

Effect of Fish Effluent on Soil Properties and Sweet Potato (*Ipomoea Batatas* L.) Performance in Nekede, Owerri, Imo State

Peace Chinedu Abana¹, C. O. Enyia², Emmanuel C. Nleonu³, and Ogechi M. Okorochoa⁴

¹Department of Agricultural Technology (Crop Production), Federal Polytechnic Nekede, Owerri, Nigeria

²Department of Agricultural Extension and Management, Federal Polytechnic Nekede, Owerri, Nigeria

³Department of Chemistry/Biochemistry, Federal Polytechnic Nekede, Owerri, Nigeria

⁴Department of Soil Science and Land Resource Management, Federal Polytechnic Nekede, Owerri, Nigeria

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ABSTRACT

This study examined the effects of fish effluent on soil nutrient dynamics and the growth and yield of sweet potato (*Ipomoea batatas* L.) in Nekede, south-eastern Nigeria. The experiment used a randomised complete block design (RCBD) with four treatments: 0 L (control), 3 L, 6 L, and 9 L of fish effluent per plot, replicated four times. Soil samples were analysed before planting and after harvest to assess changes in soil properties, while data on vine length, leaf number, node number, and yield were collected at 3, 6, and 9 weeks after planting (WAP). The initial soil was acidic (pH 4.85) and low in fertility, with organic matter of 1.02%, total nitrogen of 0.078%, and available phosphorus of 2.35 mg/kg. Application of fish effluent improved soil properties, with pH increasing to 5.12, organic matter to 1.44%, total nitrogen to 0.109%, and available phosphorus to 3.97 mg/kg at 9 L/plot. Sweet potato growth also improved, with vine length increasing from 132.65 cm in the control to 172.55 cm, leaf number from 57.58 to 71.93, and node number from 12.47 to 28.63. Yield increased from 1.33 t/ha in the control to 5.71 t/ha at 9 L/plot. The Agronomic Efficiency Index was highest at 0.77 under the 6 L/plot treatment. The results demonstrate that fish effluent improved soil fertility, enhanced sweet potato growth, and increased yield. A moderate rate of 6 L/plot is recommended for efficient sweet potato production under the conditions of this study.

Keywords: Fish effluent; soil properties; sweet potato; organic fertilizer; agronomic efficiency; sustainable agriculture

INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) is an important staple crop in Nigeria and other tropical regions, valued for its nutritional benefits and adaptability to diverse soil conditions (FAO, 2022). In southeastern Nigeria, it is widely cultivated by smallholder farmers because of its relatively short growing cycle, drought tolerance, and economic importance (Okonkwo et al., 2021). However, sweet potato production in the region is constrained by declining soil fertility. The sandy, acidic, and nutrient-depleted Ultisols common in southeastern Nigeria are often characterised by low nutrient reserves and poor fertility status (Njoku et al., 2023).

The increasing cost of synthetic fertilisers and environmental concerns associated with their excessive use have also created a need for sustainable soil fertility management practices. Fish effluent represents a potential alternative nutrient source. It contains dissolved nutrients, including nitrogen, phosphorus, and potassium, which are essential for plant growth (Endut et al., 2010; Yeo et al., 2021). Its utilisation in

agriculture may provide the dual benefit of recycling aquaculture waste and improving soil fertility. Srivastava et al. (2011) reported that the utilisation of fish effluent in crop production contributes to nutrient recycling and soil fertility improvement. Similarly, Rakocy et al. (2012) reported improved crop growth and productivity in systems utilising aquaculture-derived nutrients. Despite increasing interest in aquaponics and fish-based fertilisation, limited information is available on the effects of different rates of fish effluent on soil properties and sweet potato performance under the soil conditions of Imo State. Therefore, this study evaluated the effect of fish effluent on soil properties and sweet potato performance in Nekede, Owerri, Imo State.

The specific objectives were to: evaluate the effect of different rates of fish effluent on soil chemical properties, determine the influence of fish effluent on the growth parameters of sweet potato, and assess the yield and agronomic efficiency of sweet potato under different fish effluent treatments.

