**Evaluating the Efficacy of Organic Manures and NPK Fertilizer in Enhancing Plant Growth in Oil-Contaminated Soil: A Study Using Abelmoschus esculentus (Okra)**

**ABSTRACT**

This study evaluates the effects of some organic manures (cow dung manure, poultry manure, fish pond wastewater) and NPK 15:15:15 fertilizer on oil-contaminated soil using Abelmoschus esculentus as a test plant. The research was conducted under controlled conditions at Nnamdi Azikiwe University, Awka, using a randomized complete block design. Soil samples were collected from an oil-contaminated mechanic workshop and treated with various organic and inorganic amendments. Growth parameters, including plant height, stem girth, leaf area, and number of leaves, were assessed over eight weeks. Results indicate that cow dung manure significantly enhanced plant height (100.33% increase), while fish pond wastewater combined with poultry droppings (FP+PD) showed the least increase (14.03%), suggesting a negative synergistic effect. The combination of cow dung and poultry manure (CD+PD) also exhibited a strong positive effect on plant growth. Soil nitrogen levels were highest in FP+PD-treated soils (5.32±1.06), while phosphorus levels were maximized with poultry droppings alone (22.90±5.80). Contaminated soil had the highest potassium levels (54.37±4.38 ppm), likely due to crude oil contamination. Despite amendments, soil pH remained largely unchanged. Leaf production was significantly enhanced by cow dung and fish pond wastewater, with a 100% increase in four weeks, while poultry droppings alone had no effect. Leaf area expansion was highest in the control group (842%), indicating that manure application may not significantly influence light-harvesting capability. Stem girth increased equally (33.33%) across all treatments except in the control (11.11%), with cow dung and fish pond wastewater showing the most rapid impact. Overall, cow dung manure proved to be the most effective treatment for improving soil fertility and enhancing A. esculentus growth in oil-contaminated soil, followed by fish pond wastewater and poultry droppings. These findings highlight the potential of organic amendments in mitigating oil pollution and promoting plant productivity.

**KEYWORDS: Oil-contaminated soil, Organic amendments, *Abelmoschus esculentus* (Okra), Cow dung manure, Poultry manure, Soil remediation, NPK fertilizer.**

**1. INTRODUCTION**

Soil contamination by oils and subsequent erosion of soil nutrients as a result of the complex reactions brought about by the oils is one of the most striking features on the land surface of South Eastern Nigeria, especially in Awka, Anambra State. Several non-responsive human activities by both the Government and the inhabitants have culminated in the devastating soil erosion spills and contamination of farmlands and vegetations in these areas. Some of these activities include indiscriminate disposal of used automobile oils, spillages from fallen tankers conveying these oils, spillages from local oil press and illegal refineries, uncontrolled population growth and poor agricultural practices. This however, posses a significant challenge to the vegetation and farming activities in the region; hence, proffering local, organic and affordable solutions is imperative.

Organic manure (cow dung) is excellent manure as it contains high amount of Nitrogen, phosphorus, potassium and other essential nutrients [1]. In contrast to chemical fertilizer, it adds organic matter to soil which improves soil structure, nutrient retention, aeration, soil moisture holding capacity and water infiltration [2]. Organic manure such as cow dung, chicken manure, goat droppings and fishpond waste water helps to improve the soil by providing nutrients for growing crops and it also improves the soil quality, because of its high organic matter content with available nutrients for plant growth.

Although, organic manure exists in readily available forms, cheap and easy to access, they need to be applied in large amount to meet the nutrient requirement of crops [3].

Cow dung is basically made up of digested grass and grain. It is high in organic material and nutrients. It contains about 3% nitrogen, 2% phosphorus, and 1% potassium (3-2-1 NPK) [4]. It is said to contain high level of ammonia and potentially dangerous pathogens. For this reason, it is usually recommended that it be aged or composted prior to its use as cow manure fertilizer. Cow manure adds significant amount of organic material to the soil, it improve overall health of the soil and produce healthy vigorous plants.

Inorganic fertilizer is fertilizer mined from mineral deposits or manufactured from synthetic compounds. In the past years, inorganic fertilizer (N: P: K) was advocated for crop production to improve low inherent fertility of soil in the tropics since it provided readily available nutrient for plant. Their use has however, not always been successful in the tropics due to the enhancement of soil acidity, easy leaching of nutrient, low organic matter status, reduced crop yield and degradation of soil physical properties.

NPK fertilizer comprised primarily of Nitrogen, phosphorus and potassium required for healthy plant growth. The agriculture industry relies heavily on the use of NPK fertilizer to meet global food supply and ensure healthy crops but the environmental consequences and cost of this fertilizer makes them undesirable and also uneconomically out of reach to the poor farmers.

Titiloyer [4] reported that the most satisfactory method of increasing plant yield was by judicious combination of organic waste and inorganic fertilizer. As the integration of organic sources and synthetic sources of nutrient not only supply essential nutrient but also have some positive interaction with chemical fertilizer to increase their efficiency and thereby reduce environmental hazards [5], [6]. Murwira and Kirchman[7] observed that nutrient use efficiency might be increased through the combination of organic manure and inorganic fertilizer.

