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Effect of Fish Pond Effluent on Soil Microbial Population and Maize *Zea mays L.* Growth

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Abstract

Fish pond effluent is discharged untreated into the soil thereby producing objectionable odour and flies' infestations. However, the effluent has been known to contain organic and inorganic nutrients and microorganisms which may promote crops growth and productivity, therefore this work was conducted to evaluate the response of microbial population and maize growth using fish pond effluent. The microbial counts of the soil samples, chemical properties and growth characteristics of the maize crop were obtained. It was observed that the microbial population of the fish effluent samples increased from 3.9×10^3 to 3.8×10^5 while that of the tap water increased from 3.5×10^3 to 4.0×10^5. The diversity of bacteria species identified includes: E coli, Citrobacter sp, Streptococcus sp., Enterobacter sp., Pseudomonas sp., and Proteus sp. for both treatments as opposed to the Pseudomonas sp. and E. Coli initially observed in the fish effluent sample and E. coli, Citro bacter sp. and Streptococcus sp. which were observed in the initial Tap water sample. The maize crop grown on the effluent-receiving soil had better growth characteristics than those planted on the pipe borne water (unpolluted) soil with plant height with means of 41.3, 58.8 and 83.3 in (2 weeks, 4 weeks and 6 weeks) respectively, which differ significantly from that of tap water 38.3, 51.9 and 72.0 recorded bi-weekly. This study showed that the fish pond effluent had positive effect on the soil microbial populations and enhanced the growth of maize crop, therefore, its use in agriculture to enhance soil fertility and crop growth is advocated.

Keywords: Fish, Maize, Growth, Pond Effluent, Pollution

1. Introduction

Growing populations have increased wastewater production, which has led to an increase in wastewater irrigation in many developing nations. In many places, agriculture depends on this water (Mehdi *et al.*, 2019) [7]. Developing nations account for a sizable portion of the world's irrigated land, and wastewater utilization is not restricted to arid and semiarid regions. There are no restrictions on access to this kind of water, and it can be used all year round. Additionally, because of the acute water scarcity, it is vital to look for new water sources, like wastewater and fish farm effluent (Mehdi *et al*., 2019) [7].

Irrigation is the artificial supply of water to farm crops and livestock, applied through various methods such as drip irrigation, sprinklers, surface irrigation, and sub-surface irrigation. In addition to these systems, scientists and agriculturists are developing new techniques to improve crop production using less water and conserving aquatic ecosystems. One such technique involves utilizing water from fish culture, a type of aquaculture where fish are farmed under controlled conditions (Chidiebere, 2018) [2].

During fish harvesting, ponds are drained, releasing nutrient-rich fish waste. Historically, this waste was either poured directly onto soil or allowed to flow into waterways, enriching the soil with nutrients. Fish water effluents, rich in essential nutrients like phosphorus, are now used as fertilizers in plant cultures, offering a sustainable alternative for agriculture (Chidiebere, 2018) [2].

The fish processing industry, characterized by substantial water use, generates significant amounts of nutrient-rich effluents (Mehdi *et al.*, 2019) [7]. With rising costs of nutrients like phosphorus and increasing water scarcity, aquaculture wastewater has become a critical alternative resource, particularly in regions with limited freshwater supplies (Lijuan *et al.*, 2017) [6]. However, irrigation with aquaculture wastewater can significantly alter soil microbial diversity and community structure due to changes in the soil environment (Lijuan *et al.*, 2017) [6].

Soil microbes play a crucial role in decomposing organic matter and maintaining soil structure. Thus, the integration of aquaculture wastewater into irrigation systems not only addresses water scarcity but also enriches soil fertility, supporting sustainable agricultural practices.

Maize (*Zea mays L.*), a cereal plant of the grass family (Poaceae) was used as a test crop for this research. It is grown for its edible grain which can be used as food by humans as well as livestock (Payebo and Ogidi, 2020).

Therefore, the purpose of this study is to determine whether fish culture effluent nutrients affect maize growth characteristics and the soil microbial community, as well as to explore the viability of using fish culture effluent as irrigation water for maize plants. Without the use of chemicals or fertilizers, the emphasis is on how fish pond wastewater affects the number of microorganisms and plants that develop in the soil. The ultimate goal of this research is to identify fresh approaches to the problems facing dryland agriculture.

The objective of this study is to evaluate the response of microbial population and maize growth using fish culture water as irrigation.

2. Materials and Methods

Description of experimental site

The experiment was a pot experiment and was conducted in the department of Crop/Soil science screen house at the Rivers State University, Port Harcourt for 6 weeks.