MATERIALS AND METHODS

Study Area

The study was conducted at the Fishery Farm of the Federal Polytechnic, Nekede, Owerri West Local Government Area, Imo State. The area lies between latitude 5°41'N and longitude 7°34'E and falls within the rainforest agro-ecological zone (Enyioko et al., 2019). The climate is humid, with a bimodal rainfall pattern averaging 1800 ± 250 mm annually, a mean temperature of $25 \pm 6^\circ\text{C}$, and relative humidity of $85 \pm 10\%$ (NIMET, 2017). The soils in the study area are predominantly Ultisols, which are strongly acidic and low in nutrient reserves and are derived from coastal plain sands. The vegetation has been modified by agricultural and construction activities (Ufot et al., 2016).

Source of Planting Material

Orange-fleshed sweet potato vines were collected from the National Root Crops Research Institute (NRCRI), Umudike.

Experimental Design and Treatments

The experiment was laid out in a randomised complete block design (RCBD) consisting of four treatments replicated four times. Each plot measured $3 \text{ m} \times 4 \text{ m}$, giving a total area of 12 m^2 . Plots were separated by 1 m buffer zones. Sweet potato vines were planted at a spacing of $30 \text{ cm} \times 80 \text{ cm}$, totalling 12 stands per plot.

Table 1. Experimental treatments

Treatment	Fish effluent rate
T1	Control (0 L/plot)
T2	2,500 L/ha (3 L/plot)
T3	5,000 L/ha (6 L/plot)
T4	7,500 L/ha (9 L/plot)

Fish Effluent Collection and Application

Fish effluent was sourced weekly from an existing fish pond containing *Clarias gariepinus* (catfish) at the fishery farm. The effluent was allowed to settle for 24 hours before application. The fish effluent was applied uniformly to designated plots using watering cans. Application commenced one week after planting and continued weekly for 10 weeks. The fish effluent was evaluated in the laboratory before application.

Soil and Crop Management

The experimental field was manually cleared and ridged. No additional fertiliser or pesticides were applied during the experiment. Manual weeding was carried out as required.

Soil Sampling and Analysis

Soil samples were collected before planting and after harvest at a depth of 0–30 cm. The samples were analysed for pH, organic matter, total nitrogen, available phosphorus, and exchangeable potassium using standard methods (Enyioko et al., 2019).

Growth Parameters

Vine length was measured at 3, 6, and 9 weeks after planting (WAP), from the base of the plant to the tip of the vine, using five randomly selected plants per plot. The number of leaves and nodes was determined on the same selected plants at the corresponding growth stages.

Yield Parameters

The number of tubers per plant was determined by counting the harvested tubers. Tuber yield per plot was determined by weighing the harvested tubers, while total yield per hectare was calculated from the obtained tuber yield.

Agronomic Efficiency Index

The Agronomic Efficiency Index (AEI) was determined as:

$$AEI = (Y_t - Y_c) / A_t$$

where Y_t represents the yield from treated plots, Y_c represents the yield from the control plot, and A_t represents the amount of fish effluent applied.

Statistical Analysis

Data were analysed using analysis of variance (ANOVA), and treatment means were separated using the Least Significant Difference (LSD) at the 5% significance level.

RESULTS

Chemical Properties of Fish Effluent

The chemical properties of the fish effluent are presented in Table 2. The fish effluent had a pH of 7.4 and an electrical conductivity of 1.8 dS/m. It contained 750 mg/L total nitrogen, 30 mg/L soluble phosphorus, and 400 mg/L soluble potassium.

Table 2. Chemical properties of fish effluent

Parameter	Value
pH	7.4
Electrical conductivity	1.8 dS/m
Total nitrogen	750 mg/L
Soluble phosphorus	30 mg/L

Soluble potassium	400 mg/L
BOD (organic load)	1,500 mg/L
Total organic carbon	1,200 mg/L
Calcium	120 mg/L
Magnesium	45 mg/L
Sodium	90 mg/L

Initial Soil Properties Before Treatment Application

The initial soil properties before treatment application are presented in Table 3. The soil had a pH of 4.85, organic matter of 1.02%, total nitrogen of 0.078%, available phosphorus of 2.35 mg/kg, and exchangeable potassium of 0.080 cmol/kg.

