included two amaranth varieties (NHAM 0116-1-2 and NHAM 0112-1-4) and six application rates of fish pond sediment (0, 5, 10, 15, 20, and 25 Mg/ha). Sediment, sourced from Alasela Farm, was air-dried and incorporated into the soil two weeks before planting.

The land was prepared by ploughing, harrowing, and creating 2 x 2-meter plots with 0.5-meter alleys. Seeds were sown by drilling, thinned to a spacing of 30 x 30 cm, and managed with manual weeding. Yield data, including fresh and dry weights of leaves and stalks, were collected and extrapolated to a hectare scale. Nutritional analysis of amaranth leaves assessed crude fibre content following standard procedures using sulfuric acid and sodium hydroxide treatments, while chlorophyll levels were measured spectrophotometrically using Arnon's (1949) method. Soil and sediment samples were analysed for physical and chemical properties using standard protocols established by ISRIC and FAO (2020).

Harvesting was conducted manually, and data were analysed using ANOVA with GenStat software (17th Edition), applying the Least Significant Difference (LSD) test at a 5% significance level to evaluate treatment effects.

4. RESULTS AND DISCUSSION

4.1. Characteristics of experimental soil and fish pond sediment

The characteristics of the experimental soil and fish pond sediment are presented in Table 1, the soil at the experimental site was characterized as a loamy sand with a pH of 6.8, indicating slightly acidic conditions. Organic carbon and organic matter contents were low, at 0.68% and 1.17%, respectively, reflecting the soil's poor fertility status. The available phosphorus was minimal at 0.03 mg/kg, and total nitrogen content was only 0.1%, further emphasizing nutrient limitations. Among the exchangeable bases, calcium was notably low at 0.035 cmol/kg, while magnesium and potassium levels were 1.26 cmol/kg and 0.24 cmol/kg, respectively. Sodium was recorded at 0.163 cmol/kg, and the exchangeable acidity was 0.48 cmol/kg. The soil texture comprised 89.9% sand, 8.04% silt, and 2.06% clay, resulting in its classification as loamy sand, which is prone to low water retention and nutrient-holding capacity.

In contrast, the fish pond sediment exhibited superior fertility attributes, with a pH of 7.4, indicating slightly alkaline conditions. Organic carbon and organic matter contents were significantly higher than the soil, at 2.2% and 3.79%, respectively. The available phosphorus content was 0.15 mg/kg, while the total nitrogen concentration reached 0.293%, reflecting the sediment's nutrient richness. Calcium content was markedly higher at 0.532 cmol/kg, and magnesium and potassium levels were 2.05 cmol/kg and 0.53 cmol/kg, respectively, further underscoring the sediment's nutrient advantages. These characteristics make fish pond sediment a valuable amendment for improving soil fertility and supporting crop growth (Ojobor & Tobih, 2015).

Table 1. Pre-plant soil and fish pond sediment characteristics

Parameters	Soil	Fish Pond Sediment
pH	6.8	7.4
Organic carbon (%)	0.68	2.2
Organic matter (%)	1.17	3.79
Available phosphorus (mgkg^{-1})	0.03	0.15
Exchangeable acidity (cmol/kg)	0.48	
Total Nitrogen (%)	0.1	0.293
Calcium (cmolkg^{-1})	0.035	0.532
Sodium (cmolkg^{-1})	0.163	
Potassium (cmolkg^{-1})	0.24	0.53
Magnesium (cmolkg^{-1})	1.26	2.05
Sand (%)	89.9	
Silt (%)	8.04	
Clay (%)	2.06	
Textural class	Loamy Sand	

NS= Not Significant Source: Field Data

4.2. Effects of variety and fish pond sediment application on chlorophyll a, b and crude fibre contents of amaranth

The data for effects of variety and rate of fish pond sediment application (Table 2) showed that the two amaranth varieties (NHAM 0116-1-2 and NHAM 0112-1-4) showed significant differences in chlorophyll A, chlorophyll B, and crude fibre contents ($P<0.05$). NHAM 0116-1-2 produced the highest chlorophyll A, chlorophyll B, and crude fibre contents of 1.68, 1.94, and 11.94 respectively and outperformed NHAM 0112-1-4 which produced the least chlorophyll A (1.40), chlorophyll B (1.54), and crude fibre (11.26) contents; suggesting that its genetic makeup may be better suited for the climatic conditions in Ilorin, which could result in more efficient photosynthesis and growth, leading to higher leaf area indices and ultimately greater yield potential.

