PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol 12(2): 1-9
https://doi.org/10.14719/pst.6620

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RESEARCH ARTICLE

Assessment of the effect of organic amendments on soil properties and yield of Brinjal (*Solanum melongena* L.)

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OPEN ACCESS

ARTICLE HISTORY
Received: 09 December 2024
Accepted: 26 January 2025
Available online
Version 1.0 : 20 March 2025
Version 2.0 : 01 April 2025

Check for updates

Additional information
Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

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Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
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CITE THIS ARTICLE
Bhan S, Thakur KS, Kansal S, Chahuan A, Deep N, Bhatia S, Dutta I, Nikhil. Assessment of the effect of organic amendments on soil properties and yield of Brinjal *(Solanum melongena L.)*. Plant Science Today. 2025; 12 (2): 1-9. https://doi.org/10.14719/pst.6620

Abstract

The study assessed the effects of organic amendments on the yield of Brinjal (*Solanum melongena* L.) cv. Pusa Purple Cluster and soil properties. The study was carried out during two consecutive kharif seasons - 2018 and 2019. The experiment was laid out in Randomised Block Design, with three replications and eight treatments (T_1: Absolute control, T_2: FYM (Farm yard manure) @10 t/ha, T_3: Vermicompost (VC) @5 t/ha, T_4: FYM @5 t/ha + VC @2.5 t/ha, T_5: Beejamrit + Jeevamrit, T_6: FYM @10 t/ha + Beejamrit + Jeevamrit, T_7: VC @5 t/ha + Beejamrit + Jeevamrit, T_8: FYM @5t/ha + VC @2.5 t/ha + Beejamrit + Jeevamrit). Treatment T_7 (application of vermicompost at 5 t/ha in conjunction with Beejamrit and Jeevamrit) showed the most significant impact on the growth of *Solanum*. The plants attained the highest yield and biomass in this treatment, where the availability of nitrogen, phosphorus and potassium content was highest. The plants of the treatment T_7 also showed high uptake of nutrients such as N, P and K. Results of the benefit-cost analysis indicated that plants of treatment of T_7 gave maximum net return and gross income. The addition of organic supplements improved soil health and increased plant resistance to biotic stressors along with increasing crop productivity. The findings of the study highlighted the significance of organic nutrient management in sustainable agriculture. Restoration of the organic content of soil can prove as an effective approach for getting high productivity. Therefore, this strategy can be recommended for brinjal farming systems as it preserves soil fertility and ensures high crop growth and productivity.

Keywords

beejamrit; biomass; brinjal; jeevamrit; organic nutrient; vermicompost

Introduction

Aubergine or brinjal is a crucial crop in the Solanaceae family that is grown year-round in various regions of India. It has high amounts of copper and vitamin C compared to green varieties and is rich in dietary fibre, antioxidants, calcium, phosphorus, iron and vitamin B (1, 2). Brinjal offers several health benefits, including aiding in weight management, regulating or lowering the blood sugar level and minimising the risk of heart disease among other health advantages (3, 4).

Soil fertility is affected by various physical, chemical and biological factors. Soil microbial characteristics act as the primary markers of soil biological fertility. Standard farming practices rely much on chemical fertilisers resulting in reduced nutrient intake efficiency, stagnant production and harmful environmental effects (5). Excessive application of chemical fertilisers resulted in soil acidification, imbalance of soil nutrient levels and a decline in agricultural sustainability. Partial replacement of chemical fertilisers with organic amendments can help lower the input of chemical fertilisers and guarantee soil sustainability (6).

Compost and other amendments add a substantial amount of organic matter to the soil, which positively impacts the soil's physical, chemical and biological characteristics (7, 8). The nutrients from compost and other organic sources get added to soil and transform into available forms that plants can use. Organic amendments such as compost, farmyard manure and vermicompost play an important role in sustainable brinjal production. These amendments improve soil structure, increase soil fertility, lower production costs and benefit the environment. Organic supplements used for nutrient management boost soil quality, elevate microbial activity and support sustainable agriculture (9). It is a very effective system that focuses on the use of green manures, organic manures and biofertilizers in order to promote soil health as it results in increased yield leading to high economic value.

