

ASSESS THE EFFECT OF ORGANIC AND INORGANIC SOIL SUPPLEMENTS ON GROWTH AND YIELD OF SPINACH (*SPINACIA OLERACEA*)

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Abstract

Spinach (*Spinacia oleracea*) is an important leafy vegetable valued for its high nutritional content, particularly essential minerals such as calcium and magnesium. Sustainable nutrient management and efficient irrigation practices are essential for improving soil health and crop productivity. The present study evaluated the effect of organic and inorganic soil supplements on the growth, nutrient enrichment, and soil properties of spinach cultivated under a sprinkler irrigation system. The experiment was conducted at the field laboratory. The study consisted of three treatments with two replications: T1 - organic fertiliser (egg shell powder, fish meal, and panchagavya), T2 - inorganic fertiliser (NPK), and T3 - control without fertiliser application. Soil samples were collected before and after the cropping period to analyse physicochemical parameters, including pH, electrical conductivity, organic matter, nitrogen, phosphorus, and potassium. The results indicated that the T1 treatment improved soil quality by increasing soil organic carbon and slightly reducing soil pH compared to T2 and T3, suggesting enhanced soil fertility due to organic amendments. Nutrient analysis of spinach leaves showed that T1 recorded the highest calcium content (8429.7 ppm), while T2 exhibited the highest magnesium content (8183.95 ppm), whereas the control plot showed comparatively lower values. The sprinkler irrigation system maintained good water distribution efficiency, ranging from 81% to 88% during the cropping period. Overall, the study demonstrates that the integration of organic soil supplements with an efficient sprinkler irrigation system can improve soil health, enhance nutrient enrichment in spinach, and support sustainable vegetable production.

Keywords: *Spinach, cropping period, organic, nutritional content, inorganic soil.*

1. Introduction

By 2050, the world population is projected to rise by 9 billion, presenting an unprecedented challenge for global food security. To meet the nutritional needs of this growing population, we must double our current crop production. Achieving this goal will require the adoption of innovative and environmentally sustainable technologies, with a particular focus on optimising the soil microenvironment, which is the critical zone surrounding plant roots where essential interactions between nutrients, roots, and plants [1]. At the same time, many farmers use chemical fertilisers to boost crop production. However, the long-term use of chemical fertilisers negatively impacts the environment, degrades soil quality, reduces biodiversity, and increases input costs, making them unaffordable for many farmers. In response, organic agriculture is gaining global attention, particularly through the use of microbial-based biofertilizers. In this practice, carriers play a crucial role by protecting beneficial microbes, providing them with nutrients, energy, and suitable conditions for survival as they are introduced into natural environments as well as organic amendments provide dual benefits to farmers: they are both economical and environmentally friendly, by improving soil fertility and structure without the harmful side effects associated with chemical fertilizers, Spinach (*Spinacia oleracea* L.) is an important leafy vegetable known for its high nutritional value, particularly as a rich source of calcium and magnesium, which are essential for bone health, enzyme activity, and metabolic functions in humans [2]. Additionally, spinach contains antioxidants that support overall health and help in managing conditions such as diabetes [17]. This study supports the UN Sustainable Development Goals, particularly SDG 2 (Zero Hunger), by enhancing crop productivity and nutritional quality. It promotes SDG 12 (Responsible Consumption and Production) by using organic soil supplements that improve soil health and reduce environmental impact. The study also contributes to SDG 3 (Good Health and Well-being) by improving the calcium and magnesium content of spinach to support human nutrition. Overall, it emphasises sustainable agricultural practices for long-term soil fertility and food security.