A very common practice by farmers is the use of organic manure and inorganic fertilizer to raise the yield of crops especially under improved husbandry. Farmers are unable to produce their crops economically without adding to the soil the element which helps boost their growth and yield.

According to Ogunkeyede*et al.* [8], fertilizers are added to the soil to encourage fast growth, boost yield and enrich the plant with the most important element such as Nitrogen, phosphorus and potassium.

Okra *Abelmoschus esculentus* L. (Moench), is an economically important vegetable crop grown in tropical and sub-tropical parts of the world. This crop is suitable for cultivation as a garden crop as well as on large commercial farms. It is grown commercially in India, Turkey, Iran, Western Africa, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Burma, Japan, Malayasia, Brazil, Ghana, Ethiopia, Cyprus and the Southern United States. India ranks first in the world with 3.5 million tonnes (70% of the total world production) of okra produced from over 0.35 million hectare land [9].

Okra is known by many local names in different parts of the world. It is called ‘okwuru’ in Igbo, lady’s finger in England, gumbo in the United States of America, guino-gombo in Spanish, guibeiro in Portuguese and bhindi in India. It is quite popular in India because of easy cultivation, dependable yield and adaptability to varying moisture conditions. Even within India, different names have been given in different regional languages [10].

Its ripe seeds are roasted, ground and used as a substitute for coffee in some countries. Mature fruits and stems containing crude fibre are used in the paper industry. Extracts from the seeds of the okra is an alternative source for edible oil. The greenish yellow edible oil has a pleasant taste and odour, and is high in unsaturated fats such as oleic acid and linoleic acid. The oil content of the seed is quite high at about 40%.

Soil contamination by oils and the dart in sustainable crop production requires judicial use of inputs such as fertilizers. The use of inorganic fertilizers has drastically declined following the energy crisis, which has immensely affected most of the developing countries [11]. In Nigeria, reduced use of inorganic fertilizers has largely been aggravated by the removal of fertilizer subsidies by the government. This has resulted in low crop yields due to deteriorating land productivity. Nigeria is however, endowed with a large number of livestock such as cattle, goats, sheep, pigs, donkeys and poultry. In view of the apparent decline in soil fertility as a result of oil contamination, deliberate efforts are required to promote utilization of animal manure for crop production. Most studies on utilization of animal manure in Nigeria have largely focused on crop yield responses of field crops with very little effort to relate such responses with availability of nutrients and amendment of soil texture, structure and organic matter as well as soil physicochemical properties. Efficient utilization of animal manure requires thorough understanding of the relationship between crop responses and availability of nutrients in the soil following animal manure application [12]. Furthermore, there is also a need for comparing different types of animal manures under similar field conditions. This is important in coming up with indications on manure recommendations. The current study was therefore carried out in order to evaluate the growth and development of *Abelmuschusesculentus* (Okra) in oil contaminated soil amended with different animal waste products. *Abelmuschusesculentus* was chosen as the test crop due to its nutritional and economic importance in most parts of Nigeria. It is the most popular vegetable crop grown in most home gardens and is a fast growing annual crop requiring intensive application of fertilizers.

The aim of this study is to evaluate the effect of some organic manure and NPK 15:15:15 fertilizer on oil contaminated soil using *Abelmoschus esculentus* as a test plant.

1. **MATERIALS AND METHOD**

**Study Area**

The study was carried out at the Department of Botany experimental screen house, Nnamdi Azikiwe University Awka is geographically located between Latitudes (70 00 and 70 10) E and Longitudes (60 05 and 60 15) N southeastern Nigeria. The region has luxuriant vegetation of the tropics and is densely populated with grasses and trees of different sizes. It is a humid tropical region, which experiences eight months of rainy season and four months of dry season. The mean annual temperature stands at 28°C and the mean annual rainfall is 2500 mm. The soil type is loamy clay.

**2.1 Collection of Materials**

**2.1.1 Seed Collection and Viability Check**

*Abelmoschus esculentus* seeds used in this study was sourced from Anambra Agricultural Development Programme (ADP). The viability of the seeds was also checked by pouring them into bowl containing water and seeds that floats on the surface of the water were considered non viable and the ones that sinks were considered viable and was used for this study.

**2.1.2 Manure Collection**

Cow dung manure was collected from the cow market in Amansea, poultry manure and fish pond waste water (FPWW) was collected from departments of Animal science and Fishery and Aquaculture experiments farms both is Faculty of Agriculture, Unizik. The plastic bags and inorganic manure was procured from the market.

**2.1.3 Soil Collection**

Soil samples for this study were collected from a mechanic workshop where the soils there have been soaked with oils and grease from a mechanic workshop for a period of time.

**2.2 Study Design and Treatment**

Plastic bags of 30 cm length by 15 cm width were used for this experiment. The experimental layout was a randomized complete block design (RCBD); three plastic bags was used for each treatment and standard (N: P: K) as well as control groups. Two kilograms of oil contaminated soil was measured and mixed with 0.5 kg of manure and then poured into the plastic bags. For the FPWW, 300 ml of it was used to water the soil. This set up was allowed to sit for 7 days for ammonification to take place.

