The Future of Horticulture

Article

Organic and Biofertilizer Resources Impacts on Banana Safe Production and Greenhouse Gas Emissions

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Abstract: In order to investigate the impact of fertilization by utilization organic manures (gradable waste) at different levels (25, 50 and 75 %) combination with thee rates (50, 75 and 100%) mineralized NPK from its suggested doses, all treatments with or without a combination of biofertilizers, such as *Bacillus megaterium*, which dissolves phosphate, and *Azotobacteras chroococcum*, which fixes nitrogen Potassium-solubilizing bacteria *Bacillus circulans* on psedostem tallness and cinch, number of green leaves, leaf area, yield, crop quality and Williams banana plants' fruit heavy metal content. Banana plants that were 100% fertilized and inoculated with town waste manure produced the best results. Additionally, fruit quality and output were enhanced with biofertilizers including organic manure. Every evaluated parameter improved when the organic manure rate was increased, either with or without inoculation, especially when the rate was high. When N was provided from different both organic and mineral sources instead of just one, the chemical composition of Grand Nain banana fruits greatly improved. Natural fertilizer made from town trash improved fruit quality by increasing finger weight, soluble solids, and total sugar concentrations while decreasing starch and nitrate concentrations. Organic fertilization with 100% municipal waste, 50% mineralized NPK at the necessary rate, and biofertilizer inoculation produced the greatest results with all the traits of Grand Nain banana trees. Meanwhile, the increase in heavy metals concentration (Cd, Pb and Ni) in banana fruits did not reach to significant level. Moreover, using of organic and Biofertilizers reduced GHG emissions (No2 & Co_2) significantly through a strategy for mitigating

Key words: Banana, (*Musa cavendishii* L.), Grand Nain, Town Wastes, Organic Fertilizers, Biofertilizes, Yield, Fruit Quality, Heavy Metals, GHG emissions.

1. Introduction

In addition to their nutritional value, bananas are an integral part of the world's diet. Bananas are one of Egypt's most important and popular fruit crops due to their great nutritional value. They can be consumed raw or processed into flour, dry catsup, alcohol, vinegar, breweries, spirits, banana puree, juice, and a source of carbs.

It is common knowledge that banana plants require significant amounts of fertilizers, particularly nitrogen and potassium. Therefore, the primary issues that banana farmers face are the exorbitant expenses of the large amounts of artificial fertilizers that the plants require.

Additionally, during manufacture and use, these chemical fertilizers are regarded as polluting agents of the soil, water, and air. This issue highlights the use of organic and biofertilizers, which may be especially beneficial for people, animals, and the environment, to researchers and banana growers. Conversely, applying organic fertilizer enhances the soil. Additionally, it lowers production costs and promotes a sufficient economy by enhancing the physical, chemical, and biological qualities of the soil that are necessary for long-term plant growth. **Sanyakamthon (2009)**. Town garbage compost is rich in nitrogen, phosphorus, and potassium, all of which are essential for plant growth. It strengthens the structure of the soil, increasing its porosity and water retention. Moreover, it's a sustainable way to recycle waste, reducing landfill use and promoting environmental sustainability (Eco-Friendly). Additionally, the nutrients are released slowly, reducing the risk of over fertilization and nutrient overflow and consider cost-effective: It's often cheaper than chemical fertilizers and can be produced locally. However, there's a chance that heavy metals like lead and cadmium will build up in the soil and plants, which might be detrimental to human health and the environment **(Zhang *et al.*, 2020)**.

Applying organic fertilizer, which is safer for human consumption, better for the environment, and better for farmers' health, has the potential to replace chemical fertilizer. As a result, it prevented pollutants and lowered fertilizer costs **(Kamel, 2002)**.

Using organic fertilizer is another method of supplying bananas with nutrients. The combination application of inorganic and organic fertilizers might be an excellent alternative technique for controlling soil fertility in farms with insufficient amounts of animal manure **Meya (2020)**.

Reducing the agriculture sector's substantial contribution to greenhouse gas (GHG) emissions, especially carbon dioxide (CO2) and nitrous oxide (N2O), is a critical problem. This load is mostly caused by conventional farming methods that mostly rely on synthetic fertilizers. Fortunately, cutting-edge approaches like organic and biofertilizers are showing promise as viable substitutes for reducing greenhouse gas emissions and encouraging sustainable food production. **Chen *et al*. (2020)**.

A viable and adaptable method for reducing CO2 and N2O emissions in agriculture is the use of organic and biofertilizers. Even if there are obstacles, policy actions, farmer support, and research and development can open the door to broader adoption and a more sustainable future for our food systems. **Luo *et al*. (2023) and Paustian *et al*. (2019)**.

The aim of this study compared Grand Nain banana plants that were fertilized with 50% NPK and town refuse manure inoculated with or without biofertilizers to those that were only fertilized with 100% NPK in terms of yield, fruit quality, and fruit heavy metal content. It also estimated the effect of using these treatments on the rate of greenhouse gas emissions.

2. Materials and Methods

Williams banana trees (*Musa cavendishii* L.) produced in a private orchard in the Khatatba area were used in the experiment during the course of two consecutive seasons in 2024 and 2025. Banana plants were grown three to three meters apart, free of diseases, and under the same horticultural supervision. With a drip irrigation system, the soil has a sandy texture.

Physical and chemical study of the soil: According to **Wild *et al*., (1985)**, soil samples were taken from various locations throughout the plantation at depths of 0.0 to 60 cm. The results are displayed in Table (1).

Table (1). Physical and chemical study of orchard soil (0 – 60 cm, depth) during season of 2024

Physical character	Value	Chemical constituents Obtainable macro- elements (%)	Value
Clay %	5	N	0.90
Silt %	5	P	0.28
Sand %	90	K	0.36
Texture	Sand	**Obtainable micro -elements (ppm)**	
Ec mm hos/cm 1:2.5	1.5	Zn	0.28
pH	8.29	Fe	2.38
Organic matter%	0.65	Mn	0.58
$CaCO_3$ %	1.60		

To determine how the plants reacted to chemical fertilizers and organic manures (gradable waste produced by Kattamia Company for compost), thirty Williams banana plants, each in a different soil, were chosen for eight treatments. Each therapy was applied five times, with one stool serving as a duplicate.

The following six treatments were used in the experiment:

1. Only 100% of the necessary NPK mineral fertilizers, or 400 kg N/fed, were applied to the control treatment. Ammonium nitrate (1200 kg) 50 kg P_2O5/fed, 33.5% N/fed/year. (52 cc and 250 kg of calcium superphosphate 15.5% P2O5 given annually). phosphoric acid 80%/fed/year) and 800 kg K_2O/fed (1600 kg potassium sulphate 48% K_2O/fed/year).
2. 100% of the suggested NPK fertilizers in addition to biofertilizer.
3. 25% town refuse manure at a rate of 8 kg per plant (25% of required NPK mineral fertilizers) with 75% of recommended NPK fertilizers.
4. 25% town refuse manure at a rate of 8 kg per plant (25% of required NPK mineral fertilizers) with 75% of recommended NPK fertilizers plus biofertilizer.
5. 50% of the suggested NPK fertilizers plus 50% town refuse manure at a rate of 16 kg per plant (25% of the suggested NPK mineral fertilizers)5. 50% of the suggested NPK fertilizers plus 50% town refuse manure at a rate of 16 kg per plant (25% of the suggested NPK mineral fertilizers).
6. 50% of the suggested NPK fertilizers with 50% town refuse manure at a rate of 16 kg per plant (25% of the suggested NPK mineral fertilizers) plus biofertilizer.
7. 25% of required NPK fertilizers plus 75% town refuse manure at a rate of 16 kg per plant (25% of recommended NPK mineral fertilizers).
8. 25% of suggested NPK fertilizers with 75% town refuse manure at a rate of 16 kg per plant (25% of suggested NPK mineral fertilizers) plus biofertilizer.

Fertilization program: Microelements such as Zn sulphate (5 kg/fed.), Mn sulphate (5 kg/fed.), and Fe chelate (3 kg/fed.) were also added in each season for both 50 and 100% of the recommended NPK. During the first week of December in both seasons under study, organic manures were combined with each plant's soil root zone.

Azotobacter chroococcum CLOA A27, a biofertilizing strain, was employed as a nitrogen-fixing bacterium. The phosphate-dissolving bacteria (PDB) employed were *Bacillus megaterium* CLOA Bm 3. The potassium solubilization bacteria (PSB) utilized were *Bacillus circulans* CLOA Bc 4. The Central Lab. of Organic Agriculture (CLOA), Agricultural Research Center (ARC), Giza, Egypt, kindly provided the bacterial strains. A liquid solution of biofertilizers was added at a rate of five liters per feed. For every season, during the first week of April (Recommended). There were 10^6–10^8 cells in one milliliter of biofertilizer. The chemical analysis of the organic manure was shown in Table (2).

Table (2). Chemical analyses of city garbage manure

Organic Manure	Organic matter%	Total N %	Total P %	Total K %	Fe (ppm)	Mn (ppm)	Zn (pp)	Ni (ppm)	Pb (ppm)	d (ppm)
Gradable waste	32.85	1.25	0.35	0.69	1959	275	382	12.0	12.5	3.25

Growth characteristics: At the bunch shooting stage, the following growth metrics were recorded for each season:

According to **(Murry, 1960)** leaf area (m2) of the third leaf from the top using the formula (leaf area = length × width × 0.8) was used to calculate the leaf area, number of green leaves per plant, pseudostem height (cm) from the soil surface to the petiole of the last emerged leaf and pseudostem girth (cm) at a height of 20 cm above the soil surface.

Leaf chemical constituents

An area of around 100 cm2 from the third leaf (counted from the top of the plant) in each individual plant at the bunch shooting stage was collected from each treatment, as recommended by **Hewitt (1955)**. After cleaning the leaf sample with tap and distilled water, it was dried for 48 hours at 72°C in an oven. Every therapy was utilized in three duplicates. Two leaf samples were used to represent each replication. An electric mill was used to grind the two dried leaf samples after they were combined into a composite sample. According to **Jackson (1967)**, a combination of one part perchloric acid to ten parts sulfuric acid (1:10) was used to digest 0.2g of each pulverized sample in order to determine the following mineral elements:

Total nitrogen: According to **Pregl (1945)**, the Micro-Kjeldahle technique was used to quantify total N.

Phosphorus: The cholorostannous reduced molybdophosphoric blue color technique, as outlined by **Jackson (1967)**, was used to colorimetrically quantify phosphorus.

Potassium, cadmium, nickel and lead concentrations: The Atomic Absorption Spectrometer (PerKin–Elemer, Model 3300) was used to measure the amounts of potassium, cadmium, nickel, and lead using the procedures outlined by **Chapman and Pratt (1964)**.

Fruit attributes and yield: according to **Van Loesecke (1950)** bunch weight (kg) and yield per Fadden estimate (ton) at the harvest date when the tops of the hands have become somewhat yellow.

Fruit physical and chemical characteristics: Fruit samples were collected from middle portion of bunch in each studied treatment and exposed to ethylene (1000 ppm) in room ripening of Horticulture Research Institute for 24 h, then kept for five days at room temperature to reach the ripening stage. Fruit physical & chemical characteristics were determined as follows: fruit weight (g), pulp weight (g) and percentage of pulp per fruit. Total sugar and starch concentration in fruit were measured by using phenol sulphuric acid method according to **Dubois (1956)**.