2. Materials and methods

2.1 Study Area and Experimental Design

The present research was conducted in a field laboratory to evaluate the efficiency of organic fertiliser and the nutrient uptake mechanisms of spinach (*Spinacia oleracea*) compared with soil supplemented with inorganic fertilisers. The experiment was conducted under controlled field conditions, using a sprinkler irrigation system, to assess the crop's growth performance. The field experiment was conducted by dividing the study area into three treatments with two replications. The treatments were arranged as R1T0, R1T1, R1T3 and R2T0, R2T2, R2T3. Treatment T0 consisted of organic soil supplements such as eggshell powder, Pancha Kavya, and fish meal, which were applied to improve soil fertility and plant growth. Treatment T1 received inorganic fertilisers, mainly NPK, to evaluate the effect of chemical nutrient supply on crop performance. Treatment T3 served as the control plot without the application of any soil supplements. The crop selected for the experiment was spinach (palak), which was cultivated under these treatment conditions. Soil supplements were applied at an interval of 15 days throughout the crop growth period. Regular crop management practices, including weeding, fertiliser application, and efficiency testing of the sprinkler irrigation system, were carried out on a weekly basis to maintain proper field conditions. Irrigation was provided through a sprinkler system at an interval of every two days to ensure adequate soil moisture for optimal crop growth.

2.3 Crop and Variety Selection

Spinach (*Spinacia oleracea* L.), commonly known as palak, was selected as the test crop for this study due to its high nutritional value and importance in the human diet. Spinach is widely recognised as a rich source of essential minerals such as calcium (Ca) and magnesium (Mg), which play a vital role in bone health and metabolic functions. In addition, spinach is considered beneficial for individuals with diabetes because of its low glycaemic index and high antioxidant content, which may help regulate blood sugar levels. Due to these nutritional and health benefits, spinach has gained significant attention as a functional leafy vegetable crop. Moreover, spinach is a fast-growing leafy vegetable that responds well to soil nutrient management practices, making it suitable for evaluating the effects of organic and inorganic soil supplements under field conditions [3], [4], [5].

2.4 Soil Supplements

Soil samples were collected from each experimental plot using the scattered sampling method to obtain representative samples for nutrient analysis. Pre-soil and post-soil sampling were carried out to evaluate the changes in soil nutrient status before and after treatment application. In this study, organic soil supplements such as eggshell powder were applied to improve soil fertility and supply essential nutrients, particularly

calcium, which can enhance soil structure and nutrient availability [6]. Inorganic fertilisers (NPK) were applied in selected plots (R1T1, R2T2) to compare their influence on soil nutrient dynamics and crop performance with other plots. The results obtained from these treatments (R1T1, R2T1) were compared with the (R1T0, R2T0) organic plots, (R1T3, R2T3) control plots, where no soil supplements were applied. However, prolonged and excessive use of inorganic fertilisers may lead to soil salinity and alterations in soil pH, which can negatively affect plant growth and reduce soil microbial diversity and activity, ultimately impacting soil health and sustainability [7], [8].

Field preparation and sowing

The experimental field was prepared by ploughing with a tractor to obtain a fine tilth suitable for crop establishment. Proper land preparation improves soil aeration, water infiltration, and root development, which are essential for uniform germination and crop growth [9]. After ploughing, the field was levelled and divided into experimental plots based on the treatment design. Spinach (*Spinacia oleracea* L.) seeds were sown using the broadcasting method to ensure uniform seed distribution across all plots. Broadcasting is a commonly adopted method for leafy vegetables, as it facilitates rapid establishment and efficient ground coverage [10]. Adequate soil moisture was maintained during and after sowing to promote proper seed germination and early seedling development. Overall, appropriate field preparation and sowing techniques play a crucial role in achieving better plant stand and higher productivity in spinach cultivation [9], [10].

Sprinkler irrigation system

Irrigation was carried out using a sprinkler irrigation system based on crop water requirements estimated through the CROPWAT 8.0 model, which incorporates evapotranspiration and climatic parameters [11]. Water was applied once every two days to maintain optimum soil moisture for the growth of spinach (*Spinacia oleracea* L.) and to ensure efficient water use [12]. The use of scientific irrigation scheduling methods has been reported to improve crop productivity and reduce water losses under field conditions [11], [12]. To evaluate the performance of the sprinkler system, catch can tests were conducted twice a week throughout the experimental period, enabling the assessment of water distribution uniformity and irrigation efficiency [13]. Regular monitoring of sprinkler performance helps in achieving uniform water application, enhancing crop response, and promoting sustainable irrigation practices [13], [14].