Table 3. Initial soil properties before treatment application

Parameter	Value
pH	4.85
Organic matter (%)	1.02
Total nitrogen (%)	0.078
Available phosphorus (mg/kg)	2.35
Exchangeable potassium (cmol/kg)	0.080

Soil Properties After Harvest

The effects of different fish effluent rates on soil properties after sweet potato harvest are presented in Table 4.

Table 4. Soil properties under different rates of fish effluent after sweet potato harvest

Treatment	pH	Organic matter (%)	Total N (%)	Available P (mg/kg)	Exchangeable K (cmol/kg)
T1 (0 L)	4.91	1.14	0.081	2.55	0.085
T2 (3 L)	4.93	1.16	0.084	2.72	0.096
T3 (6 L)	5.01	1.35	0.085	3.15	0.103
T4 (9 L)	5.12	1.44	0.109	3.97	0.107
LSD	0.13	0.20	0.018	0.88	0.013

Growth Response of Sweet Potato

The growth response of sweet potato to different rates of fish effluent is presented in Table 5.

Table 5. Growth response of sweet potato to different rates of fish effluent

Treatment	Vine length 3 WAP (cm)	Vine length 6 WAP (cm)	Vine length 9 WAP (cm)	Leaves 3 WAP	Leaves 6 WAP	Leaves 9 WAP	Nodes 3 WAP	Nodes 6 WAP	Nodes 9 WAP
T1 (0 L)	39.06	77.53	132.65	28.77	40.68	57.58	9.31	10.56	12.47
T2 (3 L)	41.86	83.35	150.88	30.95	47.13	62.31	9.97	13.68	16.00
T3 (6 L)	46.49	96.53	155.08	32.99	54.70	66.79	12.38	13.81	16.74
T4 (9 L)	48.11	127.59	172.55	36.55	58.44	71.93	12.61	15.67	28.63
LSD	5.79	31.07	22.77	4.60	11.01	8.53	2.32	2.94	9.77

Yield Response of Sweet Potato

The yield response of sweet potato to different rates of fish effluent is presented in Table 6.

Table 6. Yield of sweet potato under different rates of fish effluent

Treatment	Number of tubers	Tuber yield (kg/plot)	Total yield (t/ha)
T1 (0 L)	2.75	1.60	1.33
T2 (3 L)	4.21	2.83	2.36
T3 (6 L)	6.23	6.22	5.18
T4 (9 L)	7.25	6.85	5.71
LSD	2.80	3.55	2.96

Agronomic Efficiency of Fish Effluent

The Agronomic Efficiency Index of the different fish effluent rates is presented in Table 7.

Table 7. Agronomic efficiency index of different rates of fish effluent for sweet potato production

Treatment	AEI
T2 (3 L)	0.41
T3 (6 L)	0.77
T4 (9 L)	0.58
LSD	0.33

DISCUSSION

Fish Effluent Quality and Its Implications for Soil Fertility

The chemical composition of the fish effluent provides an important basis for understanding the responses observed in both soil properties and sweet potato performance. The effluent had a slightly alkaline pH of 7.4 and contained appreciable concentrations of total nitrogen, soluble phosphorus, soluble potassium, calcium, magnesium, and organic carbon. These constituents indicate that the fish effluent served as a source of both essential plant nutrients and organic materials.

The presence of nitrogen, phosphorus, and potassium is particularly important because these nutrients play complementary roles in plant growth and productivity. Nitrogen supports vegetative development, phosphorus is associated with energy transfer and root development, while potassium contributes to several physiological processes involved in plant growth and productivity. Consequently, the application of fish effluent provided a nutrient input that could account for the progressive improvement in soil nutrient status and sweet potato growth observed across the treatments. The relatively high organic load and total organic carbon of the effluent may also have contributed to the observed improvement in soil organic matter after harvest. Organic inputs can influence soil nutrient availability by contributing organic materials that become incorporated into the soil. This is consistent with the general principle underlying the agricultural use of aquaculture wastewater, where nutrients originating from fish feed and metabolic waste can be recycled for crop production rather than being discarded as waste (Endut et al., 2010; Srivastava et al., 2011; Yeo et al., 2021). Therefore, the chemical characteristics of the fish effluent suggest that its effect on sweet potato production was not due to a single nutrient but to the combined contribution of dissolved nutrients and organic materials supplied to the soil.