Thus, the aim of this study is to know whether various organic nutrients affect the properties of soil and the productivity of brinjal. It will also help in developing strategies for maximising productivity, improving soil health and getting maximum economic benefits for the farmers via promoting agricultural growth.

Materials and Methods

The study was carried out at the Department of Vegetable Science, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP), India. The experimental site was situated at an elevation of 1,270 meters above sea level. The site was located within the mid-hills of Himachal Pradesh, positioned at approximately 30˚5' North latitude and 77˚11' East longitude (Fig. 1). The studies were carried out during the Kharif seasons of 2018 and 2019. Seeds of the Pusa Purple Cluster variety of Brinjal were sown in the month of March of both years to raise seedlings. The experiment comprised 8 treatments with 3 replications each (Table 1). Before sowing, half of the seeds were treated with beejamrit to enhance seed vigour, promote beneficial microbial activity and protect against soil-borne pathogens. This was to ensure improved germination and healthy growth, crop was raised by following standard cultural practices outlined in the Package of Practices for vegetable crops published by the Directorate of Extension, UHF, Nauni. Organic manures, specifically vermicompost and well-rotted farmyard manure, were

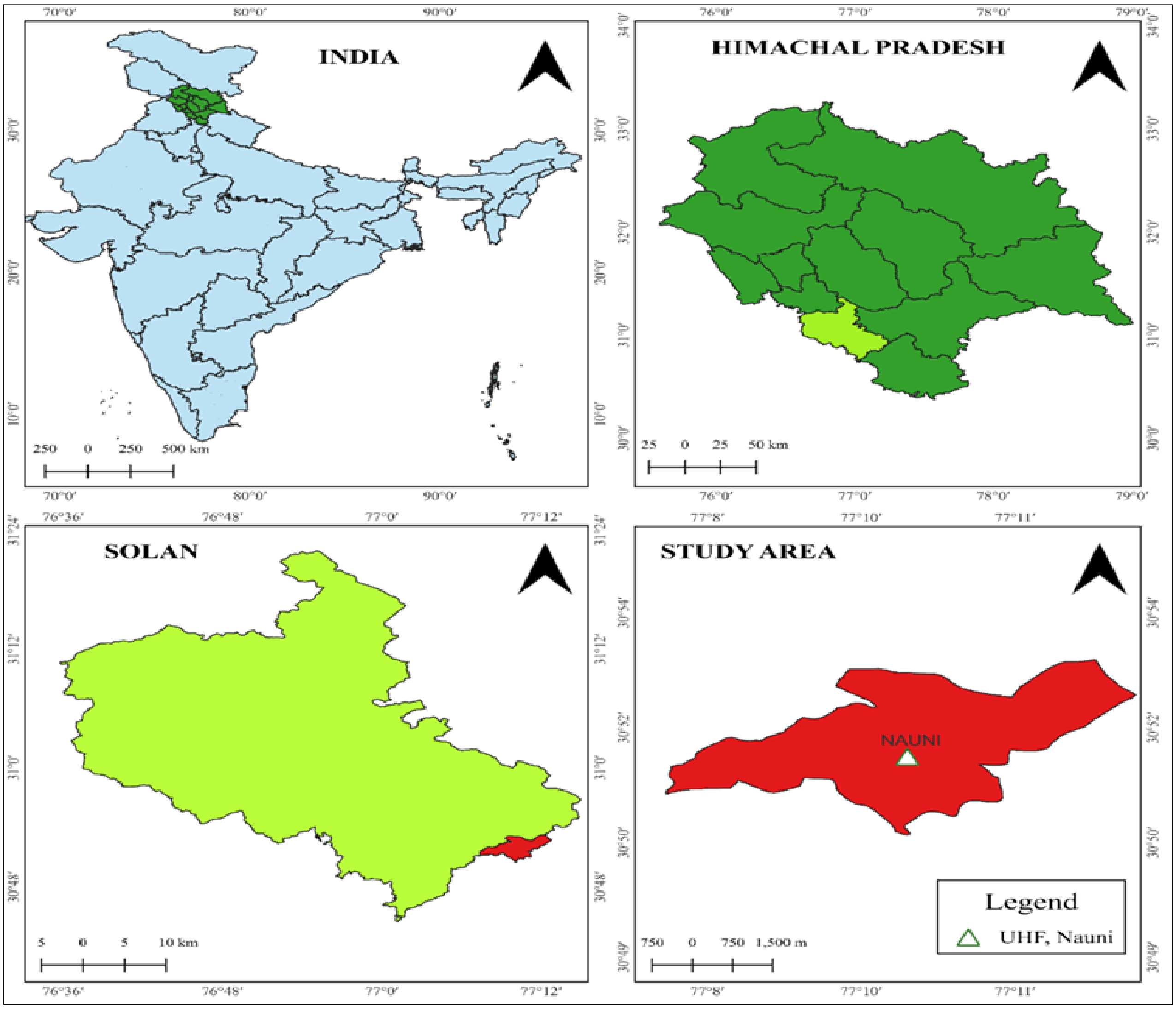

Fig. 1. Graphical representation of study area.

Table 1. Details of the soil treatment

Treatment code	Treatment Details
T_1	Absolute Control
T_2	Farm Yard Manure (FYM) @ 10 t/ha
T_3	Vermicompost (VC) @ 5 t/ha
T_4	Farm Yard Manure (FYM) @ 5 t/ha + Vermicompost (VC) @ 2.5 t/ha
T_5	Beejamrit (Seed treatment) + Jeevamrit (Drenchings + Foliar spray)
T_6	Farm Yard Manure (FYM) @ 10 t/ha + Beejamrit (Seed treatment) + Jeevamrit (Drenchings + Foliar spray)
T_7	Vermicompost (VC) @ 5 t/ha + Beejamrit (Seed treatment) + Jeevamrit (Drenchings + Foliar spray)
T_8	Farm Yard Manure (FYM) @ 5t/ha + Vermicompost (VC) @ 2.5 t/ha + Beejamrit (Seed treatment) + Jeevamrit (Drenchings + Foliar spray)

