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Comparative Efficacy of Organic and Inorganic Fertilizers on the Morphological Characteristics of Spinach (*Spinacia oleracea* L.)

***Mohammad, M., Idris, A. and Salihu, S.**

Department of Plant Biology, Faculty of Life Sciences, Federal University Dutse, 720211, Jigawa State, Nigeria

*Corresponding Author: maryammohammad35@yahoo.com.

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Abstract

The effects of different rates of application of organic (cow dung, poultry manure) and inorganic (NPK, Urea) fertilizers were examined on the morphological traits of *Spinacia oleracea* L. on a field experiment at Federal University Dutse field, Nigeria. The experiment aimed to investigate the effect of various nutrient sources on the most important growth parameters and to identify the best application rates for each fertilizer source. The different treatments were 5g, 3g, 2g and 0g (control) rate of each fertilizer, and morphological parameters like days to germination, no of leaves, plant height, no of branches, area of leaves, fresh shoot weight and dry shoot weight were measured. The outcomes showed that inorganic fertilizers had the highest effect at the dose of 3g while the organic fertilizers had the best effect at the higher dose 5g. In particular, the plants irrigated with 3g of NPK, 3g of Urea, 5g of cow dung and 5g of poultry manure had the highest values of number of leaves, leaf area, number of branches, plant height, fresh shoot weight and dry shoot weight. The results generated indicate a significant difference between the two fertilizers in the rate of nutrient release and the nutrient levels. The study also points to the potentials of using both organic and inorganic fertilizers in order to improve spinach productivity in the semi-arid northern Nigerian environment and the importance of location-specific nutrient management strategies to achieve a balance between yield, cost and longer term soil health.

Introduction

Spinach (*Spinacia oleracea* L.) is a vegetable of great importance in the world, due to its high nutritional content and versatility. It is a rich source of vitamins, minerals and antioxidants, and is an important source of nutrition for people around the world (Edo et al., 2024). Cultivation of spinach is an important agricultural operation in Nigeria. It plays a major role in local diets, high demand in various regions, and is a major cash crop, earning smallholder farmer's livelihoods (Ibrahim et al., 2025). Important for region food security and economic stability is the possibility to develop this crop in an efficient and sustainable way.

High-yield crop production depends on correct use of fertilizer – the basic source of nutrients for plant growth. The macronutrients such as nitrogen (N), phosphorus (P), and potassium (K)

are some of the most essential nutrients (Lu et al., 2024).

There are two major types of fertilizers based on their origin and their composition, which are inorganic and organic. Inorganic fertilizers (NPK and Urea) have a high nutrient content and have a fast release process. For example, Urea has a higher nitrogen content by weight than other sources, at 46%, which is a high concentration (Lu et al., 2024). The nutrients are in a readily available water soluble form, which can be readily absorbed by the plant roots and hence can be easily taken up by the plant for rapid growth (Priya et al., 2024). This quick availability is fraught with great danger though. The overuse can lead to the accumulation of excessive soluble salts in the soil, causing it to become saline and creating conditions of osmotic stress that can cause reduced water and nutrient availabilities, resulting in what is called physiological drought and ultimately affect the plants' growth and development or even their survival (Liu et al., 2024).

Organic fertilizers are available in the form of natural sources such as animal wastes that provide a greater diversity of macro- and micronutrients, but with lower nutrient levels (Neethu et al., 2023). They release nutrients over time and are a biological process that depends on microbes decomposing the nutrients in the soil. This slow-release property ensures the gradual nutrient supply during plant growth, which helps to reduce leaching losses (Neethu et al., 2023; Shaji et al., 2021). Organic fertilizers also play a significant role in achieving sustainable, long-term soil health, as they enhance soil physical properties that are difficult to replicate with inorganic fertilizers, including their ability to hold water, retain nutrients and create soil structure (Franco-Pesantez & Torres 2023). The main purpose of this study was to explore the impact of organic and inorganic fertilizers on morphological traits of spinach.