Effect of Fish Effluent on Soil Reaction and Nutrient Status

The initial soil analysis showed that the experimental soil was acidic, with a pH of 4.85, and had relatively low levels of organic matter, total nitrogen, available phosphorus, and exchangeable potassium. This initial condition indicates that the soil had limited nutrient reserves before treatment application and therefore provided an appropriate condition for evaluating the response to nutrient addition through fish effluent. Following harvest, soil pH increased progressively with fish effluent application, reaching the highest value of 5.12 under the 9 L/plot treatment. Although the soil remained acidic, the increase in pH indicates that fish effluent application reduced the degree of soil acidity. This response may be associated with the slightly alkaline nature of the fish effluent, which had a pH of 7.4. Repeated application of an effluent with a higher pH than the original soil may have contributed to the observed shift in soil reaction. The improvement in soil pH is agriculturally important because soil acidity can influence nutrient availability and the overall chemical environment of the soil. Organic matter also increased progressively from 1.14% in the control to 1.44% under the highest effluent treatment. This increase suggests that the organic constituents of the fish effluent contributed to the soil organic matter pool. Since the fish effluent contained measurable total organic carbon and biochemical oxygen demand, its repeated application likely introduced organic materials into the soil. The increase in soil organic matter is significant because organic matter contributes to soil quality and nutrient retention. In this study, the increase in organic matter occurred alongside increases in total nitrogen, available phosphorus, and exchangeable potassium, suggesting an overall improvement in soil fertility status. The increase in total nitrogen from 0.081% in the control to 0.109% at 9 L/plot demonstrates that fish effluent served as a source of nitrogen. This observation corresponds with the measured nitrogen concentration of the effluent. Since nitrogen is a major nutrient required for vegetative growth, the improved nitrogen status of the soil provides a reasonable explanation for the enhanced vine development and leaf production observed in the treated plots. Available phosphorus also increased progressively with fish effluent application, from 2.55 mg/kg in the control to 3.97 mg/kg at 9 L/plot. This indicates that phosphorus contained in the fish effluent contributed to the available phosphorus pool of the soil. Similarly, exchangeable potassium increased from 0.085 cmol/kg in the control to 0.107 cmol/kg under the highest treatment. The simultaneous improvement in nitrogen, phosphorus, and potassium demonstrates that fish effluent supplied multiple nutrients rather than functioning as a single-nutrient fertiliser. This nutrient

recycling function is consistent with reports that aquaculture wastewater can be utilised as a nutrient source for agricultural production (Endut et al., 2010; Rakocy et al., 2012; Yeo et al., 2021). The progressive increase in soil nutrient values with increasing fish effluent rates further indicates a dose-dependent response. Higher application rates supplied greater quantities of nutrient-containing effluent, resulting in greater changes in soil properties.

Effect of Fish Effluent on Vegetative Growth of Sweet Potato

The improvement in soil nutrient status was reflected in the vegetative growth of sweet potato. Vine length, number of leaves, and number of nodes generally increased with increasing fish effluent application rates. At 9 WAP, vine length increased from 132.65 cm in the control to 172.55 cm under the 9 L/plot treatment. This indicates that the treated plants experienced greater vegetative development than the untreated plants. The response in vine length may be linked to the improved nutrient status of the soil, particularly the increase in nitrogen. Nitrogen is strongly associated with vegetative growth, and the increased nitrogen content of the treated soils may have supported greater vine development. The number of leaves also increased from 57.58 in the control to 71.93 under the highest treatment. Increased leaf production is important because leaves constitute the major photosynthetic structures of the plant. A greater number of leaves can potentially increase the photosynthetic capacity of the crop, thereby providing more assimilates for plant growth and storage root development. The number of nodes also increased substantially with fish effluent application. Nodes are important structural components of sweet potato vines and represent points of leaf and branch development. The increase in node number therefore further confirms that fish effluent promoted vegetative development. An important feature of the results is that the growth response was progressive across the treatments. The control consistently recorded the lowest values, while the highest application rate generally produced the highest growth values. This pattern supports the conclusion that the observed differences were associated with fish effluent application rather than normal growth alone. The improved vegetative performance observed in this study agrees with the general concept of using nutrient-rich aquaculture water to support crop growth. Previous studies cited in the manuscript have similarly emphasised the potential of aquaculture-derived nutrients for improving crop performance (Srivastava et al., 2011; Rakocy et al., 2012; Okomoda et al., 2022).