Total sugar concentration: It was measured using the colourimetric method according to **Dubois *et al*., (1956)**, which can be summarized as follows: 0.03 g of banana dry weight was weighed and located in a test tube (2.5X15.0 cm). Then, 10ml of 1 N H_2SO4 were added. The tubes were located in a boiling water bath for 30 min. Then, the tubes were left to cold and a very little amount of barium carbonate (about 0.1gm) was added. The samples were then filtrated through whatman filter paper N 10.1 and washed several times with distilled water and the volume final was brought up to 100 ml with (DW) distilled water. One ml from this filtrate was placed in a test tube and 1 ml of 5% phenol and 5 ml conc. entreated sulphuric acid (A.R.) were additional and mixed thoroughly. Then, the tubes were placed in a cold water bath. A series of D-glucose standard preparations of the concentrations 10, 20, 30, 40, 50, 60 and 70 µg/l was prepared and proceeded as mentioned above to obtain the corresponding coloring solution. Then, the optical densities of these solutions were determined at 490 nm using spectrophotometer. The percent total sugar was calculated from the equation:

$$\% \text{ Total sugars} = \frac{\text{Reading (ppm)} \times 100 \times 100}{\text{wt. of sample} \times 1000 \times 1000}$$

Starch content: it was measured as method according to **A.O.A.C. methods (1964)**. A representative sample (about 7g accurately weighed, was extracted several times with neutral 70% ethyl alcohol by heating on boiling water bath under a reflux condenser.

Total soluble solids (TSS %): Few drops of pulp filtrate were used to obtain TSS through hand refractometer

Total titratable acidity: It was measured as grams (g) of (MA) malic acid in 100g of fresh pulp weight as titration with a NaOH (0.1 N) and phenolphthalein indicator according to **A.O.A.C (1980)**.

Nitrate concentration: Fruit nitrate conc. was measured by using salicylic acid method as according to **Cataldo *et al*., (1975)** which can be summarized as follows:0.1 g dry weight banana fruit dissolving in 10 ml distilled water and kept in fan over at 45 ºC for one hour and filtrated. A 0.8ml.was added as a mixture from salicylic acid and sulphoric acid 5% (5g salicylic acid / 100ml sulphoric acid) to 0.2 ml sample extract. After 20 minutes added 19 ml NaOH 0.2 N (80 g NaOH / liter distilled water) and mixed thoroughly. Then, the optical densities of these solutions were determined at 410 nm using spectrophotometer. The standard curve using 0.1629 potassium nitrate dissolving in 100 ml (DW) distilled water to give a solution of 1000 ppm.

Total soluble solids in fruits: It's were measured by using hand refractometer. Nitrate conc. was measured by using salicylic acid method as according to **Cataldo *et al.* (1975)**.

Heavy metal cadmium, nickel and lead (Cd, Ni and Pb): were determined in ripping fruit by applying the (AAS) Atomic Absorption Spectrometer (PerKin – Elmer, Model 3300) along with the methods according to **Chapman and Pratt (1961)**.

GHG emission measurement: Method of **Wang *et al.*, (2011 a, b)**. Soil samples from the study area were collected represented to the whole planted sector with take in consecration temperatures, humidity, and soil type. Then estimation of soil gas emissions by the equipment of LI-7700 from LI-COR Co_2 and N_2o.

Statistical analysis: According to **Steel and Torrie (1985)**, statistical analysis was used to count significant discrepancies between the obtained data. According to **Waller and Duncan (1969)**, individual comparison was made by the least significant differences (LSD) of 0.05.

3. Results and Discussion

Vegetative growth

It is obvious from data shown in Figures (1,2,3 and 4) that the mean values of pseudostem (height and girth cm), leaf area cm2 and number of green leaves significantly greater than before with addition biofertilizers in this experiment to reach the maximum results in the studied seasons compared to the control ones. Actually, vegetative growth was the best with fertilizing 50% NPK + 50% gradable waste (GW). Addition NPK at the rate of 75% or 25% companied with GW at the rate of 25% or 75% lead to significantly decrease of vegetative growth in studied seasons.

The results from the experiment clearly demonstrate the significant impact of Biofertilizers on vegetative growth. The adding of Biofertilizers led to a notable raise in pseudostem height and girth, leaf area, and the number of green leaves. This suggests that Biofertilizers play a vital role in promoting vegetative growth by improving nutrient accessibility and uptake. Studies have revealed that Biofertilizers improve soil microbial activity, which in revolve improves nutrient cycling and ease of use to plants **(Vessey, 2003 and Bhardwaj *et al*., 2014)**. The best vegetative growth was observed with a combination of 50% NPK and 50% gradable waste (GW). This balanced approach likely provided an optimal mix of essential nutrients and organic matter, enhancing soil richness and plant health. Research indicates that inserting organic and inorganic fertilizers can lead to enhanced crop performance by supporting soil structure and nutrient accessibility **(Liu *et al*., 2010 and Singh *et al*., 2011)**.

When NPK was applied at 75% or 25% along with GW at 25% or 75%, there was a significant decrease in vegetative growth. This indicates that an imbalance in the ratio of chemical fertilizers to organic matter can negatively affect plant growth, possibly due to nutrient imbalances or reduced microbial action in the soil. Studies have highlighted the importance of maintaining a balanced fertilization strategy to avoid adverse effects on plant enlargement and soil health **(Zhang *et al*., 2016 and Chen *et al*., 2018)**. The positive effects of the 50% NPK + 50% GW combination were consistent across the studied seasons, highlighting the reliability of this fertilization strategy for sustained vegetative growth. Consistent results across different seasons suggest that this approach can be a viable long-term strategy for improving crop productivity **(Sharma *et al*., 2017 and Kumar *et al*., 2020)**. Furthermore, according to **Abdel Hafiz *et al*. (2016)**, using organic or bio-form together with mineral-N sources was effective in boosting the nutritional status and growth vigor of banana plants in order to improve fruiting. Additionally, **Gouda *et al*. (2021)** found that all growth characteristics were successfully supported by providing 25% of the prescribed nitrogen level together with 25 to 50% organic-N enhanced with EM as a bio-form at 50 or 25%. Overall, these results underscore the importance of using a balanced fertilization approach that combines both chemical and organic inputs to achieve optimal vegetative growth. This strategy not only supports plant growth but also supporting sustainable agricultural practices by plummeting confidence on chemical fertilizers and support soil health.

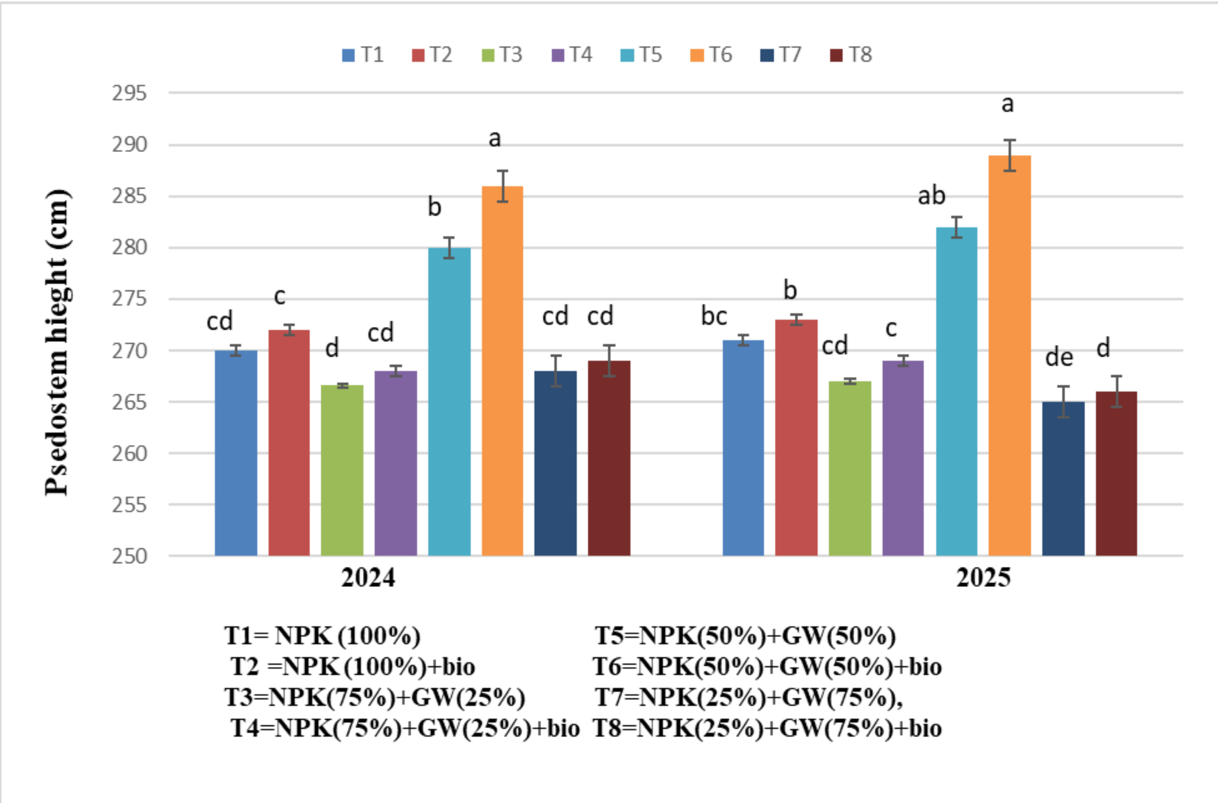

Figure (1). Effect of mineral, gradable waste (GW) as organic manure and Biofertilizers on pesudostem height (cm) at maturity of Grand Nain banana plants

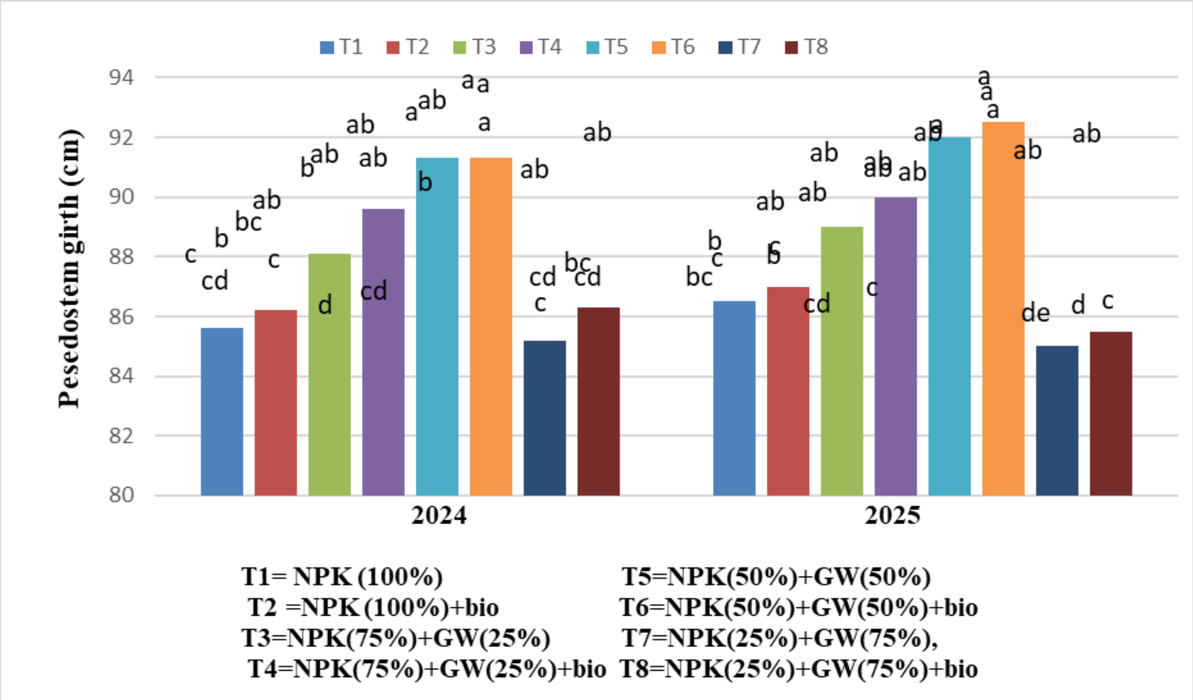

Figure (2). Effect of mineral, gradable waste (GW) as organic manure and Biofertilizers on pseudostem girth (cm) at maturity of Grand Nain banana plants