Crop nutrient analysis

Crop nutrient analysis was conducted to determine the calcium (Ca) and magnesium (Mg) content in spinach (*Spinacia oleracea* L.) under different treatment conditions. From each plot, three representative samples were collected at harvest, cleaned, oven-dried, and finely ground for laboratory evaluation. Standard analytical methods were followed to quantify the mineral content accurately [15]. The analysis aimed to assess the influence of organic and inorganic soil supplements on nutrient uptake and crop quality [16]. The obtained values were compared with control plots to understand the effectiveness of different treatments in enhancing nutritional composition [16], [17]. Since calcium and magnesium are vital for bone health and metabolic activities in humans, improving their concentration in spinach can contribute to better nutritional intake and overall well-being [17], [18].

Results and discussion

Soil samples were collected from the experimental plots before and after treatment to assess the changes in soil chemical properties under different treatments. The results of the soil parameter analysis are presented in the following table.

Table 5.1 Comparative analysis of Pre and post-soil sample results

Chemical properties	Pre-soil sampling (T0)	Post-Soil Sampling			TNAU Range
		T1	T2	T3	
Electrical Conductivity (dS/m)	0.12	0.27	0.2	0.17	0.0-1.0
pH	7.1	7.4	7.4	7.3	6.0-7.5
Organic Carbon	0.28	0.53	0.09	0.22	0.51-0.75
N (Kg/ha)	17	73	54	70	113-180
P (Kg/ha)	08	08	08	5	4.5-9
K (Kg/ha)	25	31	34	34	48-113
S (Kg/ha)	12	16	20	22	10-15
Fe (Kg/ha)	5.28	5.02	4.43	4.36	Greater than 3.5
Mn (Kg/ha)	3.06	2.69	2.36	2.28	>2.0
Zn (Kg/ha)	0.56	0.47	0.43	0.42	>1.2
Cu (Kg/ha)	0.62	0.73	0.72	0.8	>1.2
B (Kg/ha)	0.4	5	0.4	0.2	>0.5