Four seeds were sown in per bag; a peg was also be placed in each potting bag, making sure that the tip projects above the soil by 2cm, the tip of this peg was serve as basement or position for measurements of height and girth. Following germination of the plants, inorganic fertilizer treatment was applied after 21days of growth. The control was not treated with either the organic or inorganic fertilizer; rather four seeds were planted in the moisturized soil. After one week of ammonification, it was ensured that the soil is aerated and not waterlogged before the planting was done. Growth parameters such as changes in length, girth, leaf area and number of leaves was measured on weekly bases and recorded accordingly.

**2.3 Measurement of Growth Parameters**

**Plant Height:** Height was measured with the use of measuring tape starting from the base of plant to the shoot apex and the values recorded accordingly in centimeter.

**Plant Girth:** Stem girth was measured using a rope clung around the stem of each seedling and read against the graduated measuring tape and the values recorded accordingly (in centimeters).

**Leaf Area:** The length and breadth of the leaf were measure using a measuring tape and recorded accordingly in square centimeter. Leaf area was then calculated as;

**Leaf area (cm2)** = L x W x 0.75

Where:

L = length of Leaf

Width = Width of leaf

0.75 = Constant

**Leaf Number:** The leaves of every seedling in each replicates were counted and the mean per replicate was determined.

**2.4 Soil Textural and Chemical Analysis**

**2.4.1 Nitrogen determination**

The nitrogen content of the soil samples was determined using the microkjeldahl method of AOAC [13]. The samples were digested with concentrated sulphuric acid, using copper sulphate and sodium sulphate as catalyst to convert organic nitrogen to ammonium ions. Alkali was added and the liberated ammonia is distilled into an excess boric acid. The distillate was titrated with hydrochloric acid or sulphuric acid.

**Procedure**

One gram (1g) of the sample was weighed and transferred into the kjeldahl digestion flask followed by the addition of 3g of a mixture of sodium sulphate and copper sulphate pentahydrate in the ratio 10:1 as catalyst. Four anti-bumping chips were added to prevent sticking of the mixture to the flask during digestion and also to enhance boiling. The kjeldahl flask content was digested with 25ml concentrated H2SO4. The flask was inclined and heated gently at first until frothing ceased, then heated strongly with shakings, at intervals, to wash down charred particles from sides of the flask. Heating was continued until the mixture become clear and free from brown or black colour. This was allowed to cool and the content of the flask made up to 100ml using distilled water. 20ml of this diluted digest was placed in the distillation flask. 20ml of 2% boric acid solution was measured into a conical flask, and few drops of screened methyl red indicator was added into the conical flask. The conical flask and its content were placed on the receiver, so that the end of the delivery tube dips just below the level of the acid. Few pieces of granulated zinc and anti-bumping granules was added to the distillation flask and about 40ml of 40% NaOH solution was run into the flask to make the liquid in the flask alkaline. The content was boiled vigorously until the content of the flask bumps. The distillate was titrated with 0.1N HCl to a purple coloured end point (Vml).

CALCULATION

Nitrogen(%) = $\frac{1.4 x Titre Volume x total volume of digest}{1000 xweightofSamplexAliquotdistilled}$ x 100.

**2.4.2 Soil phosphate, according to Ganesh *et al*. [14]**

**Procedure**:

To suitable aliquots of stock standard solution and sample, 1 ml of 0.0055M ammonium molybdate and 0.4 ml of 0.0096M hydrazine sulphate were added and the solution was made up to 10 ml with double distilled water in a standard measuring flask. The standard measuring flasks were kept in a water bath for heating for 30 min. The temperature of the water bath was set to 60oC. While heating, a blue colour develops due to the formation of ammonium phosphomolybdate complex. After heating for 30 min the solution was cooled and its absorbance was measured at wavelength 830 nm. An experimental blank solution was used for carrying out correction for the baseline.

**2.4.3 Methods for the Metal Analysis of Sample**

Metal analysis was conducted using Varian AA240 Atomic Absorption Spectrophotometer according to the method of APHA [15].

**Sample digestion (Wet digestion technique)**

The method of Sun [16] was adopted. Samples weighing approximately 1g were transferred into a 100ml digestion flask, then 10ml of 70% HNO3 was added followed by heating until any vigorous reaction subsided (30-45 minutes). After cooling, 8ml of 70% perchloric acid (HClO4) was added to each flask and the contents were gently heated on a hot plate until the solutions became colorless or nearly so, and white fumes of HClO4 were evolved making sure contents didn’t dry. After cooling, approximately 30ml of distilled water was added to each flask and boiled for another 10 minutes, cooled and then filtered at room temperature. The digests were then subjected to atomic absorption spectrophotometric analysis.

**Preparation of Reference Solutions**

A series of standard metal solutions in the optimum concentration range are prepared, the reference solutions were prepared daily by diluting the single stock element solutions with water containing 1.5 ml concentrated nitric acid/litre. A calibration blank was prepared using all the reagents except for the metal stock solutions.