Materials Used

Materials used includes: Maize seeds, catfish pond effluent, polybags, masking tape, marker/pen, petri dish, electron microscope, meter rule, measuring rope, weighing balance, personal protective equipment (PPE).

Sample Collection

Sandy loam soil was obtained from different points in the Rivers State University Teaching and Research Farm and bagged in six (6) poly bags, with each bag containing about 10 kg of soil. The fish pond effluent was obtained from a concrete fish pond in the Rivers State University, Fisheries Department, which contained juvenile catfishes and the water changed every two days. The test crop used for this research was a local Maize, obtained from the market.

Methodology Employed

The Maize kernels was sown three (3) per hole at a depth of 2cm per hole in each bag, and later thinned to one (1) plant per stand to obtain the required pant population. No chemical or organic fertilizers was used during the experiment.

Watering was done thrice weekly for the first two weeks of planting, and later reduced to twice weekly.

Growth Parameters Measured

Parameters measured includes: Plant height, number of leaves, leave area and percentage germination which were taken biweekly.

Plant height (cm): This is the height of each plant measured using a measuring tape. Measurement was taken from soil level to the apex of each plant, mean values was calculated and recorded.

Number of leaves: The leaf numbers was obtained by visual counting of the leaves and the mean values taken.

Leaf area: Leaf area (LA) was determined by multiplying leaf length by leaf width with the correction coefficient (r) which is 0.75 as proposed by (Hoyt and Brafield, 1962; Watt., 1973) [5, 13]. Leaf Area was calculated thus: LA =L X W X r.

Percentage germination (%): Percentage of germinated plants was recorded after seven days of planting.

$$\% \text{ Germination} = NSG \div NSP \times 100$$

Where:

NSG = Number of seedlings that germinated per bag;
NSP = Number of seedlings planted per bag

Determination of Microbial Population

Enumeration of Bacterial

1 gram of top soil sample was collected and put into a sterile specimen bottle. The samples were immediately taken to a laboratory for microbial analysis.

Total number of microorganisms in untreated soil and treated soil was determined, and the planting dilution technique using nutrient agar medium. The rhizosphere soil sample was processed using soil sample suspended in a conical flask containing 10ml of sterilized distilled water and thoroughly shaken by 15 minutes. About 1ml of sample were serially diluted with sterilized distilled water up to 10-1, 10-2, 10-3, 10-4, 10-5, 10-6, 10-7, 10-8 and 0.1ml of appropriate dilution was spread plated onto the surface of sterile nutrient agar medium (for heterotrophic bacterial) inoculated plats was incubated at 25-300c for 24 hours and colony forming unit was counted and calculated.

Total number of colonies per gram of soil = Number of colonies (CFU) ÷ (Dilution factor × amount plated)

*CFU = Colony Forming Unit

Laboratory Analysis

Soil samples were air dried for two days and passed through 2mm mesh size sieve before checking for the following parameters:

Determination of Chemical Properties

Soil pH: This was carried out using the glass electrode pH meter.

Organic Carbon: This was done using the Walkley and Black wet oxidation method.

Total Nitrogen: This was carried out using the Kjeldahl method.

Available Phosphorus: This was carried out using the Bray and Kurtz no.1 method.

Data Analysis

This experiment was conducted in a complete randomized design with two treatments, Fish Pond effluent and Tap water with three replications.

Analysis of variance method was used to analyze both soil and growth parameters, and means were tested using Tukey means method of grouping at 5% level of probability with ASSISTAT version 7.7 to know the treatment effects.

3. Results

Germination Percentage (%)

The result of germination rate shows that a high percentage rate of germination (100%) was seen in the fish water treatment when compared to the Tap water treatment with 66.7%. showing that the fish effluent increases germination rate in maize plants.

Microbial Population

It was observed that the microbial population of the fish effluent samples increased from 3.9×10^3 to 3.8×10^5 while that of the tap water increased from 3.5×10^3 to 4.0×10^5.

The diversity of bacteria species identified includes: E coli, Citrobacter sp, Streptococcus sp., Enterobacter sp., Pseudomonas sp., and Proteus sp. for both treatments as opposed to the Pseudomonas sp. and E. Coli initially observed in the fish effluent sample and E. coli, Citro bacter sp. and Streptococcus sp. which were observed in the initially Tap water sample.

Table 3.1: Soil microbial population before and after application of Catfish effluent and pipe borne water

Code	Microbial count before the experiment (cfu/g)	Microorganisms identified before the experiment	Microbial count after the experiment (cfu/g)	Microorganisms identified after the experiment
Catfish effluent	3.9×10^3	Pseudomonas spp, E. coli	3.8×10^5	Pseudomonas spp, E. coli, Citro bacter spp., Enterobacter spp., Streptococcus spp.
Pipe borne water	3.5×10^3	E. coli, Citro bacter spp., Streptococcus spp.	4.0×10^5	Pseudomonas spp., E. coli, Citro bacter spp., Enterobacter spp., Streptococcus spp.