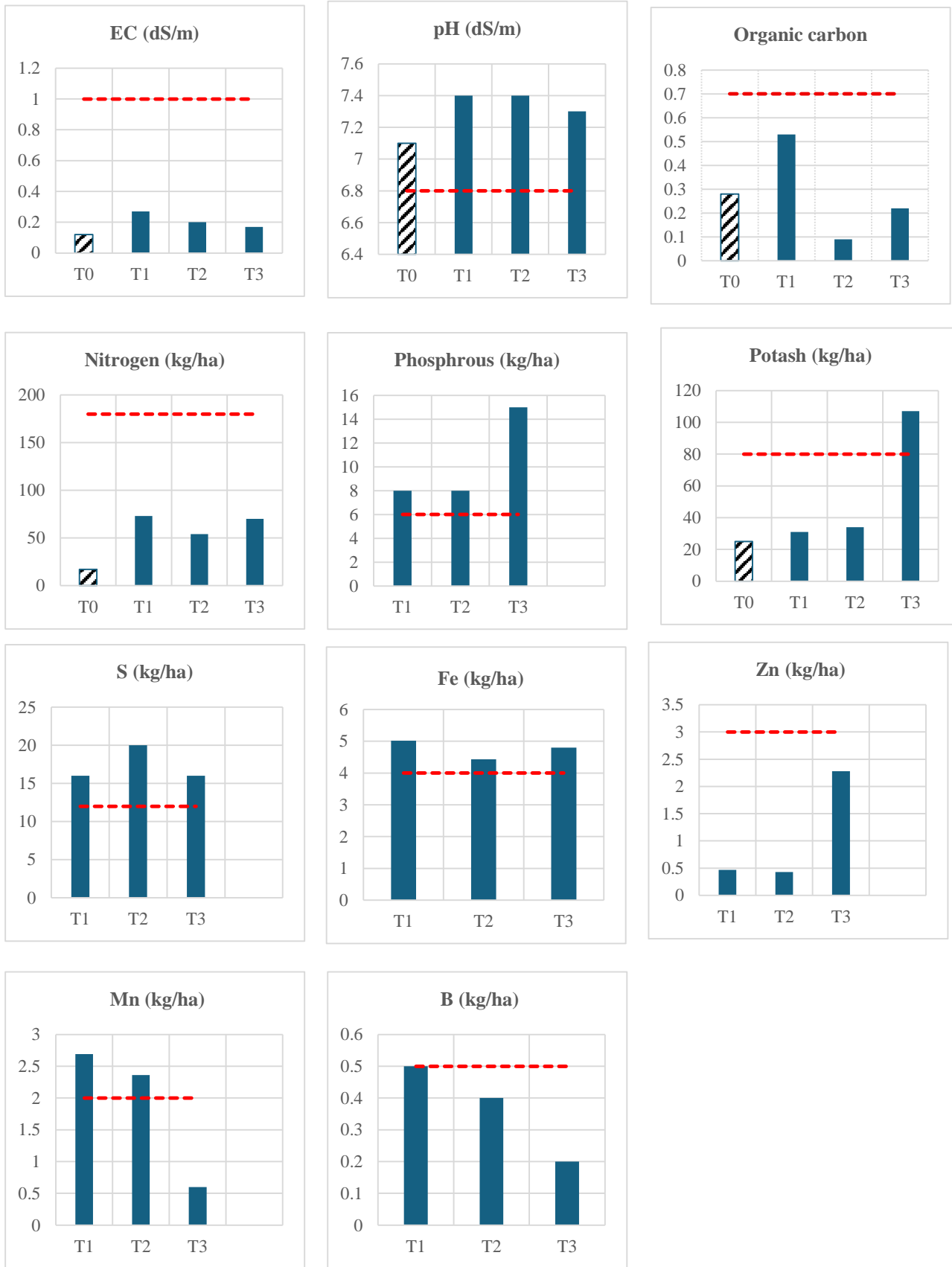


Fig Comparative analysis of Pre and post-soil sample results

The soil test results showed noticeable differences among the treatments. The plots T1R1 and T1R2, supplemented with eggshell, panchagavya, and fish meal, recorded higher organic carbon (0.53%) and nitrogen (73 kg/ha) compared to other treatments, indicating improved soil fertility due to organic amendments. The T2R1 and T2R2 plots treated with inorganic fertilisers showed moderate nutrient availability, particularly in potassium (34 kg/ha) and sulphur (20 kg/ha). The control plots (T3R1 and T3R2) recorded comparatively lower nutrient status,

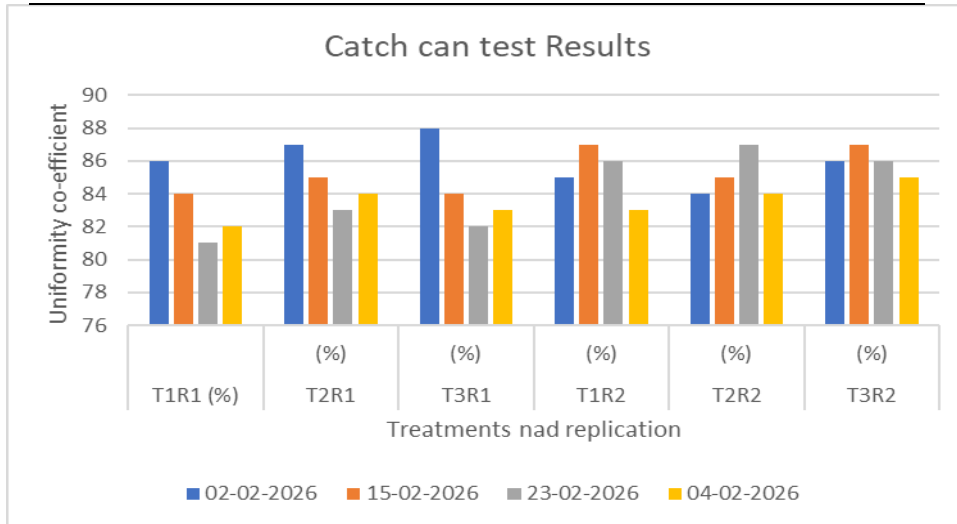
especially in organic carbon (0.22%) and phosphorus (5 kg/ha). However, the pH (7.1–7.4) and electrical conductivity (0.12–0.27 dS/m) across all treatments remained within the acceptable range, indicating suitable soil conditions for crop growth. Overall, the organic amendment treatment (T1) showed better improvement in soil nutrient status compared to the inorganic fertiliser and control treatments.