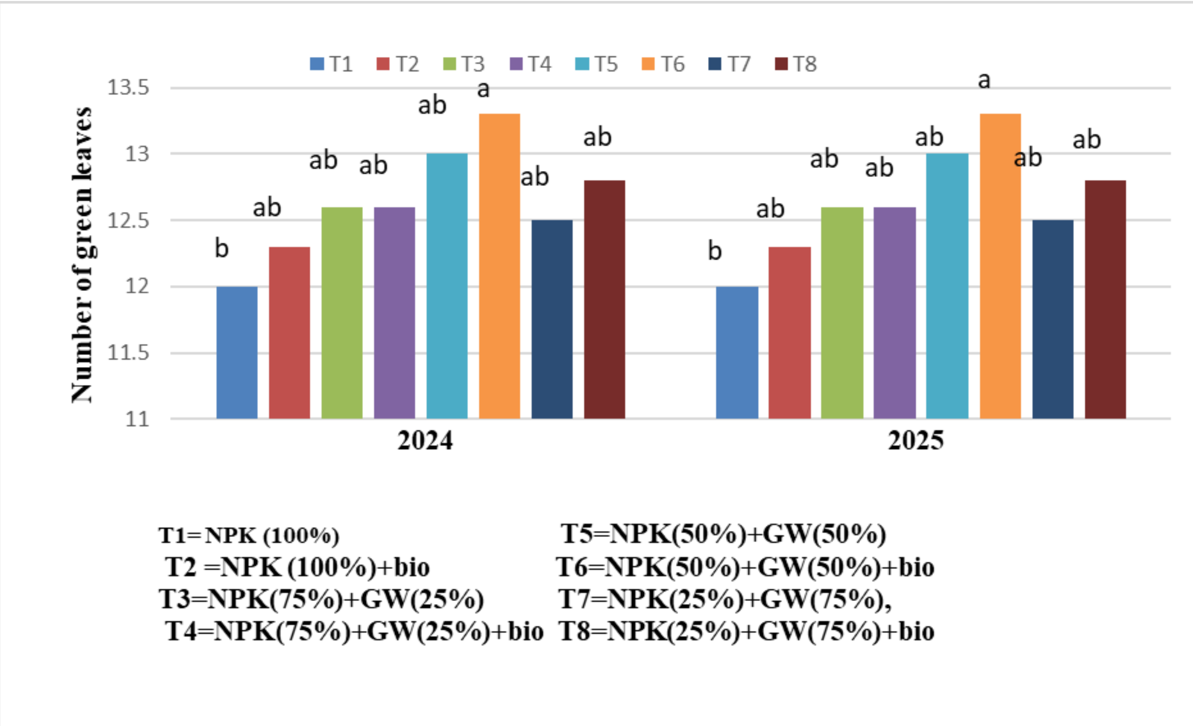

Figure (3). Effect of mineral, gradable waste (GW) as organic manure and Biofertilizers on number of green leaves at maturity of Grand Nain banana plants

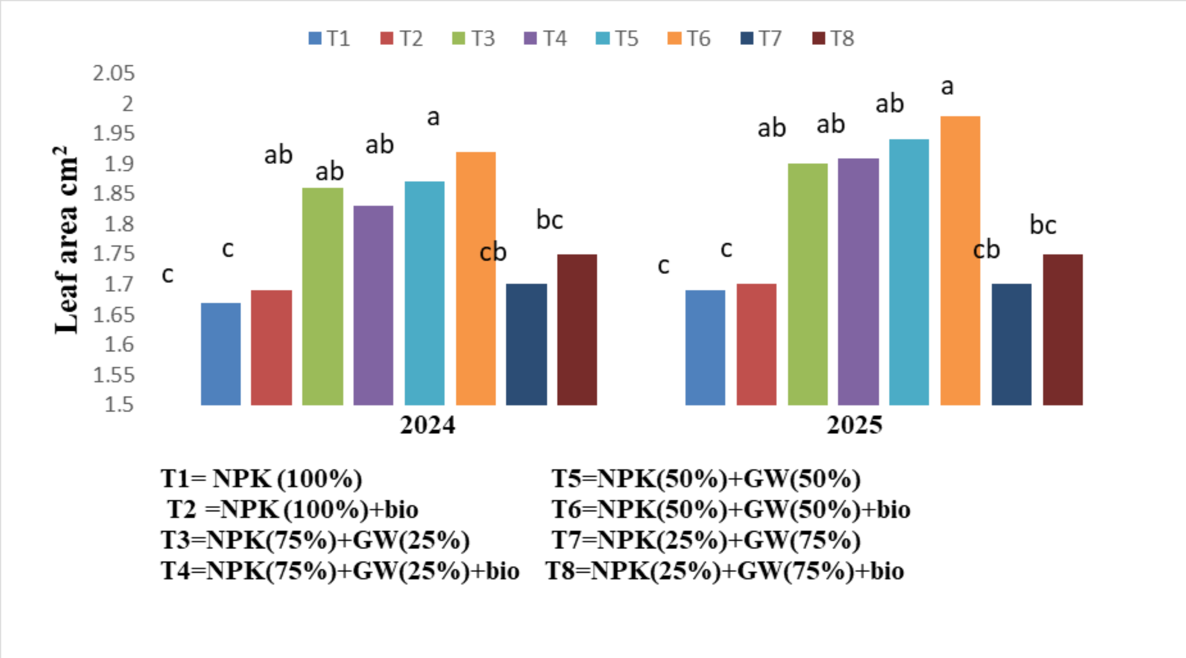

Figure (4). Effect of mineral, gradable waste (GW) as organic manure and Biofertilizers on leaf area ($m^{2)}$ at maturity of Grand Nain banana plants

Leaf chemical constituents

Results listed in Figures (5, 6 and 7) noted that the leaf nitrogen concentration values showed a significant difference between the treatments compares with the control. The recommended rate of NPK (100%) achieved the highest percentage of nitrogen concentration and the lowest record was recorded in applied with 25% NPK+75% GW on studied seasons.

Obviously, the addition of biofertilizers mixture with the different rate of NPK and GW organic manure produced a significant increase in leaf N concentration.

Likewise, the treatments had a considerable effect on leaf K concentrations where combining between NPK, GW and Biofertilizers. The best results in general with the high rate of NPK in two seasons. However, fertilized banana plants with the high rate of NPK combining with Biofertilizers attended the highest value of leaf K concentrations in two seasons. In comparison to the control in both seasons, there were no discernible variations in P conc. in the leaves of banana plants that were fertilized with NPK, GW manure, and bio at varying rates.

The records indicate significant very differences in leaf nitrogen concentration between treatments compared to control. The recommended rate of 100% NPK achieved the highest nitrogen concentration, while the lowest value was recorded with 25% NPK + 75% GW. This suggests that higher rates of NPK are more effective in increasing leaf nitrogen levels. Studies have shown that adequate nitrogen fertilization is crucial for optimal plant growth and progress, as nitrogen is a key element of chlorophyll and amino acids **(Marschner, 2012 and Fageria *et al*., 2011)**. The addition of biofertilizers, in mixture with different rates of NPK and GW, significantly increased leaf nitrogen concentration. Biofertilizers enhance nutrient availability and uptake by promoting beneficial microbial activity in the soil **(Vessey, 2003 and Bhardwaj *et al*., 2014)**. This synergistic effect of biofertilizers and chemical fertilizers can lead to enhanced nutrient use effectiveness and plant growth **(Adesemoye *et al*., 2009)**. The treatments also had a substantial effect on leaf potassium concentrations. The best results were generally observed with higher rates of NPK, particularly when combined with biofertilizers. Potassium is essential for several physiological functions, including photosynthesis, osmoregulation, and enzyme activation **(Marschner, 2012)**. Adequate potassium fertilization has been shown to improve plant output and stress tolerance **(Zörb *et al*., 2014)**. The content of phosphorus in leaves did not change significantly between treatments and the control. This confirms that phosphorus absorption was not significantly affected by the various fertilization techniques. Although phosphorus is a crucial mineral for root growth and energy transfer, a number of variables, such as pH and microbial activity, can affect its accessibility in soil **(Richardson *et al.*, 2009)**.

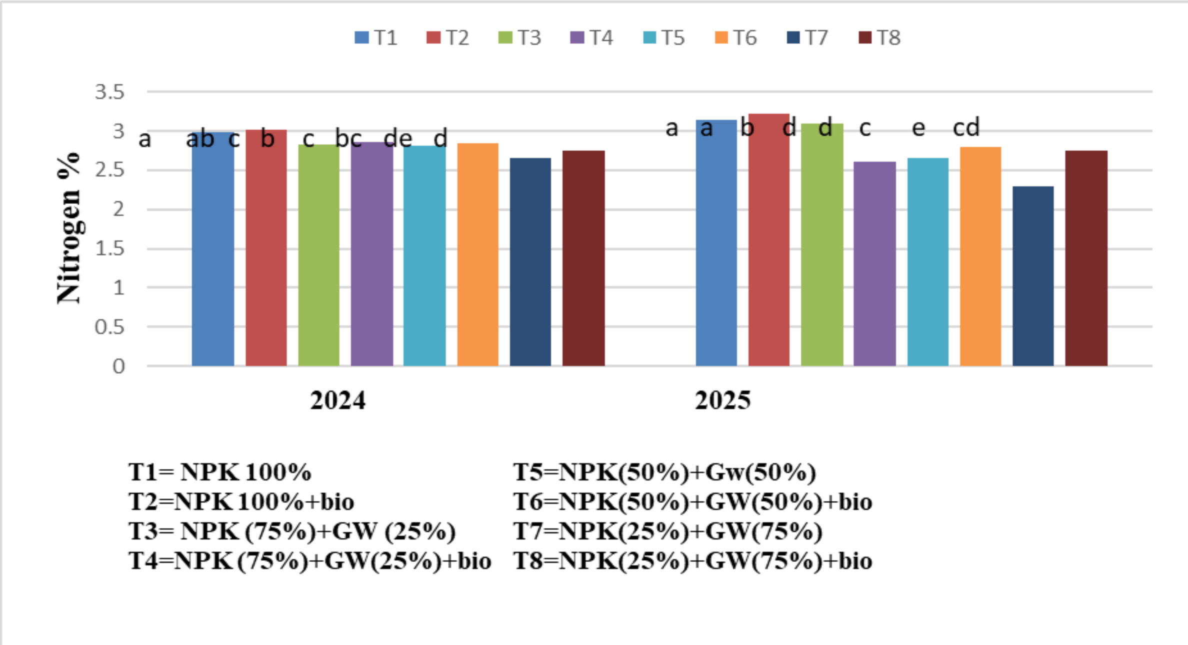

Figure (5). Effect of mineral, gradable waste (GW) as organic manure and Biofertilizers on nitrogen (%) in leaves through inflorescence emergence of Grand Nain banana plants

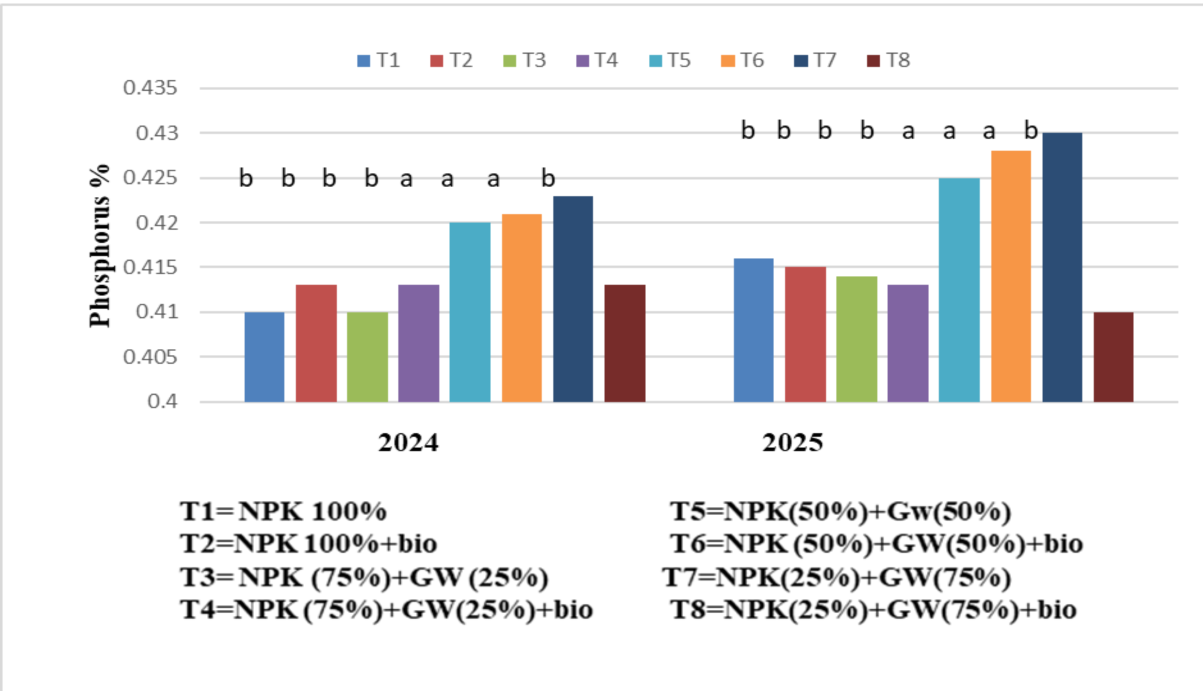

Figure (6). Effect of mineral, gradable waste (GW) as organic manure and Biofertilizers on phosphorus (%)in leaves through inflorescence emergence of Grand Nain banana plants