Calibration curve for each metal was prepared by plotting the absorbance of standards versus their concentrations.

**2.4.4 Soil pH**

1g of soil samples were mixed with 10 ml of distilled water whose pH had been measured (pH: 7). This was mixed and allowed to stand for two hours before determination of pH using a digital pH meter by immersing its electrode.

## 2.5 Statistical Analysis

Data collected were subjected to Analysis of variance (ANOVA) at 0.05% level of significance and the mean separated by Duncan Multiple Range Test (DMRT). Statistical Package for Social Sciences (SPSS) version 20 statistical tool was used to run the analysis.

1. **RESULTS**

**3.1 Physicochemical parameters of Oil Contaminated Soil after Treatment**

The FP+PD soils had the highest nitrogen levels (5.32±1.06) while the FP only had the least (2.37±0.45). These nitrogen levels though weren’t significantly different from each other (p>0.05) when all the groups were compared. This shows that combining the two manure types had a good positive synergistic effect. The cow dung and CD+PD group also had high soil nitrogen levels. The comparatively high nitrogen levels in the soils could be attributed to crude oil contaminants in the soil.

Poultry droppings promoted higher phosphorus levels (22.90±5.80) while the FP+CD and contaminated soils had the least phosphorus levels. The lower levels in the FP+CD could be attributed to negative synergy thus a reduction in phosphorus levels when compared to the normal control.

The contaminated soil had the highest soil K levels (54.37±4.38 ppm). This could be attributed to the contamination from the crude oil making it significantly higher than the normal control soil. FP and its combination with CD and PD also significantly increased the K levels, thus their ability to increase the K levels in the soil which correlates with the level of soil fertility.

There was no significant change in the pH of all the soils when they were compared with the normal control (p>0.05); though some of the manure types like the FP, FP+CD, CD and FP+PD could make the pH of the soil alkaline on the long run.

**Table 1: Average Physicochemical Parameters of the Various Soil Treatments**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Groups | Nitrogen (%) | Phosphorus (%) | Potassium (ppm) | pH |
| Cow dung (CD) | 4.26±0.71 | 22.58±5.23 | 31.52±0.94 | 7.58±0.04 |
| Poultry droppings (PD) | 2.43±0.15 | 22.90±5.80 | 12.75±1.93 | 7.25±0.27 |
| Fish pond waste water (FP) | 2.37±0.45 | 9.23±0.08 | 42.18±2.01 | 7.89±0.05 |
| CD+PD | 4.08±1.36 | 15.70±0.95 | 21.35±0.46 | 7.45±0.13 |
| FP+CD | 3.69±0.00 | 2.68±0.13 | 42.21±1.02 | 7.74±0.02 |
| FP+PD | 5.32±1.06 | 15.48±2.13 | 38.61±1.52 | 7.54±0.05 |
| NPK | 2.65±0.74 | 14.93±4.78 | 35.05±1.51 | 7.23±0.12 |
| Control | 2.48±0.47 | 14.60±1.75 | 33.41±0.75 | 7.41±0.33 |
| Contaminated soil | 4.10±0.44 | 5.95±2.10 | 54.37±4.38 | 7.39±0.34 |

**3.2 Plant Morphometric Parameters**

**Plant Height**

From the results, the plants that received cow dung had the highest percentage increase in plant height (100.33%) while the FP+PD group had the least (14.03%). This means that mixing the fish pond waste water and poultry droppings might inhibit plant height gain on the long run; though this might be dependent on species. The group that received a mixture of CD and PD also had a rapid increase in plant height (88.71%); this shows positive synergistic effect while the FP+PD showed negative synergy. There was a significant increase in plant height in the CD, FP, FP+CD and NPK groups (p<0.05); thus these can potentiate plant height increase.

**Table 2: Average Heights of the Plants (cm) Cultivated on the Treated Soil**

|  |  |
| --- | --- |
|  |  WEEKS |
| Treatments |  **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| CD | 10.10±1.10 | 13.53±2.15 | 15.30±2.87 | 17.20±2.60 | 19.77±2.32 | 19.87±2.35 | 20.23±2.36 |
| PD | 7.05±3.25 | 7.55±3.25 | 9.40±2.20 | 10.70±1.30 | 11.60±0.40 | 11.80±0.20 | 12.10±0.10 |
| FPWW | 8.67±1.39 | 10.70±1.07 | 12.23±1.42 | 12.73±1.46 | 13.73±1.27 | 14.20±1.23 | 14.53±1.24 |
| CD+PD | 6.20±0.55 | 8.65±0.95 | 10.00±0.70 | 10.85±1.35 | 11.00±1.50 | 11.45±1.75 | 11.70±2.00 |
| FP+CD | 9.23±0.58 | 10.30±0.35 | 11.40±0.61 | 11.77±0.56 | 12.10±0.47 | 12.63±0.41 | 13.10±0.42 |
| FP+PD | 6.53±0.70 | 6.67±0.78 | 6.50±0.50 | 6.75±0.55 | 6.85±0.45 | 7.10±0.60 | 7.45±0.65 |
| NPK | 6.87±0.41 | 7.30±0.25 | 7.57±0.22 | 7.83±0.19 | 8.00±0.23 | 8.37±0.12 | 8.63±0.09 |
| Control | 8.10±0.49 | 10.00±0.70 | 11.33±0.82 | 11.40±1.20 | 11.70±1.10 | 12.30±1.00 | 12.65±0.95 |