applied during land preparation based on their respective treatments and N-equivalent requirements. Transplanting of 40-45 day-old seedlings was done in May to plots measuring 5.4 m^2 with spacing of 60 × 45 cm. To enhance soil fertility and plant growth, Jeevamrit, a bio-fertilizer, was applied by drenching the soil at a concentration of 5% (500 ml per 10 litres of water) on 15, 30 and 45 days after transplanting. Additionally, three foliar sprays of Jeevamrit at 5% concentration were applied at 15-day intervals following the initial soil drenching. The composition and preparation of beejamrit and jeevamrit are shown in Fig. 2.

The samples for the soil's physico-chemical properties from various spots were collected from a depth of 0-15 cm prior to transplanting of brinjal and have been summarised in Table 2. Details of methods for estimation of available NPK contents are described below by adopting the following methods.

Available N was estimated using the alkaline potassium permanganate method (10), while available P was assessed by the stannous chloride-reduced molybdate method in the HCL system (11). Available K was measured by the neutral ammonium acetate method (12).

To examine the effect of different organic nutrient supplements from an economic aspect, the cost of brinjal production under various treatments was evaluated. Current input and output prices were taken into account and gross return was computed using the market price of the produce when ready for sale. Net returns and benefit-cost ratios were calculated for each treatment using the following formulae:

$$\text{Net return (₹/ha)} = \text{Gross returns (₹/ha)} - \text{Cost of cultivation (₹/ha)} \qquad \text{Eqn. 1}$$

$$\text{Benefit : Cost ratio} = \frac{\text{Net returns (₹/ha)}}{\text{Cost of cultivation (₹/ha)}} \qquad \text{Eqn. 2}$$

Statistical analysis

The values of each study result were given as mean ± standard error. Two-way analysis of variance (ANOVA) was done to estimate the level of significance at a 5% level using the statistical techniques used in R (R Studio, 2024.3.6.0) (Package used: stats, Agricolae). Pooled data was analysed using a box plot technique to evaluate characteristics and heatmap was constructed (Packages used: ggplot, dplyr, tidyverse). The coefficient of variation (CV) was calculated to investigate variations within or across treatments.

Results

Yield and plant biomass

Various organic inputs had significant effects on the yield and plant biomass of brinjal (Table 3) (Fig. 3). Treatment T_7 showed maximum yield (170.31 q/ha) and plant biomass (1925.38 kg/ha), while T_1 was the treatment that produced minimum yield (114.16 q/ha) and plant biomass (1054.61 kg/ha).