The application of fish pond sediment significantly influenced the chlorophyll content and crude fibre in amaranth. The highest values for chlorophyll A (1.64), chlorophyll B (1.76), and crude fibre (12.18) were produced by 25 Mgha-1 fish pond sediment application rate, while the lowest chlorophyll A (1.44), chlorophyll B (1.72), and crude fibre (10.57) contents were produced by control. This suggests that fish pond sediment enhances the nutritional quality of amaranth by improving chlorophyll content and crude fibre, which could be due to increased nutrient availability and improved soil conditions, such as reduced acidity, enhanced nutrient absorption, and improved water retention (Mehmood *et al.*, 2022; Cakmak *et al.*, 2022; Alzamel *et al.*, 2023). The interaction between the variety and the rate of fish pond sediment application did not show significant differences (P<0.05) for yield and yield components, indicating that both varieties responded similarly to the sediment treatment in terms of these parameters.

Table 2. Effect of variety and fish pond sediment on amaranth chlorophyll a, b, and crude fibre contents

Treatment	Chlorophyll A	Chlorophyll B	Crude Fibre %
Variety (V)			
NHAM 0116-1-2	1.68	1.94	11.94
NHAM 0112-1-4	1.40	1.54	11.26
LSD	0.0790	0.0760	0.0010
Fish Sediment (FS)			
Control	1.44	1.72	10.57
5 $Mgha^{-1}$	1.50	1.73	11.70
10 $Mgha^{-1}$	1.51	1.74	11.82
15 $Mgha^{-1}$	1.54	1.74	12.03
20 $Mgha^{-1}$	1.60	1.76	12.09
25 $Mgha^{-1}$	1.64	1.76	12.18
LSD	0.1000	0.0200	0.0020
Interaction			
VxFS	NS	NS	NS

NS= Not Significant Source: Field Data

4.3. Effects of variety and fish pond sediment application on yield and yield components

The effects of variety and rate of fish pond sediment application on yield and yield components of amaranth are presented in Table 3. The data followed similar trend as with chlorophyll and crude fibre, it showed that significant differences were observed between the two amaranth varieties (NHAM 0116-1-2 and NHAM 0112-1-4) in terms of yield and yield components. NHAM 0116-1-2 consistently outperformed NHAM 0112-1-4, producing the highest fresh harvest per plant, per net plot, and per hectare. Fish pond sediment application had a significant impact on fresh leaf weight and harvest yield at all levels. The highest fresh harvest values per plant, per net plot, and per hectare were achieved at the 25 Mg/ha sediment application rate, with results closely comparable to the 20 Mg/ha rate. This indicates that fish pond sediment improves soil nutrient availability, reduces soil acidity, and enhances water retention, thereby supporting plant growth and productivity. Additionally, the larger photosynthetic surface would contribute to improved protein and carbohydrate metabolism, enhancing overall yields (Alzamel *et al.*, 2023). Despite the strong individual effects of variety and sediment application rates, their interaction was not statistically significant.

Table 3. Effect of variety and fish pond sediment on amaranth yield and yield components.

Treatment	Fresh Leaves Weight per Plant (g)	Fresh Leaves Weight per Net Plot (g)	Fresh Harvest per Plant (g)	Fresh Harvest per Net Plot (Kg)	Fresh Harvest per Hectare (Mg)
Variety (V)					
NHAM 0116-1-2	21.89	963.29	149.37	6.6	37.34
NHAM 0112-1-4	20.01	880.38	108.00	4.8	27.00
LSD	NS	NS	22.24	0.98	5.56
Fish Sediment (FS)					
Control	14.33	630.60	61.10	2.7	15.28
5 $Mgha^{-1}$	15.66	689.10	72.80	3.2	18.19
10 $Mgha^{-1}$	19.21	845.10	114.50	5.0	28.63

15 $Mgha^{-1}$	19.57	860.90	115.30	5.1	28.83
20 $Mgha^{-1}$	24.60	1082.50	202.90	8.9	50.74
25 $Mgha^{-1}$	32.34	1422.80	205.50	9.0	51.36
LSD	22.68	558.80	89.74	3.68	9.44
Interaction					
VxFS	NS	NS	NS	NS	NS

NS= Not Significant Source: Field Data

5. CONCLUSIONS

This study demonstrated that the combination of genetic variety and fish pond sediment application significantly influenced the productivity, yield, and quality of amaranth. Between the varieties tested, NHAM 0116-1-2 consistently outperformed NHAM 0112-1-4 in key yield parameters, such as fresh harvest per plant, per net plot, and per hectare. Its superior chlorophyll content facilitated more efficient light absorption and photosynthesis, which ultimately enhanced its yield and quality. The application of fish pond sediment positively impacted growth and yield, with the highest rates (25 Mg/ha) producing optimal results in fresh leaf weight and total yield. This was attributed to improved soil nutrient availability, reduced acidity, and enhanced water retention capacity provided by the sediment. The benefits were evident across multiple parameters. however, the 20 Mg/ha rate yielded comparable results, suggesting it may offer a more resource-efficient option without compromising performance. Future research could explore the long-term effects of fish pond sediment application on soil health and the potential for scaling its use in broader agricultural systems.

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