**KEY:** CD – Cow Dung, PD – Poultry Droppings, FPWW – Fishpond Waste Water, NPK – Nitrogen: Phosphorus: Potassium.

**Figure 1: Scattered Plot Showing Percentage Change in Height during the Experimental Period**

**Number of Leaves**

Poultry droppings didn’t increase the number of leaves in 4 weeks while the CD and FP had a 100% increase in number of leaves in 4 weeks. A combination of FP and CD (FP+CD) also increased the number of leaves by 83.30%; while without manure application, there was a 33.33% increase. The increases in the number of leaves in the CD, FP,CD+PD, FP+CD and NPK groups were significant (p<0.05) and non significant in the rest of the groups. A higher number of leaves also indicate greater photosynthetic activity.

**Table 3: Average Number of Leaves of the Plants Cultivated on the Treated Soil**

|  |  |
| --- | --- |
|  |  WEEKS |
| Groups | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| CD | 2.00±0.00 | 2.00±0.00 | 2.00±0.00 | 3.00±0.00 | 3.67±0.33 | 4.00±0.00 | 4.00±0.00 |
| PD | 2.00±0.00 | 2.00±0.00 | 2.00±0.00 | 2.00±0.00 | 2.00±0.00 | 2.00±0.00 | 2.00±0.00 |
| FD | 2.00±0.00 | 2.00±0.00 | 2.00±0.00 | 2.00±0.00 | 3.00±0.00 | 4.00±0.00 | 4.00±0.00 |
| CD+PD | 2.00±0.00 | 2.00±0.00 | 2.00±0.00 | 2.00±0.00 | 2.00±0.00 | 2.00±0.00 | 3.00±0.00 |
| FP+CD | 2.00±0.00 | 2.00±0.00 | 2.00±0.00 | 3.00±0.00 | 3.00±0.00 | 3.00±0.00 | 3.67±0.00 |
| FP+PD | 2.00±0.00 | 2.00±0.00 | 2.00±0.00 | 2.00±0.00 | 2.00±0.00 | 2.50±0.50 | 2.50±0.50 |
| NPK | 2.00±0.00 | 2.00±0.00 | 2.00±0.00 | 2.00±0.00 | 2.67±0.33 | 3.00±0.00 | 3.00±0.00 |
| Control | 2.00±0.00 | 2.00±0.00 | 2.00±0.00 | 2.00±0.00 | 2.33±0.33 | 2.33±0.33 | 2.67±0.33 |

**KEY:** CD – Cow Dung, PD – Poultry Droppings, FPWW – Fishpond Waste Water, NPK – Nitrogen: Phosphorus: Potassium.

**Figure 2: Scattered Plot Showing Percentage Change in Number of Leaves during the Experimental Period**

**Leaf Area**

From the results, the control group had the highest rate of increase in leaf area, while the FP+CD group had the least (350%). The higher leaf area in the control group (842%) signifies that addition of any manure type may not affect leaf area, thus may not primarily affect light harvesting capability. There was a significant increase in leaf area in all the groups when the initial and final leaf areas were compared (p<0.05) except the FD+PD groups.

**Table 4: Average Leaf Area of the Plants Cultivated on the Treated Soil**

|  |  |
| --- | --- |
|  |  WEEKS |
| Groups | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| CD | 3.33±0.50 | 8.10±1.40 | 9.60±1.40 | 11.10±1.40 | 12.70±1.39 | 14.20±1.39 | 15.70±1.39 |
| PD | 1.05±0.35 | 2.55±1.35 | 4.05±1.35 | 5.55±1.35 | 6.50±0.80 | 6.80±0.90 | 7.25±1.15 |
| FPWW | 1.97±0.55 | 2.90±0.32 | 4.40±0.32 | 6.17±0.45 | 8.17±0.75 | 9.67±0.75 | 11.17±0.75 |
| CD+PD | 1.30±0.00 | 2.10±0.30 | 3.60±0.30 | 5.10±0.30 | 6.00±0.90 | 7.00±1.40 | 8.10±1.80 |
| FP+CD | 2.60±0.56 | 4.20±0.17 | 5.70±0.17 | 7.20±0.17 | 8.70±0.17 | 10.20±0.17 | 11.70±0.17 |
| FP+PD | 1.10±0.20 | 1.87±0.38 | 3.35±0.65 | 4.15±1.05 | 4.90±1.10 | 5.70±1.10 | 6.05±1.15 |
| NPK | 0.90±0.06 | 1.40±0.21 | 2.90±0.25 | 4.23±0.36 | 5.63±0.46 | 6.93±0.47 | 8.23±0.51 |
| Control | 0.63±0.03 | 2.73±0.60 | 4.23±0.74 | 4.60±0.76 | 5.07±0.86 | 5.57±0.79 | 5.97±0.82 |