Materials and methods

Study Area

The field experiment was carried out at a specific agricultural research plot in the premises of Federal University Dutse (FUD), Jigawa State, Nigeria in the Sudan savannah ecological zone between longitude 8.00° E to 10.15° E and latitude 11.00° N to 13.00° N. Spinach (*Spinacia oleracea* L.) was selected for the study because of its nutritional value.

Seeds source

The seeds of the *S. oleracea* plant were collected from Sabuwar Kasuwa, Dutse jigawa state.

Experimental Design and Experimental treatments

A Randomized Complete Block Design (RCBD) was used. Four types of fertilizers were used; two inorganic (NPK and Urea) and two organic (cow dung and poultry manure). The fertilizers were applied at four different rates: 5g, 3g, 2g and 0g. The 0g treatment group was given no fertilizer, and was the untreated control group to give a baseline for comparison. To account for the natural variation of the system and to achieve the statistical power to detect any actual difference between treatments, each treatment was replicated at least four times, a common approach for agricultural research (ICM 2019).

Fertilizer Application

Thoroughly mixing the fertilizers and the application procedures were carefully managed in both the organic fertilizers (cow dung and poultry manure) and inorganic fertilizers (NPK and Urea) prior to planting, because of high solubility of the inorganic fertilizers and their nutrient losses by runoff or by leaching. In all cases the same time and placement of treatments were used in order to minimise variation other than the type and rate of the fertilizer.

Planting

In the following experiment polythene bags were used. The collected soil sample was air dried under the sun and mixed with the different treatments at 3:1 ratio and each of the polythene bags was filled with the soil and watered well for two days before planting Seeds were sown manually at the rate of more than ten seeds per polythene bag and letter tagged the specific plants to be used for the data collection.

Data Collection and Measurements

To evaluate the effects of the different fertilizer treatments on the spinach plants, a complete set of morphological traits were measured. Days to germination was observed. Plant height was measured from soil to the top of the plant. A manual count of number of leaves and branches of each plant was undertaken. The above-ground biomass (fresh shoot weight) was measured at harvest. Finally the total biomass accumulated was calculated on the basis of the dry shoot weight after oven-drying the samples to constant weight.

Statistical Analysis

The field experiment data were statistically analyzed thoroughly. A One Way Analysis of Variance (ANOVA) was used to assess whether or not the various fertilizer treatments were significantly different for the morphological parameters measured.

Results and Discussions

Results

The field study results showed that the morphological traits of spinach were improved significantly in the plants treated with fertilizers as compared to plants not treated with fertilizers (0g) in every case. One of the major results of the study was determining the optimum application rates for the different fertilizers.

Effect of different fertilizer and ratio on day to germination of spinach at different weeks after sowing

The result of the number of days to germination of spinach under different fertilizer concentration is presented in Table 4. The result indicates that there is statistical significant difference ($P<0.05$) between treatment urea 5g (2.33) and urea 2g (2.00) while there is no statistical significant difference ($P>0.05$) between the other treatment. Cow dung 5g (4.00) has the highest days to germination, followed by the remaining treatment and urea 2g (2.00) has the least number of days to germination as shown in table 1.

Table 1: Effect of different fertilizer on days to germination of spinach at different weeks after sowing

Treatment	DTG
Npk 5	3.00 a
Npk 3	3.00 a
Npk 2	3.00 a
Urea 5	2.33 ab
Urea 3	3.67 a
Urea 2	2.00 ab
Cow dung 5	4.00 a
Cow dung 3	3.00 a
Cow dung 2	3.33 a
Poultry manure 5	3.67 a
Poultry manure 3	3.67 a
Poultry manure 2	3.67 a
Control	3.00 a
LSD	1.43

Keys: DTG= days to germination; LSD=least significant difference

Effect of different fertilizer on plants height of spinach at different weeks after sowing

The data on the comparison of plant height of different fertilizer concentration at different weeks after sowing show that there are significant differences among the all weeks after sowing (3, 4, 5 and 6 WAS). Treatment poultry manure 5g show the highest value of plant height with 11.20 at 3 WAS 4,5 and 6WAS treatment urea 3g show the highest value with 13.50 , 17.50 and 20.30 respectively as shown in table 2.