5.2 SPRINKLER EFFICIENCY ANALYSIS

The uniformity of the sprinkler irrigation system was evaluated periodically using the catch can method during the cropping period. The uniformity percentage recorded for each treatment plot (T1, T2, and T3) on different dates is presented in the table below.

Table 4.3 Sprinkler can-can test result

DATE	T1R1 (%)	T2R1 (%)	T3R1 (%)	T1R2 (%)	T2R2 (%)	T3R2 (%)
02/02/2026	86	87	88	85	84	86
15/02/2026	84	85	84	87	85	87
23/02/2026	81	83	82	86	87	86
04/02/2026	82	84	83	83	84	85

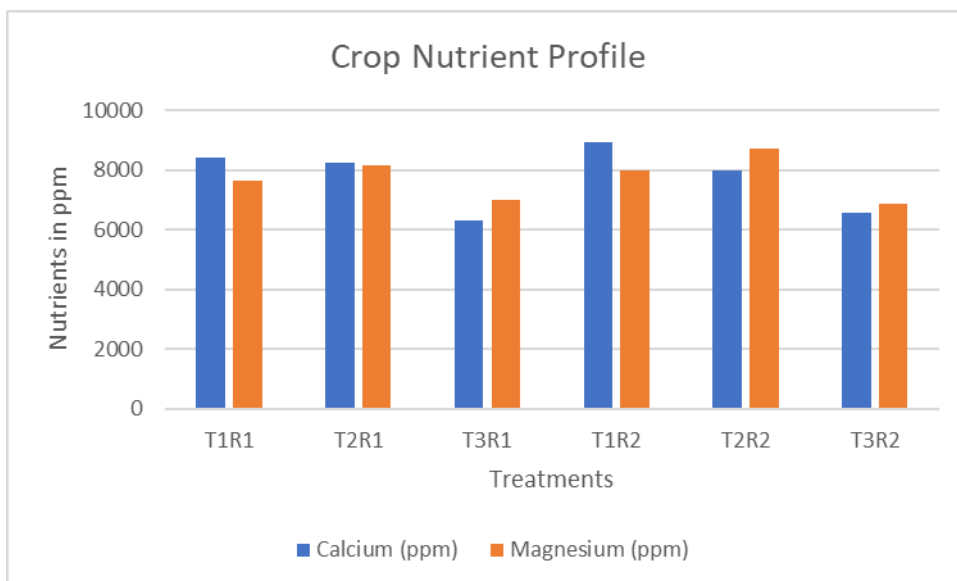


The efficiency of the sprinkler irrigation system was measured on different dates across all treatments. The results indicated that the sprinkler efficiency ranged between **81% and 88%** during the study period. The highest efficiency (**88%**) was recorded in **T3R1 on 02/02/2026**, while the lowest efficiency (**81%**) was observed in **T1R1 on 23/02/2026**. Overall, the efficiency values remained relatively consistent across treatments, indicating that the sprinkler system performed effectively throughout the experimental period.

5.3 CROP NUTRIENT ANALYSIS

Table 4.4 Crop nutrient analysis test

TREATMENT	Calcium (ppm)	Magnesium (ppm)
T1R1	8429.7	7655.85
T2R1	8257.00	8183.95
T3R1	6297.93	6994.88
T1R2	8935.3	7981.2
T2R2	7996.3	8725.23
T3R2	6581.1	6874.3