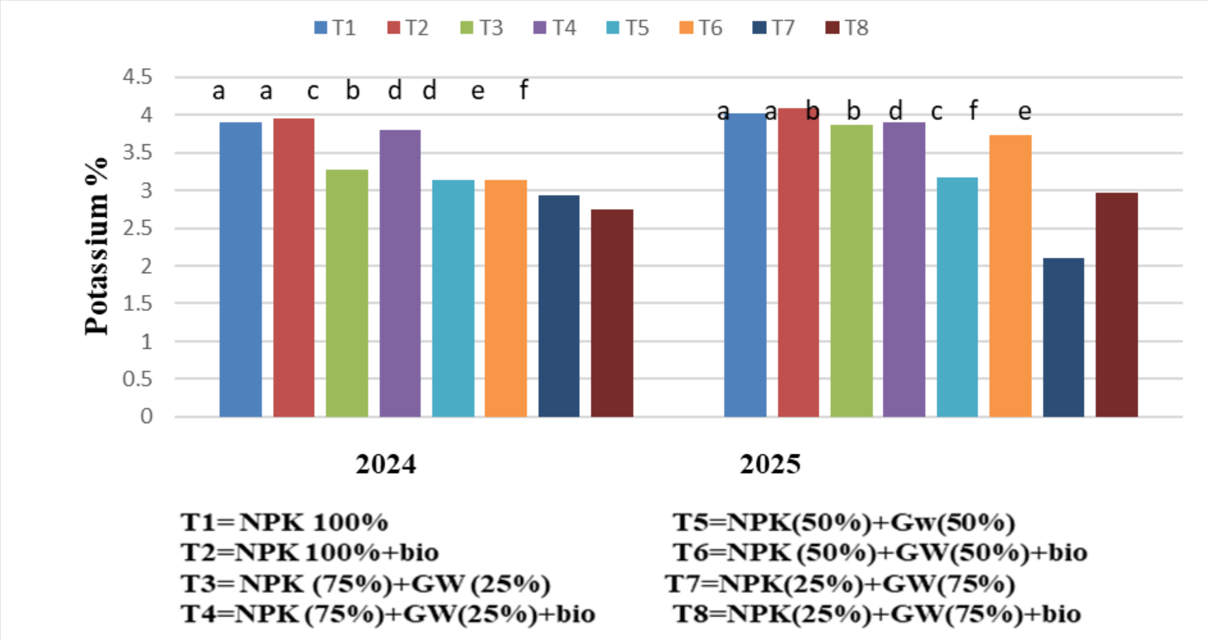

Figure (7). Effect of mineral, gradable waste (GW) as organic manure and Biofertilizers on potassium (%) in leaves through inflorescence emergence of Grand Nain banana plants

Bunch weight and yield

As can be seen in (figure 8 and 9), data showed that diverse mixtures of the organic manures, either with or without biofertilizer, significantly impacted bunch weight and yield during both growing seasons. In comparison to untreated (control) plants, which were recorded as weighing 22.55 and 22.37 kg and 22550 and 22370 kg respectively in both seasons, plants treated by town refuse at a rate of 100% plus point biofertilizer record the highest value of the bunch weight and yield (28.72 & 29.93kg and 28720 & 29930 Kg). When compared to their non-inoculated or control counterparts, banana plants with Biofertilizers added to a mixture of municipal waste manures produce more bananas per plant and have heavier bunches overall.

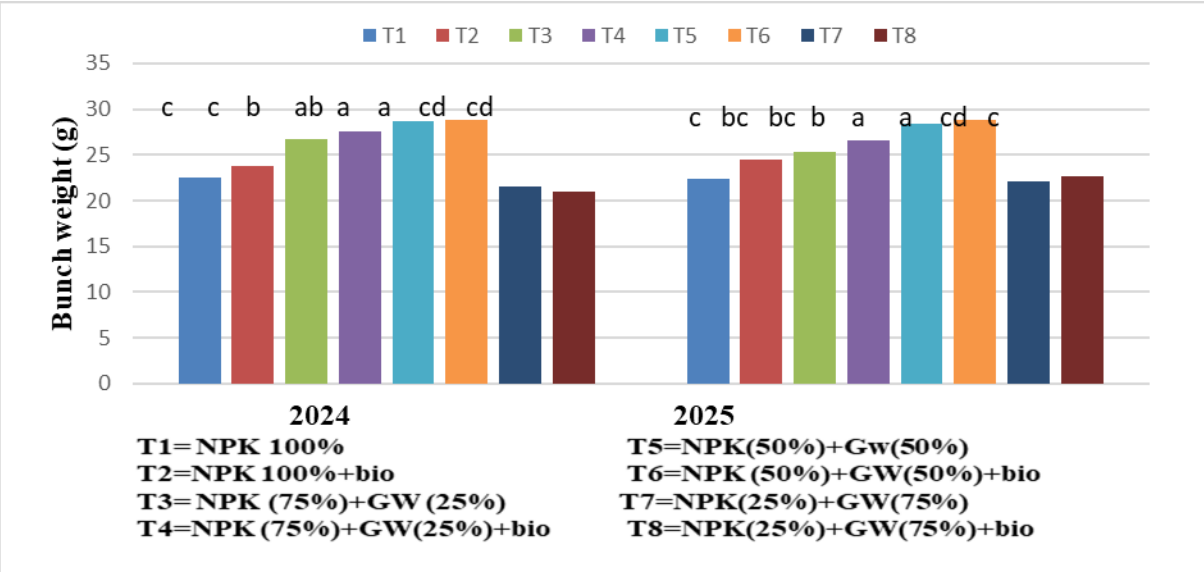

Figure (8). Effect of mineral, gradable waste (GW) as organic manure and biofertilizers on bunch weight (Kg) of Grand Nain banana plants

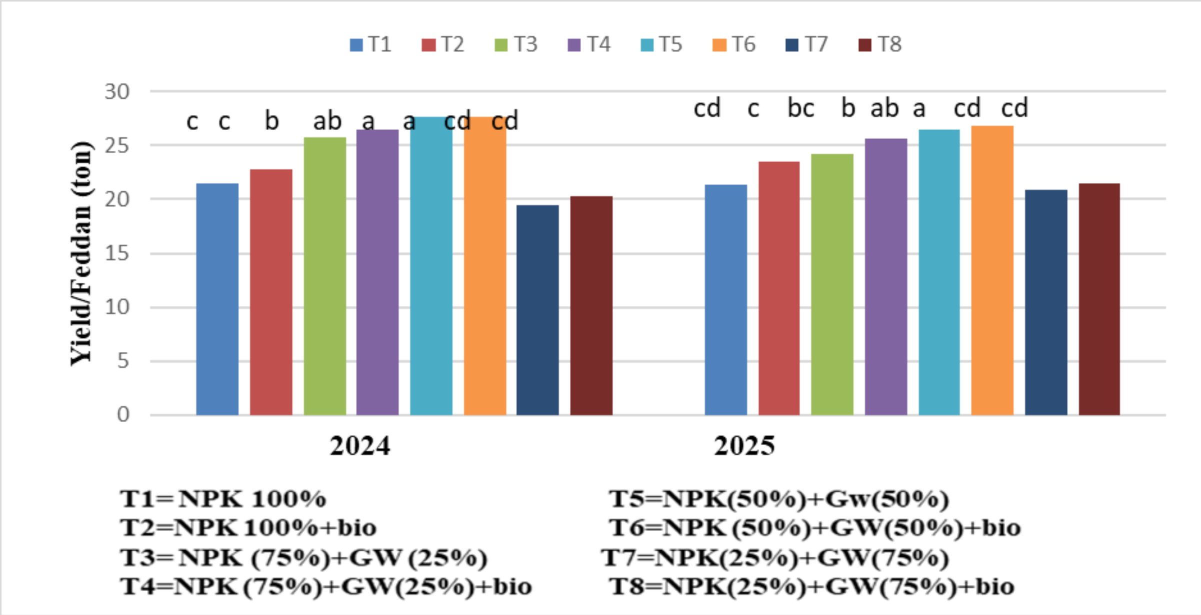

Figure (9). Effect of mineral, gradable waste (GW) as organic manure and biofertilizers on Yield / fed at maturity of Grand Nain banana plants

The experiment's results indicate that the use of diverse mixtures of organic manures, particularly when combined with Biofertilizers, significantly enhances both bunch weight and yield in banana plants. The data reveal that adding organic manures, either alone or in grouping with biofertilizers, significantly greater than before both the bunch weight and overall yield of banana plants compared to the untreated controls. This can be accredited to the improved soil health and nutrient availability provided by organic manures, which improve root growth and nutrient uptake **(Pant *et al.*, 2012)**. By increasing the availability of essential nutrients through microbial processes including nitrogen fixation and phosphate and potassium solubilization, biofertilizers further promote plant development **(Bhardwaj *et al.*, 2014)**. Additionally, plants fed with biofertilizer and 100% municipal waste had the maximum bunch weight and yield, suggesting a synergistic impact. This mixture likely increased soil fertility and microbial activity by offering a plentiful supply of organic matter and vital nutrients **(Adesemoye *et al.*, 2009)**. The high nutrient content of municipal waste manures, coupled with the microbial benefits of biofertilizers, creates a conducive surroundings for robust plant growth (PG) and higher yields **(Ghosh *et al.*, 2010 and Hosny 2010)**. On the other worlds the control plants, which received no treatment, showed significantly lower bunch weight and yield compared to the treated plants. This underscores the significance of organic and biofertilizer amendment in supporting crop productivity. The organic amendments not just supply nutrients but also recover soil construction, water maintenance, and microbial diversity, all of which add to better plant performance **(Lal, 2004 and Tilman *et al.*, 2002)**. Finally, positive effects of the organic manures and biofertilizers were consistent across both growing seasons, highlighting the reliability of these treatments for sustained yield improvement. Consistent results across seasons suggest that these fertilization strategies can be effective long-term solutions for enhancing crop production **(Kumar *et al.*, 2020)**.

Fruit physical analysis

It is evident that both seasons' treatments with various mixtures of organic manure had a substantial impact on fruit weight, pulp weight, and pulp percentage (Figures 10, 11 and 12). According to the findings, organic manures increased the physical characteristics of fruit more than controls did at various rates. Furthermore, in both seasons, it was shown that organic manures significantly greater than before the weight of fruit and pulp compare to non-inoculated or control plants. The plants treated with 100% of the town's trash plus biofertilizer recorded the greatest levels of all physical parameters in both seasons (119.39&122.78g and 79.67 &82.21g, respectively).