Effect of Fish Effluent on Sweet Potato Yield

The positive effect of fish effluent on vegetative growth was accompanied by a substantial improvement in sweet potato yield. The number of tubers increased from 2.75 in the control to 7.25 under the 9 L/plot treatment. Similarly, tuber yield increased from 1.60 kg/plot in the control to 6.85 kg/plot under the highest fish effluent treatment, while total yield increased from 1.33 t/ha to 5.71 t/ha. The increase in yield suggests that the improved soil fertility and vegetative growth translated into greater storage root production. The treated plots had higher concentrations of major nutrients and also produced longer vines, more leaves, and more nodes. These improvements in plant growth may have contributed to the greater yield observed at harvest. The relationship between vegetative development and yield is particularly important in this study. The highest fish effluent rate produced the greatest vegetative growth and also produced the highest tuber yield. This indicates that, within the range of application rates evaluated, increasing fish effluent application did not result in an observable decline in yield. The control treatment produced the lowest yield, which corresponds with its lower soil nutrient status and reduced vegetative growth. This provides further evidence that the nutrient input supplied through fish effluent contributed to improved sweet potato productivity. The results therefore support the use of fish effluent as a nutrient resource for crop production. Rather than being treated solely as an aquaculture waste product, the effluent demonstrated potential for recycling nutrients into agricultural production.

Agronomic Efficiency and the Difference Between Maximum Yield and Maximum Efficiency

One of the most important findings of this study is the difference between the treatment that produced the highest yield and the treatment that produced the highest Agronomic Efficiency Index. The 9 L/plot treatment produced the highest total yield of 5.71 t/ha. However, the highest AEI of 0.77 was obtained at 6 L/plot, compared with 0.58 at 9 L/plot. This distinction is scientifically important because maximum yield

does not necessarily mean maximum efficiency. The 9 L/plot treatment supplied a greater quantity of fish effluent and produced the highest total yield.

However, the additional yield obtained at the higher application rate was achieved with a greater quantity of effluent. The 6 L/plot treatment, on the other hand, produced a high yield while requiring a smaller quantity of effluent. Therefore, the 6 L/plot treatment produced the greatest yield response relative to the amount of fish effluent applied. This explains why it had the highest Agronomic Efficiency Index. The decline in AEI at 9 L/plot does not mean that the treatment reduced crop yield. On the contrary, the highest rate produced the greatest yield.

Rather, it indicates that the additional quantity of effluent applied at the higher rate produced proportionally less yield benefit per unit of effluent. From a practical agricultural perspective, this finding is highly relevant. Farmers may aim to obtain the highest possible yield, but efficient resource use is also important, particularly where the collection, transportation, and application of fish effluent require labour and resources. The results therefore present two possible production considerations. The 9 L/plot treatment may be preferred where the primary objective is maximum yield, whereas the 6 L/plot treatment may be more appropriate where efficient use of fish effluent is the major objective. This distinction strengthens the recommendation of the moderate application rate as a practical balance between crop productivity and efficient nutrient utilisation.

CONCLUSIONS

Fish effluent application improved soil properties and sweet potato performance. Increasing application rates were associated with improvements in soil pH, organic matter, total nitrogen, available phosphorus, and exchangeable potassium. Sweet potato growth and yield also increased with fish effluent application. The highest total yield was recorded at 9 L/plot, whereas the highest Agronomic Efficiency Index was recorded at 6 L/plot. The outcomes indicate that fish effluent can serve as a useful nutrient source for improving soil fertility and sweet potato production under the conditions of this study.

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