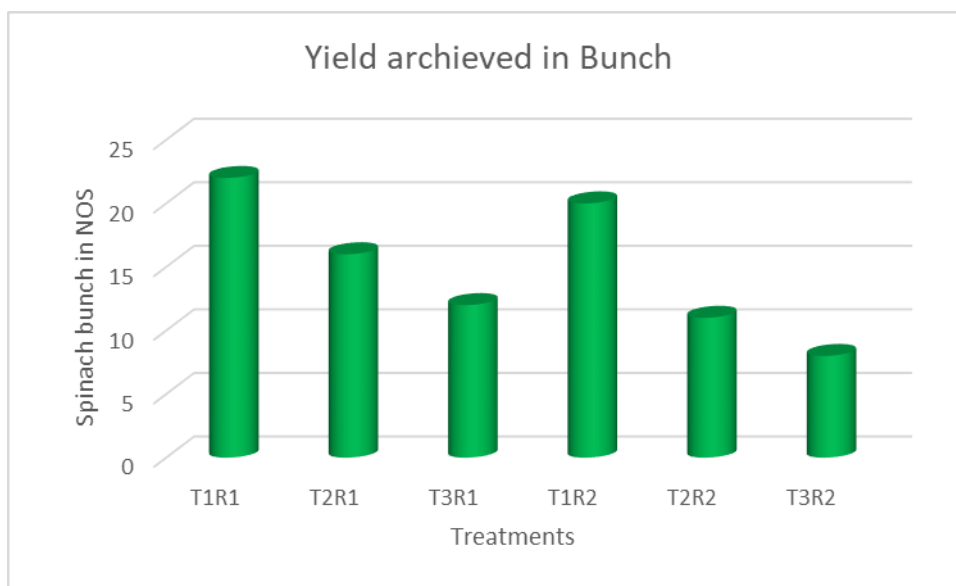


The comparison of soil test results with the mineral nutrient profile indicated that soil nutrient availability influenced the uptake of calcium and magnesium in the crop. The treatments T1R1 and T1R2, where organic supplements such as eggshell, panchagavya, and fish meal were applied, showed improved soil fertility and recorded the highest calcium content (8429.7–8935.3 ppm) and good magnesium levels (7655.85–7981.2 ppm) in the plant samples. The treatments T2R1 and T2R2, which received inorganic fertilisers, showed comparatively higher magnesium content (8183.95–8725.23 ppm) but slightly lower calcium levels than the organic treatment. The control treatments (T3R1 and T3R2) recorded the lowest values for both calcium (6297.93–6581.1 ppm) and magnesium (6874.3–6994.88 ppm), reflecting the lower nutrient availability in the soil without supplementation. Based on the correlation between soil nutrient status and plant mineral content, the T1 treatment with organic soil supplements performed the best, as it enhanced soil fertility and resulted in higher mineral accumulation in the crop compared to inorganic fertiliser and control treatments.

5.4 YIELD ANALYSIS BETWEEN THE PLOTS

Fig 5.2 Spinach Yield between the treatments

Treatments	Yield in (Bunches)
T1R1	22
T2R1	16
T3R1	12
T1R2	20
T2R2	11
T3R2	08



The yield results showed a clear relationship with the soil nutrient status obtained from the soil sample analysis. The T1 treatments (T1R1 and T1R2), where organic soil supplements were applied, recorded improved soil fertility with higher organic carbon (0.53%) and nitrogen (73 kg/ha) compared to other treatments. Correspondingly, these plots produced the highest yield of 22 and 20 bunches, indicating better crop performance due to improved nutrient availability in the soil. The T2 treatments (T2R1 and T2R2), which received inorganic fertilisers, showed moderate soil nutrient levels and produced 16 and 11 bunches, respectively. In contrast, the control plots (T3R1 and T3R2) recorded relatively lower soil fertility with organic carbon (0.22%) and lower nutrient availability, resulting in the lowest yield of 12 and 8 bunches. Thus, the results indicate that the application of organic soil supplements improved soil nutrient status and significantly enhanced crop yield compared to inorganic fertiliser and control treatments, with T1 identified as the best treatment.

6. CONCLUSION

The effect of different soil supplements on soil fertility, plant nutrient content, and crop yield was evaluated under a sprinkler irrigation system. Soil analysis showed that the application of organic amendments improved soil properties, particularly organic carbon and nitrogen levels. Plants grown in the organically treated plots recorded higher mineral concentrations, especially calcium and magnesium, indicating better nutrient uptake. The yield results also followed the same trend, where the organic treatment (T1) produced the highest yield of 22 and 20 bunches, followed by the inorganic fertiliser treatment (T2) with 16 and 11 bunches, while the control treatment (T3) recorded the lowest yield of 12 and 8 bunches. The sprinkler irrigation system maintained consistent efficiency throughout the experimental period. Statistical analysis using ANOVA showed significant differences among the treatments for soil nutrients, crop nutrient content, and yield with an F value of 8.42 at the 5% significance level. Overall, the organic soil supplement treatment (T1) showed better performance in improving soil fertility, enhancing nutrient uptake, and increasing crop yield compared to the other treatments.

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