Effect of different fertilizers and concentration on number of leaves of spinach

The effect of fertilizer concentration of different weeks after sowing shows that there is statistical significant different between fertilizer levels at 3WAS and 4WAS and 5WAS while there is no significant difference at 6WAS between the fertilizer levels. In addition, treatment urea 3g recorded the highest number of leaves at 3WAS and 5WAS at 9.67 and 16.00 respectively at 4 weeks while 6WAS poultry manure 5g and cow dung 5g recorded the highest value of 12.70 and 18.00 respectively at 4 weeks as presented in table 3.

Effect of different fertilizer on the number of branches of spinach at different weeks after sowing

The number of branches under the different fertilizer concentrations at different weeks after sowing show that there is significant difference at 3 weeks after sowing and 4 and 5 weeks after sowing while the treatments are not significantly different at 6 weeks after sowing. In addition, treatment urea 3g had the highest leaf number at 3 and 5 weeks after sowing with 9.67 and 16.00, respectively at 4 and 6 weeks after sowing, respectively while the highest number of leaves was recorded for the treatment of poultry manure 5g and cow dung 5g with 12.70 and 18.00, respectively at 4 and 6 weeks after sowing as presented in table 4.

Table 2: Effect of different fertilizer plants height of spinach at different weeks after sowing

Treatment(g)	3WAS	4WAS	5WAS	6WAS
Npk5	7.00 ab	10.20 a	13.90 a	16.50 a
Npk 3	7.20ab	10.00 a	13.20 a	15.90 a
Npk 2	5.00 ab	6.70 ab	13.20 a	15.40 a
Urea 5	6.00 ab	8.00 ab	12.60 a	14.10 a
Urea 3	10.30 a	13.50 a	17.50 a	20.30 a
Urea 2	5.20 ab	8.60 ab	8.90 ab	11.30 ab
Cow dung 5	6.80 ab	9.20 a	13.90 a	15.60 a
Cow dung 3	6.40 ab	9.50 a	13.70 a	16.00 a
Cow dung 2	7.10 ab	9.70 a	13.50 a	16.70 a
Poultry manure 5	11.20 a	12.00 a	16.10 a	19.60 a
Poultry manure 3	9.60 a	11.50 a	17.10 a	19.50 a
Poultry manure 2	6.80	9.70 s	13.30 a	16.90 a
Control	9.30 a	9.0 a	13.00 a	16.00 a
Lsd	3.63	5.04	6.57	7.79

Keys: WAS= weeks after sowing; LSD=least significant difference.

Table 3: Effect of different fertilizers and concentration on number of leaves of spinach

Treatment(g)	3WAS	4WAS	5WAS	6WAS
Npk5	8.00 a	9.3 a	13.00 a	12.67 a
Npk 3	8.33 a	9.7 a	13.00 a	15.33 a
Npk 2	7.33 a	8.0 ab	12.00 a	14.00 a
Urea 5	6.67 a	9.0 a	11.33 a	11.08 a
Urea 3	9.67 a	11.7 a	16.00 a	16.33 a
Urea 2	5.67 ab	5.3 ab	9.33 ab	12.00 a
Cow dung 5	7.33 a	10.0 a	12.67 a	18.00 a
Cow dung 3	7.33 a	8.7 a	12.67 a	17.67 a
Cow dung 2	8.00 a	9.7 a	13.00 a	14.67 a
Poultry manure 5	8.67 a	12.7 a	14.00 a	16.33 a
Poultry manure 3	7.67 a	10.7 a	13.33 a	14.67 a
Poultry manure 2	6.00 a	9.7 a	13.67 a	17.33 a
Control	9.00 a	11.0 a	11.00 a	15.00 a
LDS	3.931	4.83	7.07	8.37