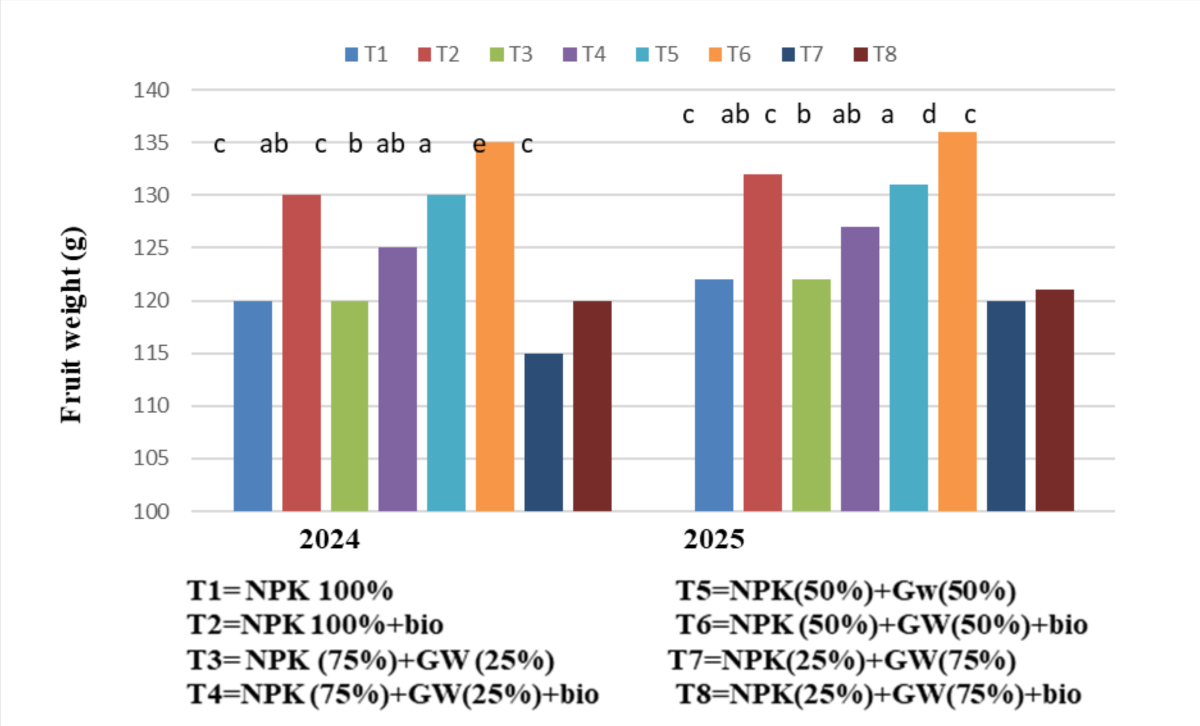

Figure (10). Effect of mineral, gradable waste (GW) as organic manure and Biofertilizers on fruit weight (g) at maturity of Grand Nain banana plants

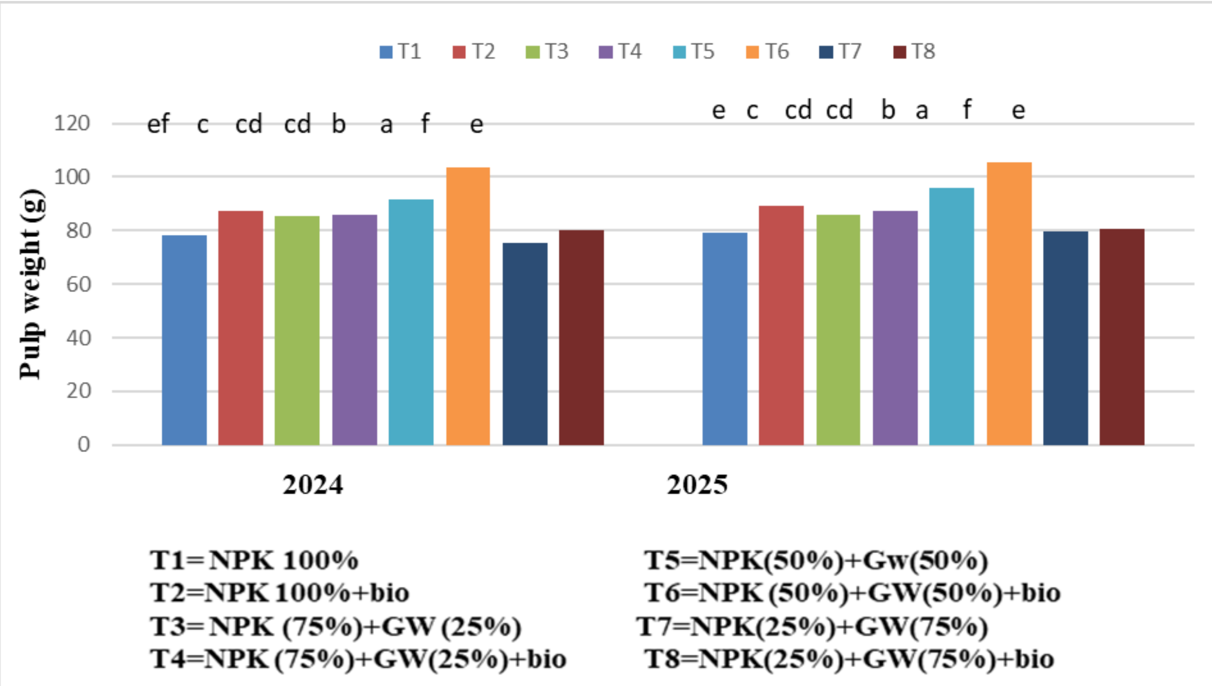

Figure (11). Effect of mineral, gradable waste (GW) as organic manure and Biofertilizers on pulp weight (g) at maturity of Grand Nain banana plants

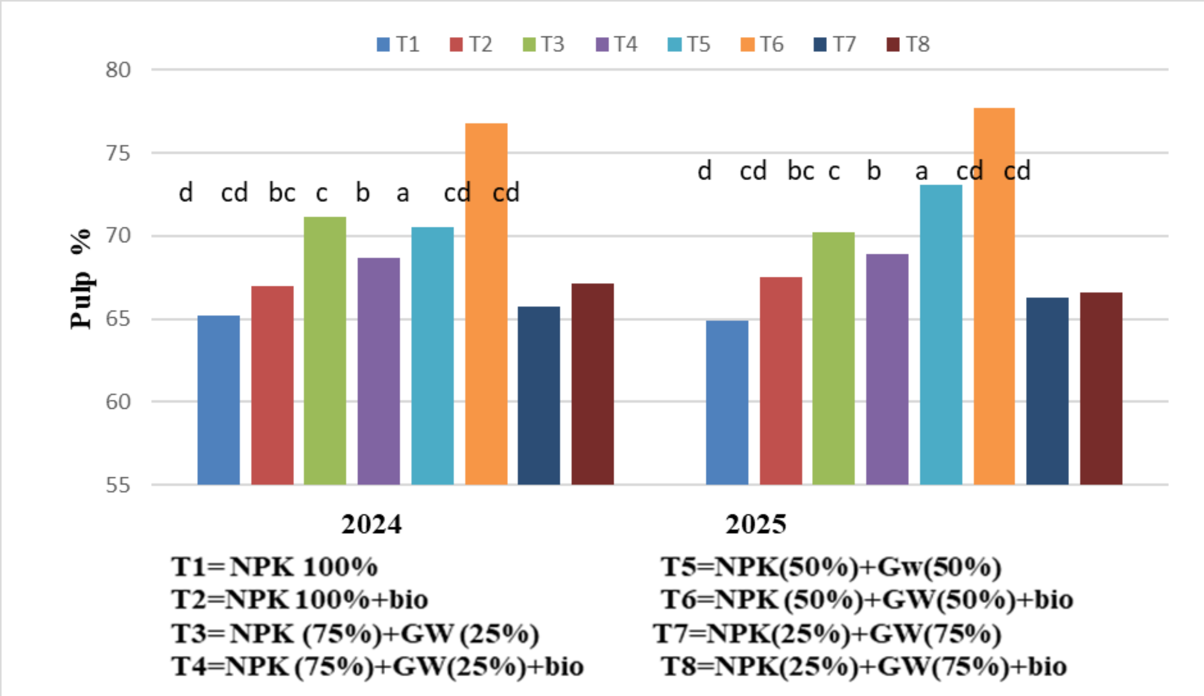

Figure (12). Effect of mineral, gradable waste (GW) as organic manure and biofertilizers on pulp% at maturity of Grand Nain banana plants

The data clearly show that organic manures significantly improved fruit weight, pulp weight, and pulp percentage compared to controls. This can be attributed to the enhanced nutrient availability provided by organic manures, which supports better fruit development. Studies have shown that organic amendments get better soil construction, water maintenance, and microbial content activity, all of which add to better plant growth and fruit quality **(Pant *et al*., 2012 and Lal, 2004)**. Addition of organic manures led to significant increases in both fruit weight and pulp weight. Organic matter in the manure enhance soil fertility by given that essential nutrients and supporting soil physical properties, which in turn boosts fruit development and quality **(Ghosh *et al*., 2010)**. This is consistent with research representing that organic fertilizers can improve the physical characteristics of fruits by supporting nutrient availability and soil structure and health **(Bhardwaj *et al*., 2014)**. The highest levels of fruit weight and pulp weight were recorded in plants treated with 100% town refuse plus biofertilizer. This combination likely provided a wealthy source of nutrients and organic material, improving soil bio-fertility and microbial activity, which are vital for optimal fruit growth **(Adesemoye *et al*., 2009)**. Municipal waste manures are known for their high nutrient matter, which supports better enlargement and yield **(Ghosh *et al*., 2010)**. The positive effects of the treatments were consistent across both seasons, highlighting the reliability of organic manures and biofertilizers for sustained improvement in fruit quality. Consistent results across different seasons suggest that these fertilization strategies can be effective long-term solutions for enhancing crop production and fruit quality **(Kumar *et al*., 2020)**. Results underscore the consequence of using organic manures and bio-fertilizers to get better the physical characteristics of fruits. This approach not only boosts yields and fruit quality but also promotes sustainable agricultural practices by support soil structure health and dropping dependence on (CF) chemical fertilizers **(Tilman *et al*., 2002 and Lal, 2004)**.

Fruit chemical analysis

T.S.S. % and (TS) total sugar content

According to data in figures (13 and 15), there were extremely substantial differences in T.S.S. and (TS) total sugar content across all treatments being studied in two seasons. In contrast to the control treatment, which recorded the lowest numbers (20.18&19.34) and (16.04 & 16.22) in two seasons, the rate of 100% town decline manure produced the maximum number of T.S.S (22.63 & 21.72) and T.S. (19.96 & 20.24), respectively.

Titarable acidity

It is evident from data in Figure (14) that in both seasons' town reuse manure showed lower records of titarable acidity in the banana fruits when comparing with control plants which fertilized with 100% NPK only.

Starch

Comparing organic manures plus the control plants only received 100% NPK fertilizer in both successive seasons, the latter revealed lower levels of starch conc. in banana fruits. Additionally, In the two following seasons, 50% of the town's trash yielded a lower value of starch concentration than the corresponding non-inoculated treatments.

The data show that treatments with 100% town refuse manure resulted in the highest T.S.S. and (TS) total sugar content in both seasons. T.S.S. is a key indicator of fruit quality, as it represents the total amount of soluble sugars, organic acids, and other soluble substances **(Marschner, 2012)**. Higher T.S.S. and sugar content suggest improved fruit sweetness and overall quality. Research indicates that organic manures can enhance fruit quality by improving soil fertility, which increases nutrient availability and promotes better carbohydrate metabolism in the plants **(Pant *et al*., 2012 and Bhardwaj *et al*., 2014)**. The data also indicate that town refuse manures resulted in lower titratable acidity compared to control plants treated with 100% NPK. Lower titratable acidity generally enhances the taste and quality of fruits by reducing their sourness **(Marschner, 2012)**. Organic manures can buffer soil pH and improve nutrient uptake, leading to better-balanced fruit composition and reduced acidity **(Lal, 2004)**. The findings reveal that control plants treated with 100% NPK had lower starch concentrations in banana fruits compared to those treated with organic manures. Starch accumulation in fruits can be prejudiced by nutrient availability and soil health. Organic manures enhance soil organic matter content, which enhances nutrient cycling and the availability, thus promote better starch synthesis in fruits **(Ghosh *et al*., 2010)**. Additionally, the 50% town refuse treatment resulted in lower starch concentration compared to non-inoculated treatments, indicating that a balanced approach using both organic and inorganic fertilizers can optimize starch accumulation **(Adesemoye *et al*., 2009)**. The records demonstrate that the use of the organic manures, particularly town refuse, significantly support fruit quality by rising T.S.S., (TS) total sugar content, and starch concentration while reducing titratable acidity. This highlights the benefits of integrating organic manures into fertilization strategies to enhance the nutritional and sensory attributes of fruits. Such practices not only get better crop quality but also help sustainable agriculture by enhancing soil health and dipping trust on chemical fertilizers **(Tilman *et al*., 2002 and Lal, 2004)**.