**KEY:** CD – Cow Dung, PD – Poultry Droppings, FPWW – Fishpond Waste Water, NPK – Nitrogen: Phosphorus: Potassium.

**Figure 3: Scattered Plot Showing Percentage Change in Leaf Area during the Experimental Period**

**Stem Girth**

There was an equal increase in stem girth in all the treatment groups (33.33%) on the 8th week except in the control where there was an 11.11% increase. This increase was significant in all the groups except in the NPK and normal control groups. The CD+PD groups also increased by 33.33%; i.e. had a significant increase in girth after the 4th week, thus the higher efficacy of this combination to increase stem girth. The CD and FP also showed higher potential to increase stem girth since they reached their maximum girth in 5 weeks.

 **Table 5: Average Stem Girth of the Plants Cultivated on the Treated Soil**

|  |  |
| --- | --- |
|  |  WEEKS |
| Groups | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| CD | 0.30±0.00 | 0.30±0.00 | 0.30±0.00 | 0.40±0.00 | 0.40±0.00 | 0.40±0.00 | 0.40±0.00 |
| PD | 0.30±0.00 | 0.30±0.00 | 0.30±0.00 | 0.35±0.05 | 0.35±0.05 | 0.40±0.00 | 0.40±0.00 |
| FPWW | 0.30±0.00 | 0.30±0.00 | 0.30±0.00 | 0.35±0.05 | 0.35±0.05 | 0.40±0.00 | 0.40±0.00 |
| CD+PD | 0.30±0.00 | 0.30±0.00 | 0.40±0.00 | 0.40±0.00 | 0.40±0.00 | 0.40±0.00 | 0.40±0.00 |
| FP+CD | 0.30±0.00 | 0.30±0.00 | 0.30±0.00 | 0.30±0.00 | 0.40±0.00 | 0.40±0.00 | 0.40±0.00 |
| FP+PD | 0.30±0.00 | 0.30±0.00 | 0.30±0.00 | 0.30±0.00 | 0.35±0.05 | 0.40±0.00 | 0.40±0.00 |
| NPK | 0.30±0.00 | 0.30±0.00 | 0.30±0.00 | 0.30±0.00 | 0.33±0.03 | 0.40±0.00 | 0.40±0.00 |
| Control | 0.30±0.00 | 0.30±0.00 | 0.30±0.00 | 0.33±0.03 | 0.33±0.03 | 0.33±0.03 | 0.33±0.03 |

**Figure 4: Scattered Plot Showing Percentage Change in Stem Girth during the Experimental Period**

1. **DISCUSSION**

A comparative analysis of organic amendments, including CD, poultry droppings (PD), and FP, alongside their mixtures and NPK fertilizer, highlights their chemical composition concerning nitrogen (N), phosphorus (P), potassium (K), and pH. Among the amendments, CD exhibits the highest nitrogen concentration (4.26±0.71%), confirming findings by Goyal *et al*. [17]. PD and FP contain lower nitrogen levels at 2.43±0.15% and 2.37±0.45%, respectively. Phosphorus content is highest in PD (22.90±5.80%), followed closely by CD (22.58±5.23%), while FP shows a significantly lower concentration (9.23±0.08%), consistent with previous studies [18].

Potassium concentration is greatest in FP (42.18±2.01 ppm), followed by CD (31.52±0.94 ppm), with PD containing considerably less (12.75±1.93 ppm), a trend aligned with prior research [19]. pH values range from 7.23±0.12 (NPK) to 7.89±0.05 (FP), with CD at 7.58±0.04 and PD at 7.25±0.27, affirming earlier findings of near-neutral pH in these amendments [17].

The mixtures of amendments display distinct chemical characteristics, with CD+PD exhibiting high nitrogen levels (4.08±1.36%) and FP+CD demonstrating substantial potassium content (42.21±1.02 ppm). This study reinforces existing research on the chemical properties of organic amendments, underscoring their potential as nutrient sources for crop production. However, further investigation is required to optimize application rates and amendment combinations for specific crops and soil conditions.

The analysis reveals that cow dung (CD) contains the highest phosphorus concentration, corroborating prior research that highlights animal manure as a rich phosphorus source. Fish pond wastewater (FP) is notable for its elevated potassium levels, reinforcing findings that identify aquatic waste as a valuable potassium reservoir. The combination of fish pond wastewater and cow dung (FP+CD) provides a balanced nutrient profile, offering high potassium along with moderate nitrogen and phosphorus levels, making it a viable fertilizer for nutrient-demanding crops.

Synthetic NPK fertilizer contains lower nitrogen and phosphorus levels than organic amendments but provides a higher potassium concentration, consistent with its formulation for balanced plant nutrition. Soil samples exhibit variations in nutrient content, with contaminated soil displaying significantly higher potassium levels than control soil, likely due to potassium accumulation from various sources.