Chemical Properties of the Soil.

pH

Regarding the soil attributes after maize cultivation, it was observed that the pH of the soil samples treated with fish effluent increased from 6.60a to 8.37^a, and 6.60 to 7.50^b in that of tap water. The result also shows that there is significant difference between the fish effluent and tap water.

Total Nitrogen (TN)

The result obtained from this study showed that the Total nitrogen present in the soil after the application of the fish effluent increased from 0.16a to 0.32a while that of the tap water samples remained unchanged.

Phosphorus (P)

The result obtained from this study showed that phosphorus values of the soil sample in contact with fish effluent increased from 15.54^a to 24.56^a and 15.54^a to 15.79^b in comparison to the tap water samples.

Potassium (K)

It was observed from the results obtained for this study that there was an increase in the value of K in the fish effluent sample from 0.31^a to 0.36^a but a decrease in that of tap water to 0.28^a

Magnesium (Mg)

The magnesium content of the various soil samples where fish pond effluent was deposited increased more than that of tap water from 2.87^a to 3.60^a and to 2.93^a respectively.

Calcium (Ca)

Calcium present in fish pond effluent sample was more than that of the tap water sample increasing from 3.60^a to 4.17^a in the fish effluent and to 3.83^a in that Tap water.

Sodium (Na)

The values obtained for the soil samples in contact with the fish pond effluent increased from 0.03^a to 0.04a but that of tap water remained unchanged.

Organic matter

The mean organic matter content increased for the fish effluent sample from 0.34^a to 0.49^a but remained unchanged at 0.34^b in that of the tap water.

Cation Exchange Capacity (CEC)

The cation exchange capacity of the soil treated with fish effluent was observed to be decreased from 4.47^a to 4.42^a but increased in that of tap water.

Hydrogen ion (H^+)

The hydrogen ion concentration was observed to be more in the fish effluent increasing from 0.40^a to 0.43^a sample and remained the same in that of tap water.

Table 3.2: Soil chemical properties before and after application of Catfish Effluent and Pipe borne water under Maize Crop

Soil Properties	Before experiment	CFE	TW
pH	6.60^a	8.37^a	7.50^b
Total Nitrogen (%)	0.16^a	0.32^a	0.16^b
Organic Carbon (%)	0.34^a	0.49^a	0.34^b
Cation Exchange Capacity (CEC) (Cmol/kg)	4.47^a	4.42^a	4.51^a
Available Phosphorus (p) (mg/kg)	15.54^a	24.56^a	15.79^b
Potassium (K) (meq/100g of soil)	0.31^a	0.36^a	0.28^a
Calcium (Ca)	3.60^a	4.17^a	3.83^a
Magnesium	2.87^a	3.60^a	2.93^a
Sodium	0.03^a	0.04^a	0.03^a
Exchangeable Acidity (E/A) (Cmol/kg)	0.40^a	0.43^a	0.40^a

Means that share the same letters along the row do no differ significantly (Tukey's method at 0.05% probability).

Maize Growth Parameters

Plant height

The table 3.3 shows the means of each treatment for 6 weeks after planting. The height of the plants was higher in that treated with catfish effluent with means of 41.3, 58.8 and 83.3 in (2 weeks, 4 weeks and 6 weeks) respectively, which differ significantly from that of tap water 38.3, 51.9 and 72.0 recorded bi-weekly. The same was reported by (Davi *et al.,* 2013).

Leaf area

The table 3.3 shows the means of each treatment for 6 weeks after planting for leaf area.

The area of leaves was higher in the treatment with catfish effluent with mean of 52.90, 106.95 and 215.17 which differ significantly from that of tap water with mean of 31.5, 56 and 79 in cm recorded bi-weekly. This was also reported by (Ndagi *et al.*, 2020) [8].

Number of leaves

The Table 3.4 shows the mean of each treatment after 6 weeks after planting for number of leaves. The number of leaves were higher in the treatment with catfish effluent with means of 4.67, 7.33 and 8.67 which differ significantly from that of tap water with mean of 4.30, 6.00 and 8.33 recorded bi-weekly.