Nitrate concentration

Regarding the impact of organic manures on fruit nitrate conc. in the two following seasons, data in Figure (17) revealed a significant decline in fruit nitrate concentration in two seasons comparison to the control treatment.

Regarding the impact of combining biofertilizers and organic manures in the both seasons, data showed that this caused a decrease in the nitrate concentration in banana fruits.

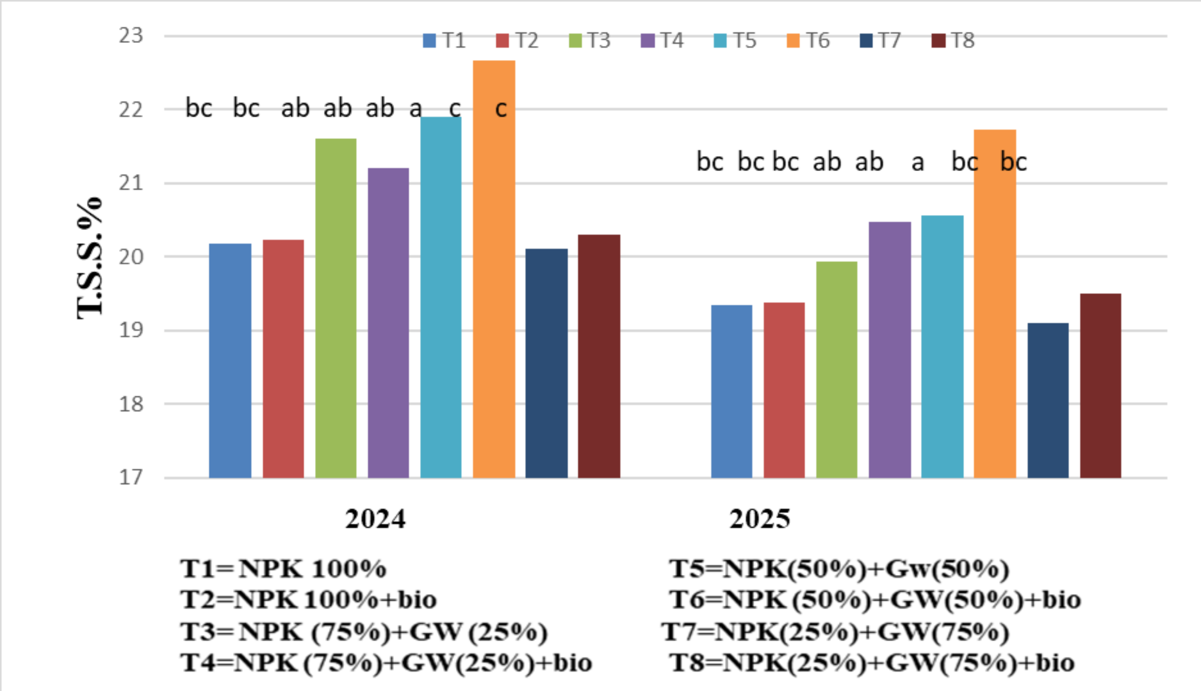

Figure (13). Effect of mineral gradable waste (GW) as organic manure and Biofertilizers on fruit T.S.S. % at ripen stage of Grand Nain banana plants

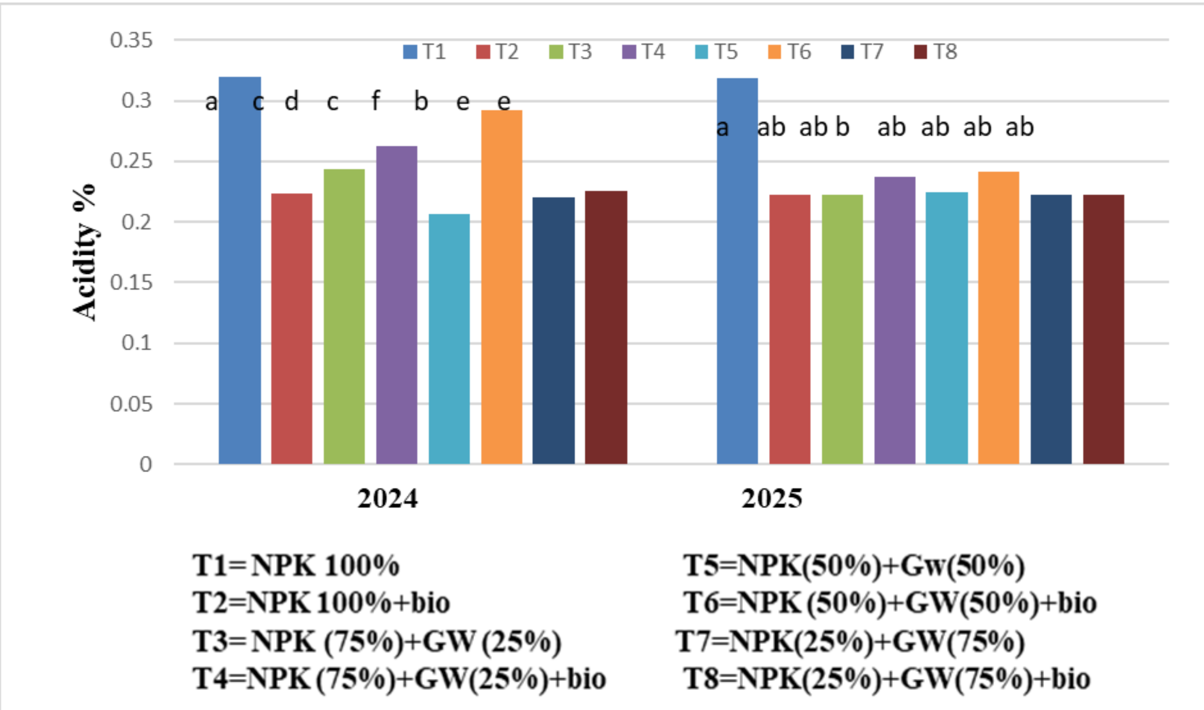

Figure (14). Effect of mineral gradable waste (GW) as organic manure and Biofertilizers on fruit acidity % at ripen stage of Grand Nain banana plants

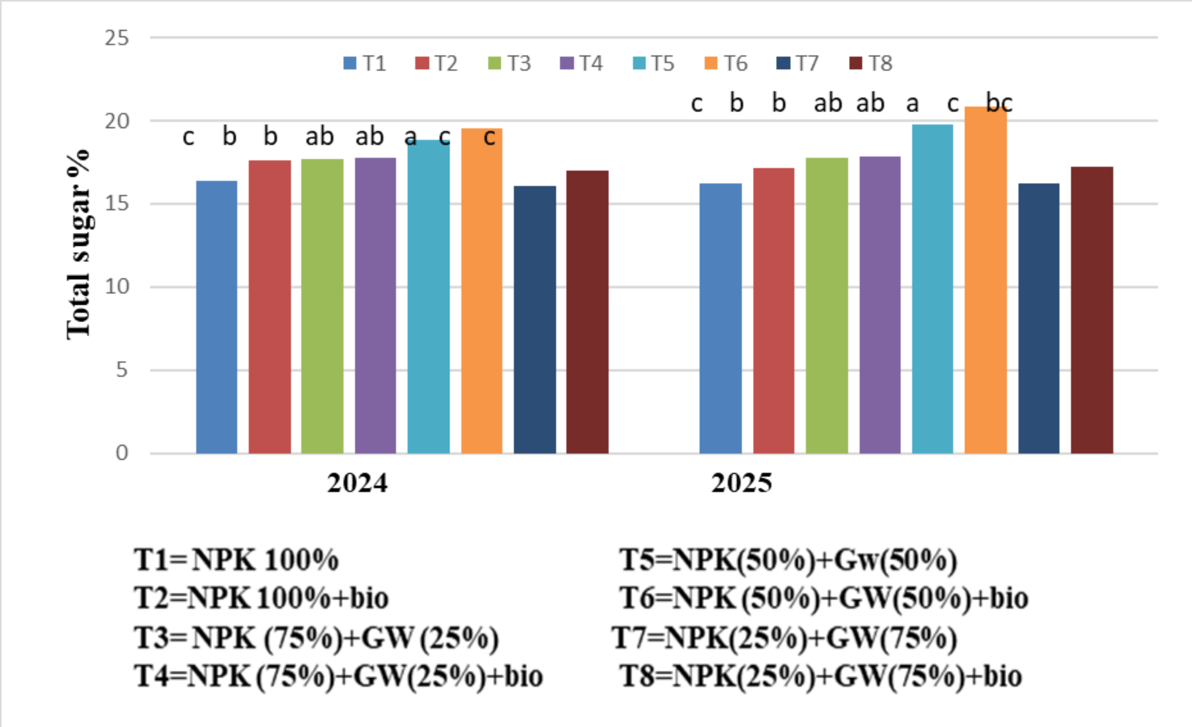

Figure (15). Effect of mineral gradable waste (GW) as organic manure and Biofertilizers on fruit total sugar content at ripen stage of Grand Nain banana plants

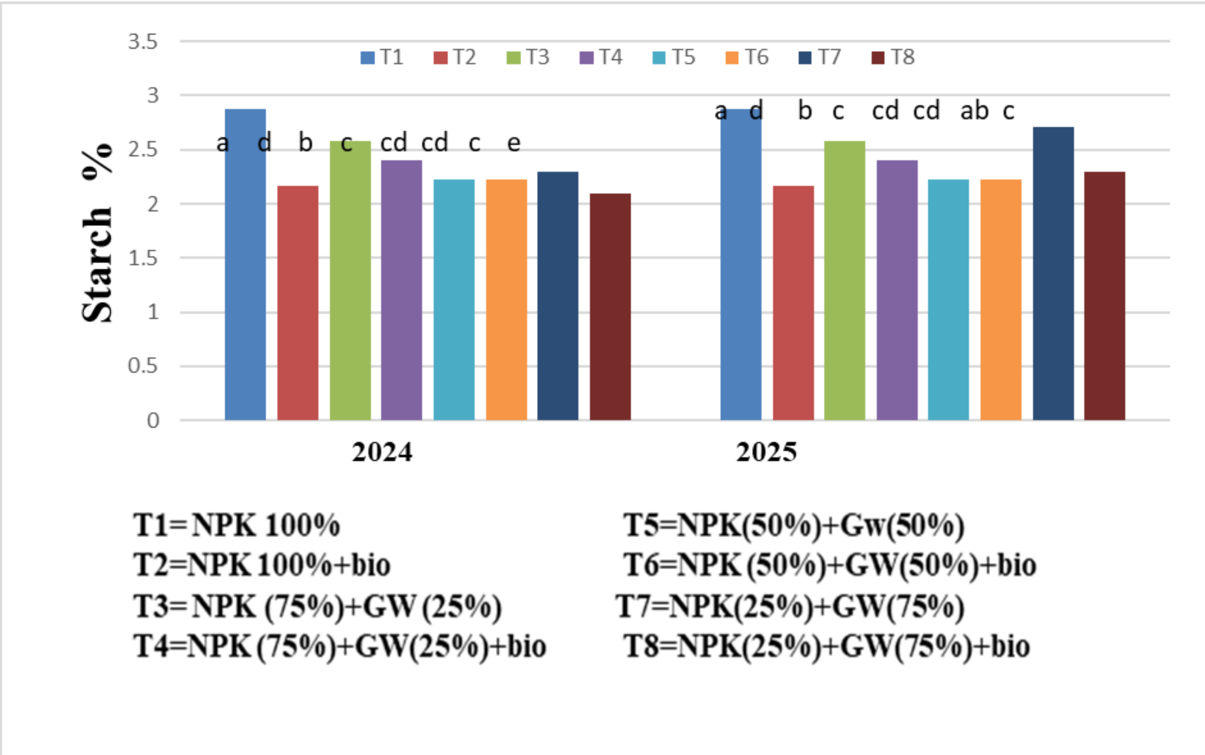

Figure (16). Effect of mineral gradable waste (GW) as organic manure and Biofertilizers on fruit starch conc. (%) at ripening stage of Grand Nain banana plants