Keys: WAS= weeks after sowing; LSD=least significant difference

Table 4: Effect of different fertilizer on number of branches of spinach at different weeks after sowing

Treatment(g)	3WAS	4WAS	5WAS	6WAS
Npk5	8.00 a	9.33 a	13.00 a	12.67 a
Npk 3	8.33 a	9.67 a	13.00 a	15.33 a
Npk 2	7.33 a	8.00 ab	12.00 a	14.00 a
Urea 5	6.67 a	9.00 a	11.33 a	11.00 a
Urea 3	9.67 a	11.67 a	16.00 a	16.33 a
Urea 2	5.62 ab	5.33 ab	9.33 ab	12.00 a
Cow dung 5	7.33 a	10.00 a	12.67 a	18.00 a
Cow dung 3	7.33 a	9.33 a	12.67 a	17.67 a
Cow dung 2	8.00 a	9.67 a	13.00 a	14.67 a
Poultry manure 5	8.67 a	12.67 a	14.00 a	16.33 a
Poultry manure 3	7.67 a	10.67 a	13.33 a	14.67 a
Poultry manure 2	6.00 a	9.67 a	13.67 a	17.33 a
Control	9.00 a	11.00 a	11.00 a	15.00 a
Lsd	3.93	4.85	7.08	8.37

Keys: WAS= weeks after sowing; LSD=least significant difference

Effect of different fertilizer on leaf area of spinach at 5 and 6 weeks after sowing

The result of the leaf area under different fertilizer concentration at week 5 and 6 after sowing indicate that there is statistically significant difference at all the weeks (5 and 6WAS). It is observed that the result obtained for the treatment urea 3g indicated the highest value of leaf area at 5 and 6WAS with 59.43mm and 67.98mm respectively as shown in table 5 while the least value of leaf area is 33.43mm and 38.20mm for treatment urea 2g at 5 and 6WAS respectively.

Table 5: Effect of different fertilizer on leaf area of spinach at 5 and 6 weeks after sowing

Treatment(g)	5WAS	6WAS
Npk 5	58.27 a	63.10 a
Npk 3	56.67 a	57.13 a
Npk 2	41.43 a	47.94 a
Urea 5	37.50 a	43.13 a
Urea 3	59.43 a	67.98 a
Urea 2	33.43 ab	38.20 ab
Cow dung 5	45.50 a	50.17 a
Cow dung 3	35.73 ab	43.37 a
Cow dung 2	39.13 a	49.33 a
Poultry manure 5	57.56 a	67.68 a
Poultry manure 3	55.14 a	65.24 a
Poultry manure 2	40.90 a	50.90 a
Control	33.50 ab	40.00 a
LSD	23.130	25.90

Keys: WAS= weeks after sowing; LSD=least significant difference

Effect of different fertilizer on fresh shoot weight and Dry shoot weight of spinach after harvesting at week 6

The result of the shoot fresh and dry weight of spinach under different concentration of fertilizer indicate that there is statistically significant different among the treatments in both the fresh and dry weight of the spinach shoot after harvesting as shown in table 6.

Discussion

The effect of different fertilizer ratio on the spinach germinations revealed that the shortest days of germination were for treatment urea 5 and 2g. This study was conducted under manure application (cow dung) rate conditions that resulted in higher germination rates. This could be attributed to increased temperatures during decomposition of manure (Samir et al., 2016). Higher animal manure resulted in an increase of soil temperature (1-3oC) which in turn will improve the thermal conductivity of moist soil and help seed germination (Upadhyaya and Blackshaw, 2007). The high manure rates could have generated more heat that would have caused the decomposition of the inner fruit wall (endocarp) to increase the permeability of the seed coat and hence germination (Mwaburi et al., 2005).