Table 3.3: Showing the height of plants for 6 weeks

Code	WEEK 2 (cm)	WEEK 4 (cm)	WEEK 6 (cm)
CFE	41.3	58.8	83.3
TW	38.3	51.9	72.0

Table 3.4: Showing the mean plant area for 6 weeks

Code	WEEK 2 (cm)	WEEK 4 (cm)	WEEK 6 (cm)
CFE	**52.90**	**106.95**	**215.2**
TW	**43.00**	**73.80**	**171.6**

Table 3.5: Showing the mean of the number of leaves for 6 weeks

Code	WEEK 2	WEEK 4	WEEK 6
CFE	**4.67**	**7.33**	**8.67**
TW	**4.30**	**6.00**	**8.33**

4. Discussion

Microbial Population

The research result shows that both fish effluent and tap water led to an increase in microbial populations, with the fish effluent experiencing a rise from 3.9×10^3 to 3.8×10^5, and tap water rising from 3.5×10^3 to 4.0×10^5. This growth in microbial populations is consistent with previous studies, such as those by Samuel *et al.*, (2021) [10], which observed significant microbial population increases in catfish effluent-treated environments. The study also noted the diversity of bacterial species in both treatments, identifying several species like *E. coli*, *Citrobacter sp.*, *Streptococcus sp.*, *Enterobacter sp.*, *Pseudomonas sp.*, and *Proteus sp.* These findings suggest that both fish effluent and tap water support diverse microbial communities, with fish effluent introducing a wider range of bacterial species compared to tap water. The shift in bacterial species over time further highlights the dynamic microbial changes occurring in response to the different treatments.

Chemical Properties of the soil

The pH of soil treated with fish effluent increased significantly from 6.60 to 8.37, indicating a more alkaline environment. In contrast, tap water-treated soil showed a smaller increase (from 6.60 to 7.50). This significant difference suggests that fish effluent may contribute to altering the soil's acidity, likely due to the nutrients and organic compounds in the effluent, similar to previous studies by Silva *et al*. (2018) [4].

Fish effluent increased the soil's total nitrogen from 0.16 to 0.32, which is important for plant growth, while tap water showed no change. This increment likely stems from nitrogen-rich fish feeds, waste, and microorganisms in the ponds, enhancing soil fertility, as also reported by Bame *et al.*, (2014) [1].

Phosphorus levels in soil treated with fish effluent increased from 15.54 to 24.56, significantly boosting the nutrient content compared to the small increase in tap water (15.54 to 15.79). Phosphorus is crucial for plant growth and quality, and this result aligns with previous studies (Bame *et al.*, 2014) [1], indicating the fish effluent's positive impact on soil productivity.

The potassium content in the soil treated with fish effluent increased from 0.31 to 0.36, while tap water resulted in a slight decrease to 0.28. Potassium is essential for plant health, supporting processes like photosynthesis, and the increase in the fish effluent sample suggests it enriches soil potassium levels.

Magnesium, vital for chlorophyll production and phosphorus transport, increased in the fish effluent-treated soil from 2.87 to 3.60, compared to a smaller increase in the tap water-treated soil (from 2.93). This suggests that fish effluent may contribute to improving soil magnesium content, supporting better plant nutrition.

Fish effluent-treated soil saw an increase in calcium from 3.60 to 4.17, whereas tap water-treated soil increased only to 3.83. Calcium is critical for root development and plant cell wall structure, and the increase in the fish effluent soil indicates that it may help improve these aspects of plant growth.

Sodium levels slightly increased in the fish effluent-treated soil (from 0.03 to 0.04), while the tap water-treated soil showed no change. Sodium is not a vital plant nutrient, and excessive levels can harm soil structure, but the relatively low levels observed in both treatments indicate that sodium is not a major concern in this study, as confirmed by Devi *et al.*, (2013) [3].

The organic matter content in the fish effluent-treated soil increased from 0.34 to 0.49, compared to no change in tap water-treated soil. Organic matter is essential for soil structure, microbial activity, and overall fertility, and the increase in the fish effluent soil shows its potential to improve soil health, as noted by Ndagi *et al.*, (2020) [8].

The cation exchange capacity, which reflects the soil's ability to retain essential cations, decreased slightly in the fish effluent-treated soil (from 4.47 to 4.42) but increased in the tap water-treated soil. This suggests that fish effluent may slightly reduce the soil's cation exchange capacity, but it remains effective for soil fertility.

The concentration of hydrogen ions, influencing soil pH, increased slightly in the fish effluent-treated soil from 0.40 to 0.43, while tap water remained unchanged. Higher hydrogen ion concentration contributes to soil acidity, and the slight increase in the fish effluent sample may indicate a slight acidification effect, which can influence microbial growth and soil conditions, as explained by Sudhir (2004).

5. Conclusion

From the results obtained, it was observed that the fish effluent can supply nutrients and increase the concentrations of these elements in plants irrigated with this effluent. High concentrations of important elements probably stimulate plant growth in the fish effluent treatment compared to that of Tap water.

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