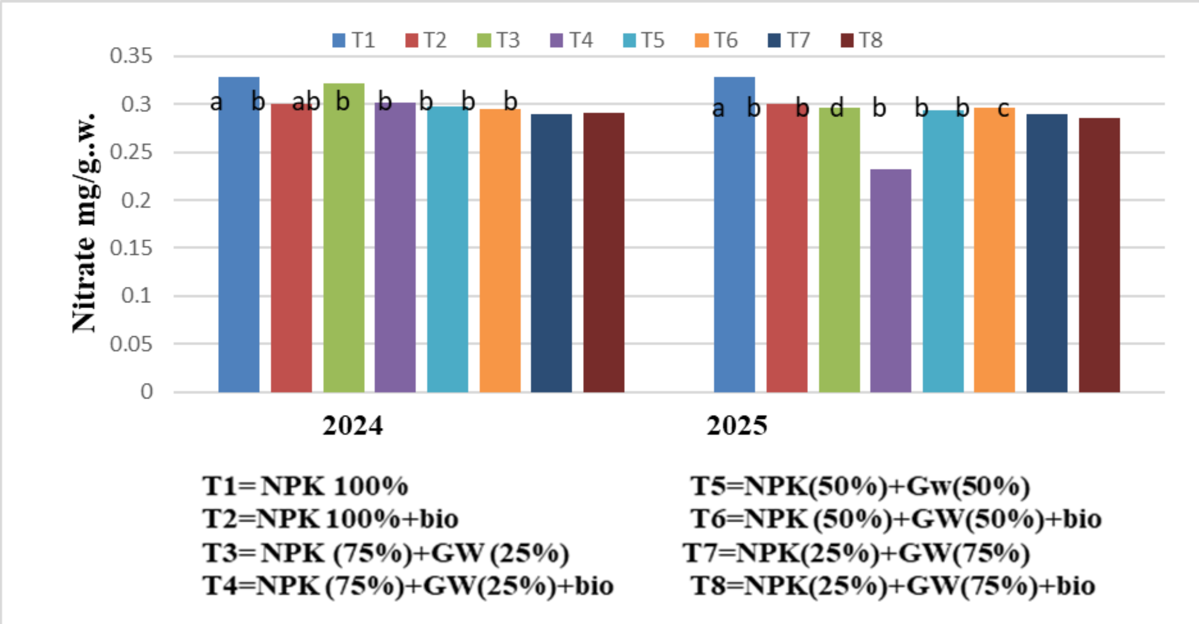

Figure (17). Effect of mineral gradable waste (GW) as organic manure and biofertilizers on fruit nitrate (mg/g F.wt.) at ripen stage of Grand Nain banana plants

The data indicate a significant decline in fruit nitrate concentration when organic manures were used compared to the control treatment. This reduction is beneficial because high nitrate levels in fruits can pose health risks to consumers, including methemoglobinemia or "blue baby syndrome" in infants **(Santamaria, 2006)**. Organic manures improve soil health and promote a balanced nutrient uptake by enhancing microbial activity, which helps in the efficient utilization of nitrates by plants **(Bhardwaj *et al*., 2014)**. This leads to lower residual nitrate levels in the fruits. The combination of biofertilizers with organic manures further decreased nitrate concentration in banana fruits. biofertilizers enhance the reaction of useful soil microorganisms (MOs) that facilitate better nutrient cycling and uptake, including the more efficient assimilation of nitrogen, which reduces the accumulation of nitrates in the fruits **(Adesemoye *et al*., 2009)**. The synergistic result of bio-fertilizers and the organic manures results in improved nitrogen use efficiency, which is reflected in lower nitrate levels in the produce **(Bhardwaj *et al*., 2014)**. Reducing nitrate concentration in fruits has important health and environmental benefits. Lower nitrate levels in fruits make them safer for consumption, especially for susceptible populations such as infants and with child women **(Santamaria, 2006)**. Additionally, the employ of organic manures and bio-fertilizers promote good farming practices by lowering the reliance on chemical fertilizers, which can contribute to nitrate pollution in water sources through leaching and runoff **(Tilman *et al*., 2002)**. Results highlight the advantages of using organic manures and biofertilizers in reducing nitrate concentrations in banana fruits. This approach not only improves the nutritional quality and safety of the produce but also supports sustainable agricultural practices by supporting soil health and reduction environmental pollution **(Lal, 2004)**.

Fruit heavy metal concentration

Fertilizing banana plants with town reject manure at various rates in both seasons, as compare to control treatment; data in Figures (18, 19 and 20) showed that Ni, Cd, and Pb concentrations in fruit pulp of banana plants significantly increased. Regarding the addition of biofertilizers mixture to town reject manure, which was found that in two seasons, both the organic manures and the biofertilizers mixture significantly enhanced the heavy metal contents of banana fruits when compared to their non-inoculated or control counterparts.

In comparison to other tested treatments, the control treatment (100% NPK fertilizer) produced lower values of heavy metal concentrations in both seasons. This may be connected to an increase in the amount of heavy metals released as organic manure biodegraded more quickly, particularly when vaccination was present.

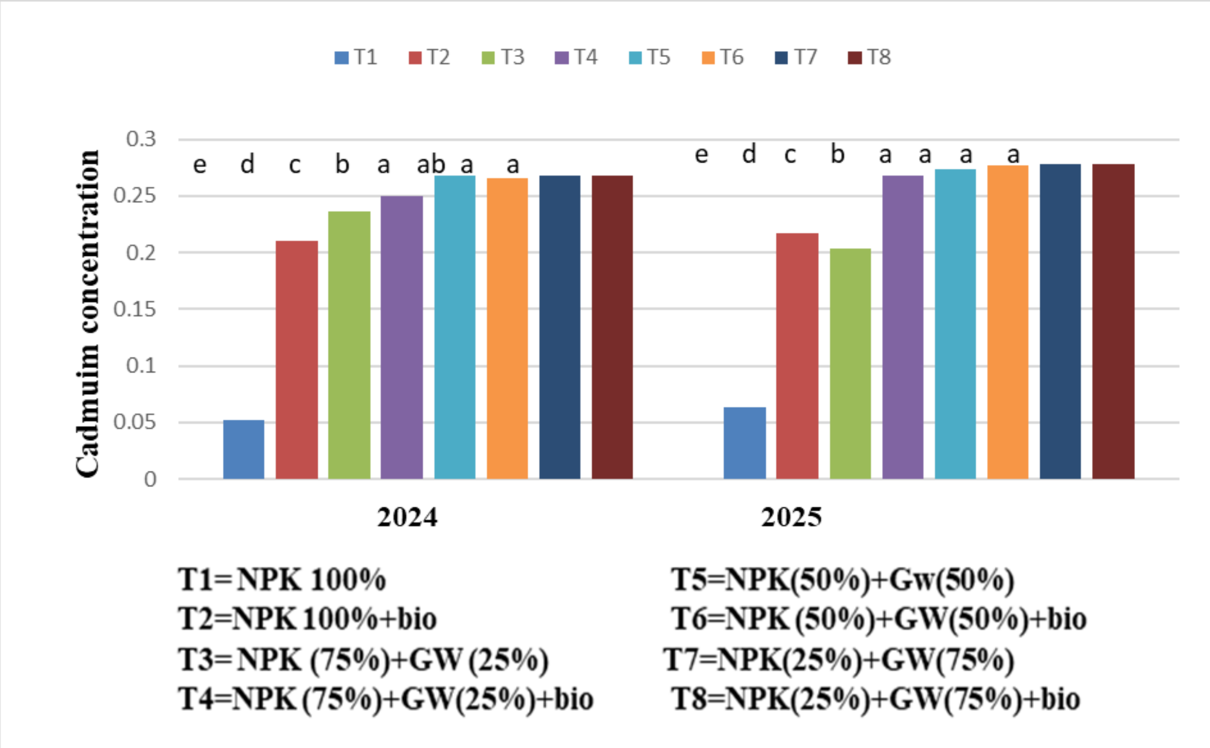

Figure (18). Effect of mineral, gradable waste (GW) as organic manure and Biofertilizers on fruits cadmium (Cd) concentration at fruit ripen stage of Grand Nain banana plants

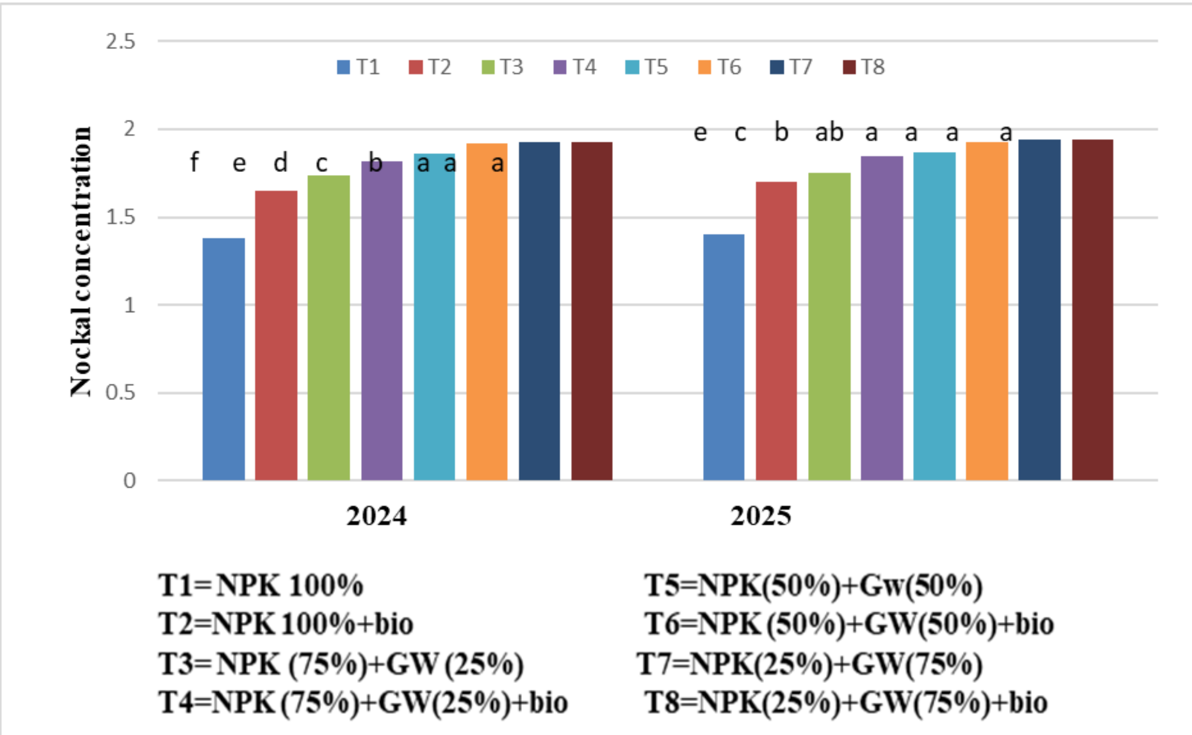

Figure (19). Effect of mineral, gradable waste (GW) as organic manure and Biofertilizers on fruits nickel (Ni) concentration at fruit ripen stage of Grand Nain banana plants