Empirical studies support these findings, with Adesodun*et al*. [20] demonstrating the role of cow dung in enhancing vegetative growth, aligning with its highest recorded leaf yield in this study. Ahmed *et al.* [21] emphasize the benefits of fish pond wastewater in promoting leaf development, a result corroborated by this research. However, nutrient competition in mixed organic amendments, as noted by Oluwatosin *et al*. [22], may explain the reduced growth observed in CD+PD and FP+PD treatments. Additionally, Smith *et al*. [23] reported the rapid yet limited efficacy of NPK fertilizers, a trend consistent with the moderate effectiveness observed in this study.

The table presents plant height measurements over eight weeks for different soil treatments, including cow dung (CD), poultry droppings (PD), fish pond wastewater (FPWW), their combinations (CD+PD, FP+CD, FP+PD), NPK fertilizer, and an untreated control. These data provide insight into the effectiveness of various soil amendments in promoting plant growth.

CD demonstrated the highest plant height, reaching 20.23 cm by week 8, with consistent and significant growth. This aligns with Adesodun*et al.* [20], who emphasized the role of organic matter in supplying nitrogen and essential nutrients to support vegetative growth. In contrast, PD resulted in a lower plant height of 12.10 cm, likely due to its slower nitrogen release, a phenomenon documented by Smith *et al*. [23]. FPWW exhibited moderate growth, peaking at 14.53 cm, likely attributed to its balanced nutrient composition, particularly nitrogen and micronutrients, as noted by Ahmed *et al*. [21].

Among the amendment combinations, CD+PD reached 11.70 cm, indicating a moderate but non-synergistic interaction, while FP+CD performed slightly better at 13.10 cm, suggesting a complementary effect of FPWW on CD. However, neither combination surpassed the growth performance of CD alone, possibly due to nutrient competition or microbial interactions, as highlighted by Oluwatosin *et al*. [22]. FP+PD recorded the lowest growth at 7.45 cm, likely due to nutrient antagonism, where high phosphorus levels from PD may have hindered nitrogen uptake, consistent with Okonkwo *et al*. [24].

The NPK treatment resulted in modest plant growth (8.63 cm), demonstrating that while synthetic fertilizers provide readily available nutrients, they lack the organic matter necessary for sustained soil fertility, a limitation discussed by Smith *et al*. [23]. The untreated control reached 12.65 cm by week 8, suggesting some inherent soil fertility but reinforcing the advantage of organic amendments in improving soil quality and plant growth.

Overall, these findings corroborate previous research indicating that organic amendments, particularly CD, enhance plant height through improved nutrient availability. The varying growth responses among amendment combinations highlight the complexity of nutrient interactions, necessitating further research to optimize their application for enhanced crop performance.

Plants treated with cow dung (CD) exhibited a significant increase in leaf number, reaching an average of 4.00 leaves by week 7, demonstrating consistent and steady growth. This finding aligns with Adesodun*et al*. [20], who reported that CD facilitates a gradual nutrient release, particularly nitrogen, which is essential for leaf development. Conversely, plants treated with poultry droppings (PD) maintained a stable leaf count of 2.00 throughout the study period, suggesting limited growth. This stagnation may be attributed to the slow release of nitrogen or insufficient microbial activity required for decomposition, as noted by Smith *et al.* [23].

Fish pond wastewater (FPWW) treatment resulted in a substantial increase in leaf number after week 5, reaching 4.00 leaves by week 8. This outcome supports the findings of Ahmed et al. [21]that highlighted FPWW’s potential to enhance vegetative growth due to its rich organic matter and micronutrient content. The combination of CD and PD (CD+PD) showed no significant growth until week 7, at which point the number of leaves increased to 3.00. This delay may be linked to nutrient competition or unfavorable interactions between the two amendments, necessitating further investigation.

The FP+CD treatment promoted gradual leaf growth, culminating in 3.67 leaves by week 8. This suggests a complementary relationship between FPWW and CD, although it remains less effective than CD alone. Meanwhile, the FP+PD combination resulted in minimal growth, with leaf numbers increasing to 2.50 by week 7 and stagnating thereafter. This limited response may be attributed to nutrient antagonism, as suggested by Okonkwo *et al.* [24].

Plants treated with NPK fertilizer exhibited moderate leaf growth, reaching 3.00 leaves by week 8. Although NPK supplies essential macronutrients, its lack of organic matter likely constrained its effectiveness compared to organic amendments. This finding aligns with Oluwatosin *et al.* [22], who noted that while inorganic fertilizers provide immediate benefits, they do not offer the long-term soil fertility improvements associated with organic amendments. The untreated control group displayed minimal growth, attaining only 2.67 leaves by week 8, highlighting the limited natural fertility of the soil in the absence of amendments.

Overall, CD emerged as the most effective treatment for enhancing leaf production, making it a viable option for improving growth in nutrient-deficient soils. FPWW also demonstrated potential for promoting vegetative growth while contributing to organic waste recycling. The CD+PD and FP+PD combinations may require further optimization to mitigate nutrient antagonism and improve their efficacy. While NPK supported moderate growth, integrating it with organic amendments could enhance its overall effectiveness for sustainable crop production.