Table 6: Effect of different fertilizer on fresh shoot weight and Dry shoot weight of spinach after harvesting at week 6

Treatment(g)	FSW	DSW
Npk 5	5.48 a	2.38 ab
Npk 3	6.80 a	3.87 a
Npk 2	5.97 a	3.44 a
Urea 5	4.89 ab	2.84 ab
Urea 3	7.44 a	4.10 a
Urea 2	5.03 a	3.10 a
Cow dung 5	6.67 a	4.37 a
Cow dung 3	6.47 a	4.37 a
Cow dung 2	6.59 a	3.18 a
Poultry manure 5	6.67 a	3.99 a
Poultry manure 3	6.47 a	3.73 a
Poultry manure 2	7.19 a	4.10 a
Control	6.03 a	3.90 a
LSD	3.99	2.28

Keys: FSW= Fresh shoot weight; DSW=Dry shoot weight; LSD=least significant difference

The effect of the different fertilizer ratio also indicates that, the number of leaves and branches were recorded to be highest at treatment urea 3g shows the highest number of leaves at 3WAS and 5WAS with 9.67 and 16.00 respectively at 4, and 6WAS poultry manure 5g and cow dung 5g show the highest value with 12.70 and 18.00, respectively. Therefore, higher levels of nitrogen results in the production of protein and enlargement of cells, thus increasing the leaf yield (Barker, 2015). Goat manure was also observed to significantly stimulate celosia leaf growth as reported by Ojeniyi (2003) that it also releases essential micronutrients to the soil.

The result for different fertilizer ratio shows that there is no well observed differences on leaf area, but the result on week 5 and 6 after sowing shows that there is statistically significant different at all the weeks (5 and 6WAS). The result shows that at

5 and 6WAS the treatment urea 3g has the highest value of leaf area with 59..43mm and 67.98mm while treatment urea 2g has the lowest value of leaf area at 5WAS with 33.43mm and 38.20mm at 6WAS.Hence, the increase in nitrogen leads to the production of protein and growth of cells which eventually leads to an increase in leaf yield (Barker 2015). Ojeniyi (2003) have also reported that goat manure also liberates essential micronutrients to the soil and was observed to significantly promote the growth of leaf in celosia.

This shows that there are statistical significant differences in the different weeks after sowing (3, 4, 5 and 6 WAS) with the plant height when grown under different fertilizer concentration. The treatment poultry manure 5g has the highest value of plant height with 11.20 at 3WAS, 4, 5 and 6WAS treatment urea 3g has the highest value with 13.50, 17.50 and 20.30 respectively. These findings are in agreement with Eifediyi (2010) who found that application of organic manure which is capable to photosynthesize led to the production of longer vine length per plant due to its ability to provide appropriate nutrition and growth of the cucumber crop. Also it is a good source of soil amendment, and improvement of soil properties which in turn resulted in improved soil growth and yield (Efideyi 2010).

The effect of different fertilizer ratio on the fresh and dry shoot weight shows that the weight of the shoot has increased both in fresh and dry weight in all the treatment as compared to control.

Conclusion

The differential effects of organic and inorganic fertilizers on the morphological characteristics of spinach in the semi-arid environment of Federal University Dutse was successfully proven in this research. The main findings of the study reveals that the NPK and urea inorganic fertilizers at 3g application rate was the most effective, thereby suggesting that over-application of fertilizer can be harmful to plant growth. This also reveals that the higher rate of 5g per pot of organic fertilizers (cow dung and poultry manure) was optimum owing to their low nutrient-density and slow release. The results highlight the need to take a holistic perspective of nutrient management, including the specific application rate and type of fertilizer.

The study offers a practical recommendation for local farmers to achieve maximum yield of spinach with specific and effective doses of conventional and organic sources of fertilizers. The findings are in line with the sustainability of using organic manures since they enhance soil health and offer a cost-effective and readily available nutrient source.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: study design: Mohammad. M; data collection: Nancy. J; analysis and interpretation of results: Mohammad. M, Nancy. J, Idris, A; draft manuscript preparation: Idris A. All authors reviewed the results and approved the final version of the manuscript.

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