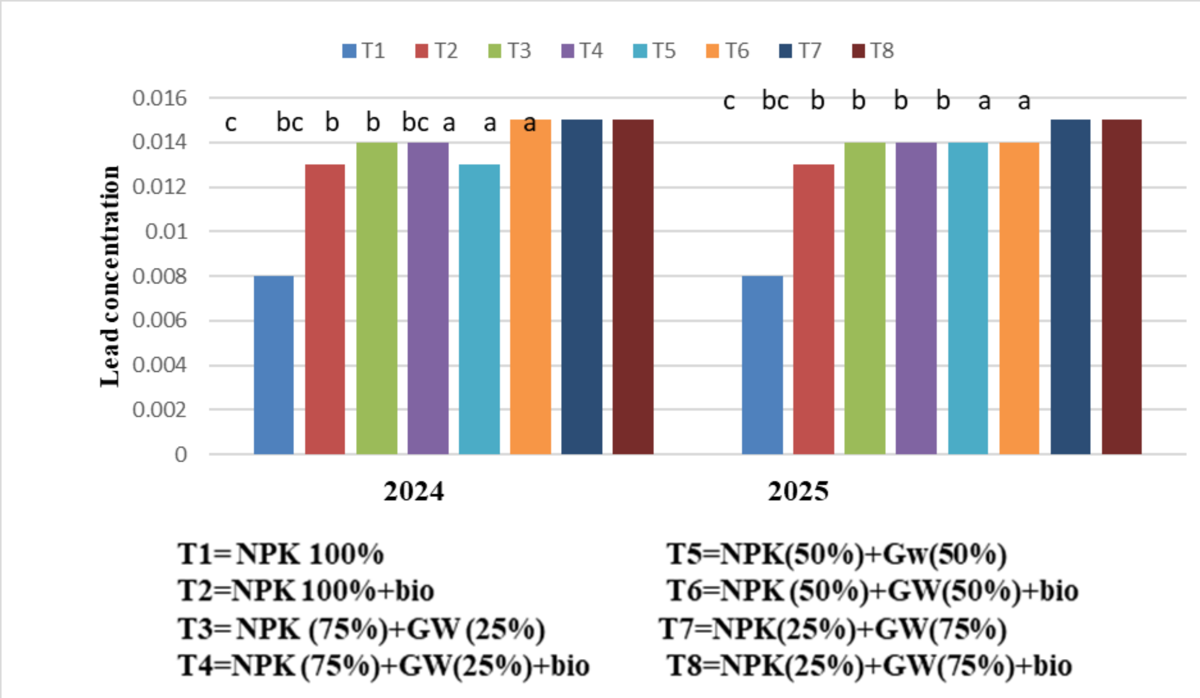

Figure (20). Effect of mineral, gradable waste (GW) as organic manure and Biofertilizers on fruits lead (Pb) concentrations (ppm) at fruit ripening stage of Grand Nain banana plants

The data show that the use of town refuse manure led to higher concentrations of Ni, Cd, and Pb in banana fruits. This could be due to the attendance of these heavy metals in the organic manure itself. Organic manures, especially those derived from municipal waste, can contain higher levels of heavy metals compared to chemical fertilizers. The biodegradation of organic manure can release these metals into the soil, which are then in use up by the plants.

The addition of biofertilizers to town refuse manure further enhanced the heavy metal content in banana fruits. biofertilizers can raise the bioavailability of nutrients and heavy metals in the soil, leading to higher uptake by plants3. This synergistic effect results in even higher concentrations of heavy metal in the fruits compare to non-inoculated treatments. The control treatment (100% NPK fertilizer) produced lower values of heavy metal concentrations in both seasons. This is likely because chemical fertilizers typically contain lower levels of the heavy metals compared to organic manures2. The controlled release of nutrients from chemical fertilizers also reduces the risk of the heavy metal accumulation in plants. The increase in heavy metal concentrations may be connected to the faster biodegradation of organic manure, especially when biofertilizers are present. As organic matter breaks down, it can release bound heavy metals into the soil, creation them more accessible for plant uptake. While organic manures and biofertilizers can get better soil health and nutrient accessibility, they also pose a risk of the heavy metal accumulation in the crops. It is essential to monitor and manage the application rates and sources of organic manures to minimize heavy metal contamination in fruits. Furthermore, **Melo and Ligo (2006)** discovered that the cadmium concentration in banana fruits that were grown under the impact of sewage sludge application of 9 or 18 t/ha was a little bit higher. Even yet, the concentration was below the permitted limits specified by the environmental standards.

Greenhouse gas emissions

No_2 emissions (μg/m²/h)

It's indicated from this investigated study that the effectiveness of biofertilizers and town refuse manure in reducing No_2 emissions compared to conventional NPK fertilizers. It includes a control group with only conventional fertilizers and various combinations of organic and biofertilizer treatments with differing NPK and manure ratios. The use of biofertilizer alongside organic treatments might further enhance emission reduction by promoting efficient nitrogen cycling and soil health.

Lowering the dependence on mineral fertilizers (Treatments 3-8) could decrease No_2 emissions compare to control (Treatment 1). Increasing percentage of town refuse manure (Treatments 5-8) might lead to further emission reduction compared to lower manure ratios (Treatments 3&4). Combining biofertilizer with organic treatments (Treatments 4, 6, &8) could potentially show the most significant decrease in No_2 emissions due to synergistic effects.

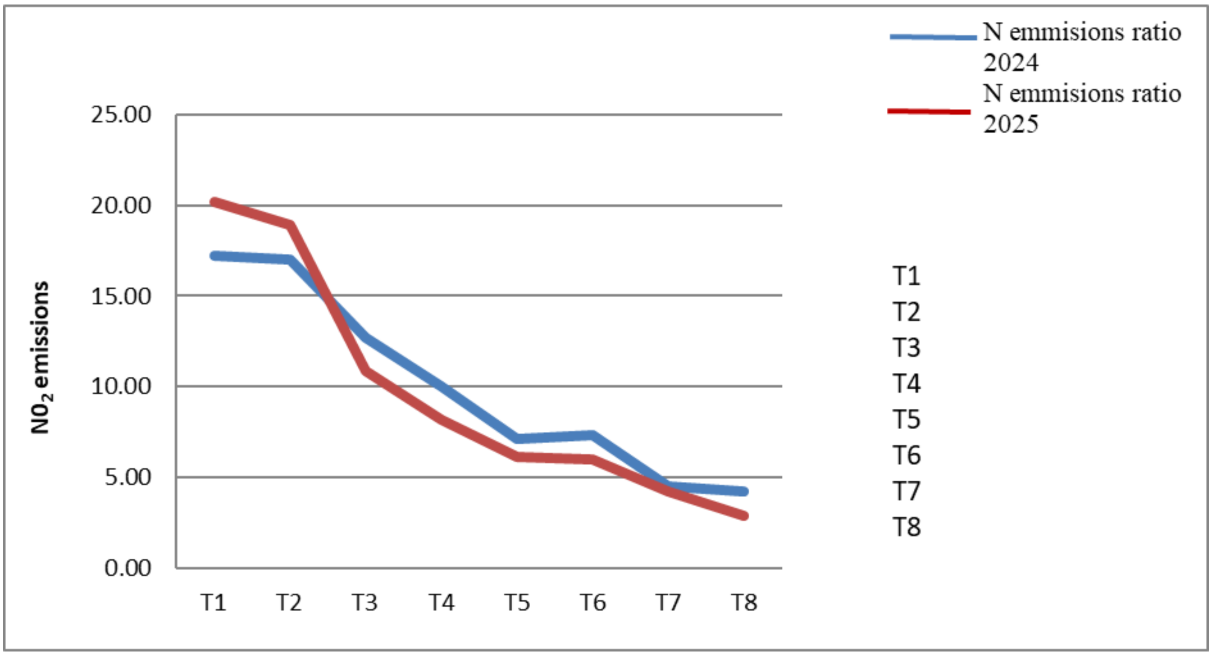

Figure (21). Result of mineral, gradable waste (GW) as organic manure and Biofertilizers on No_2 emissions concentrations (µg/m²/h) of Grand Nain banana plants

Co_2 emissions (kg/ha/year)

The study investigated the effectiveness of using organic and biofertilizers in reducing CO_2 emissions compared to conventional NPK fertilizers in a crop field. It includes eight treatments with varying combinations of conventional fertilizers, town refuse manure, and biofertilizers at different percentages. Analyzing these data can shed light on potential strategies for minimizing agricultural CO_2 emissions while maintaining or improving crop yields.

It's shown in figure 22, treatments (3 & 8) replacing part of the recommended NPK with manure might show lower CO_2 emissions compared to the control (Treatment 1) due to reduced mineral fertilizer production and soil carbon sequestration. As for increasing manure percentage it's noticed that treatments (5 & 8) with higher manure ratios could potentially have further decreased CO_2 emissions compared to lower manure treatments (3 & 4) due to enhanced soil organic matter and reduced fertilizer need. Other side, for biofertilizer impact including biofertilizer (Treatments 2, 4, 6, & 8) might further enhance emission reduction compared to their non biofertilizer counterparts through efficient nitrogen cycling and potential microbial activity modifications.

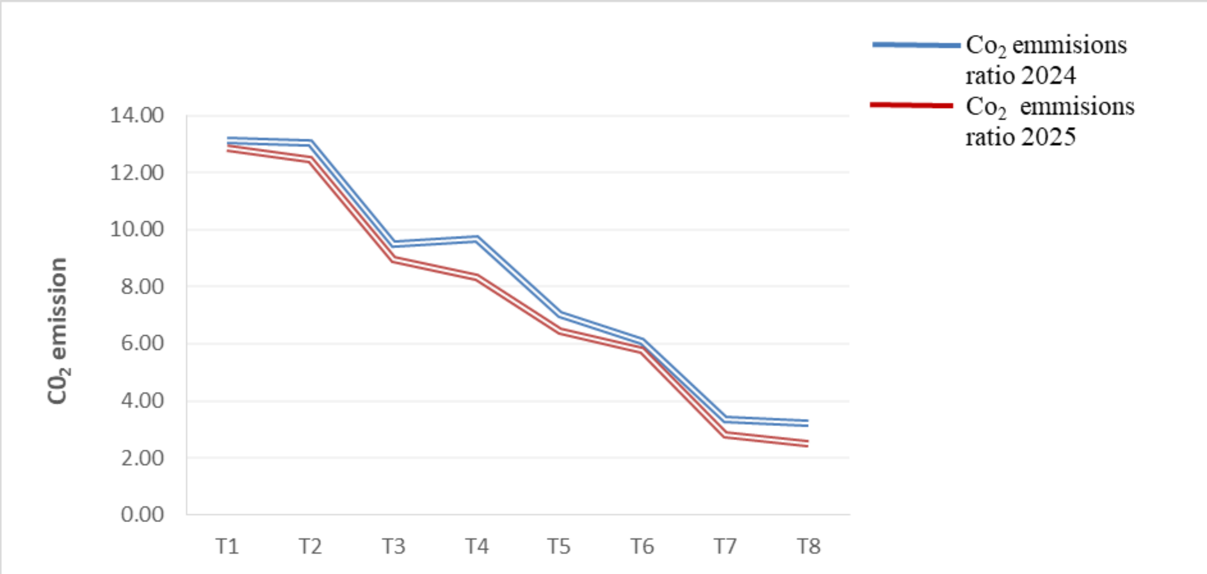

Figure (22). Effect of mineral, gradable waste (GW) as organic manure and Biofertilizers on Co_2 emissions concentrations (kg/ha/year) of Grand Nain banana plants

4. Conclusion

Finally, increasing the amount of the organic manures organic manures with or without biofertilizers to 50% of the NPK fertilizers appears to boost banana fruit output. Such improvement might be related to the improved effects of the organic manures or biofertilizers on physical, chemical and biological soil properties, which may promote the release of certain nutrients and or growth substances in the rooting zone in a readily available manner, potentially increasing their uptake by plants.

It is vital to note that the reduction of 50% from NPK fertilizers may help to lower production costs and lessen environmental pollution by limiting the unconstructive effects of utilizing chemical fertilizers on the human health. With the exception of Ni concentrations, which were discovered by town trash treatment, the increase in concentration of the heavy metals as (Cd, Pb, and Ni) in banana fruits did not reach a significant level.

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