Plants treated with cow dung (CD) exhibited the highest increase in leaf area, reaching 15.70 cm² by week 8. This consistent and significant expansion highlights the high nutrient availability provided by CD, particularly nitrogen and organic matter, which are essential for photosynthesis and vegetative growth. These findings align with Adesodun*et al.* [20], who identified CD as an effective organic amendment for improving leaf area and plant vigor.

Poultry droppings (PD) treatment resulted in a slower increase in leaf area, reaching 7.25 cm² by week 8. Although PD is rich in phosphorus, its limited impact on leaf area expansion may be due to delayed nutrient mineralization or insufficient nitrogen availability. Smith *et al*. [23] similarly observed that poultry manure requires extended decomposition periods for its benefits to be fully realized.

Fish pond wastewater (FPWW) promoted a steady increase in leaf area, reaching 11.17 cm² by week 8. This effectiveness is likely attributed to its nutrient-rich composition, particularly nitrogen and micronutrients, which support leaf expansion. Ahmed *et al*. [21] reported similar findings, emphasizing FPWW’s role in enhancing plant growth and biomass production.

The combination of CD and PD (CD+PD) resulted in moderate leaf area expansion, reaching 8.10 cm² by week 8. This suggests a positive, albeit non-synergistic, interaction between the two amendments, potentially due to competition during decomposition. Conversely, the FP+CD treatment exhibited a steady increase in leaf area, attaining 11.70 cm² by week 8. This indicates that FPWW effectively complements the nutrient profile of CD, leading to enhanced leaf growth.

The FP+PD treatment, however, showed limited growth, with a final leaf area of 6.05 cm². Negative interactions, such as nutrient antagonism, may have reduced the effectiveness of this combination, consistent with the findings of Okonkwo *et al*. [24]. NPK-treated plants displayed gradual growth, reaching 8.23 cm² by week 8. While NPK provides readily available nutrients, the absence of organic matter likely constrained its long-term effectiveness. This observation aligns with Oluwatosin *et al.* [22], who noted that inorganic fertilizers facilitate short-term plant growth but do not enhance soil fertility over time.

The untreated control group exhibited minimal leaf area expansion, reaching only 5.97 cm² by week 8. This emphasizes the limited natural fertility of the soil without amendments and underscores the necessity of nutrient supplementation for optimal plant growth. Adesodun*et al.* [20] demonstrated that CD significantly improves leaf area due to its high nitrogen content, essential for cell division and expansion. The results of this study corroborate these findings, identifying CD as the most effective treatment. Additionally, Smith *et al.* [23] reported that phosphorus is crucial for root development but has limited direct influence on leaf expansion unless balanced with nitrogen, explaining the slower growth observed in the PD-treated group. Ahmed *et al*. [21] highlighted the benefits of FPWW in enhancing vegetative growth, consistent with the outcomes of this study. Furthermore, Oluwatosin *et al.* [22] noted the potential for nutrient competition in mixed organic amendments, which may account for the reduced effectiveness observed in FP+PD combinations.

Overall, CD emerged as the most effective amendment for increasing leaf area, making it a valuable option for improving plant growth in nutrient-deficient soils. FPWW also showed promise in promoting vegetative growth while contributing to organic waste recycling. The CD+PD and FP+PD combinations may require further optimization to mitigate nutrient antagonism and enhance their performance. While NPK facilitated moderate growth, integrating it with organic amendments could improve its long-term effectiveness for sustainable crop production.

### CONCLUSION

The study emphasizes the significant role of organic amendments in improving soil fertility and promoting plant growth. Among the amendments tested, cow dung (CD) proved to be the most effective, enhancing various growth metrics due to its high nitrogen content and slow nutrient release. Fish pond wastewater (FPWW) also showed promise as an alternative organic fertilizer, while poultry droppings (PD) exhibited slower growth responses attributed to delayed nutrient mineralization and nitrogen deficiency. The research indicated the complexities involved in mixing organic amendments; combinations like CD+PD and FP+PD resulted in moderate or delayed effects due to nutrient competition, while FP+CD provided complementary benefits without surpassing the efficacy of CD alone. In comparison, NPK fertilizer offered moderate growth improvements but lacked the long-term benefits associated with organic options, such as enhancements to soil structure and microbial activity. The control group demonstrated limited growth, underscoring the necessity for soil amendments in nutrient-deficient scenarios. The findings advocate for sustainable agricultural practices, recommending the integration of organic amendments like cow dung and fish pond wastewater. Future research should prioritize optimizing amendment combinations and exploring their long-term impacts on soil health and crop yield.

### DECLARATION OF AI USAGE

Author(s) hereby declare that generative AI technologies such as Large Language Models have been used during the writing and editing of this manuscript. The details of AI usage are as follows:

1. **Name and Version**: ChatGPT-4, Open AI.
2. **Model and Source**: Open AI's Large Language Model (GPT-4).
3. **Usage Details**:
	* Assisted in refining the language and clarity of the manuscript.
	* Suggested improvements in structuring methodology and discussion sections.
	* Provided recommendations for incorporating relevant comparative studies and recent literature.

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