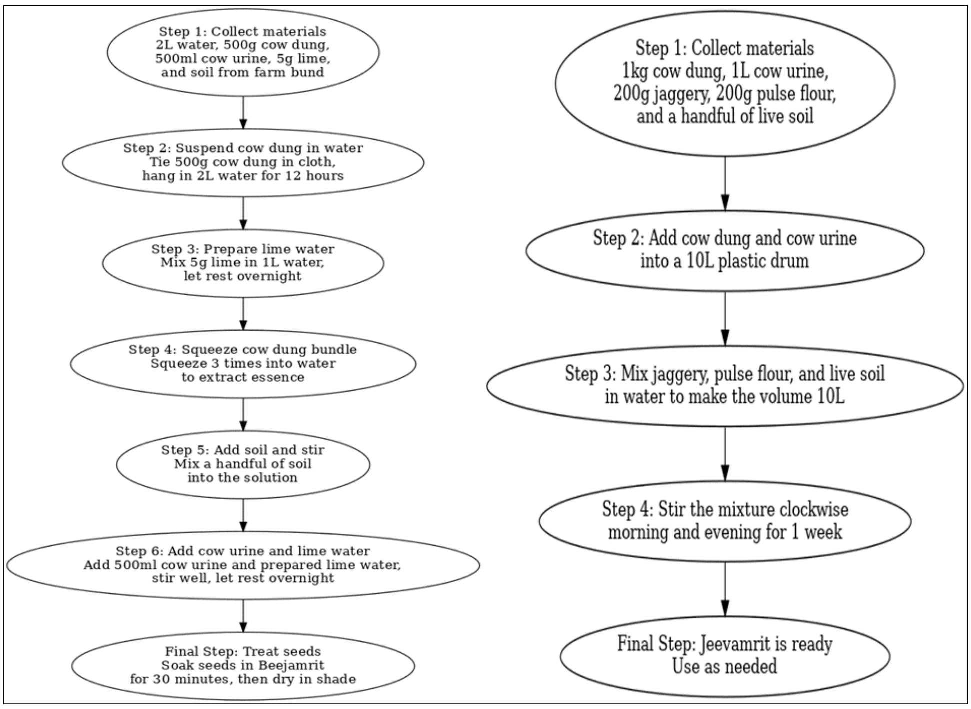

Fig. 2. Composition and preparation of beejamrit and jeevamrit.

Table 2. Physio-chemical characteristics of soil measured before crop plantation

Soil characteristics	Values obtained	Normal Range	Methods used for estimation
Electrical conductivity (ds/m)	0.43	Below 0.8	Electrical conductivity meter 1:2.5 soil water suspension (Jackson, 1967)
pH	7.26	6.5–8.5	1:2.5 soil water suspension with digital pH meter (Jackson, 1967)
Organic carbon (%)	1.28	0.40–0.75	Walkely and Black, 1934
Available Nitrogen (kg/ha)	351.23	272–544	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available Phosphorus (kg/ha)	56.00	12–22	Olsen's method (Olsen *et al*., 1954)
Available Potassium (kg/ha)	349.44	136–333	Ammonium acetate method (Jackson, 1973)

Table 3. Effect of different treatments on various plant growth parameters and nutrient levels.

Treatments	Plant Yield (q/ha)	Plant Biomass (kg/ha)	Available Nitrogen (kg/ha)	Available Phosphorus (kg/ha)	Available Potassium (kg/ha)
T_1	$114.16^{d} \pm 3.17$	$1054.61^{f} \pm 28.93$	$281.10^{d} \pm 13.31$	$44.37^{d} \pm 3.07$	$277.77^{c} \pm 14.48$
T_2	$122.57^{d} \pm 2.79$	$1209.23^{e} \pm 16.67$	$297.78^{cd} \pm 11.61$	$45.84^{cd} \pm 3.03$	$297.68^{bc} \pm 17.90$
T_3	$150.33^{b} \pm 3.71$	$1659.72^{bc} \pm 70.49$	$314.89^{abc} \pm 11.66$	$52.19^{b} \pm 1.78$	$315.06^{ab} \pm 19.34$
T_4	$138.48^{c} \pm 2.86$	$1552.05^{cd} \pm 87.45$	$309.24^{abc} \pm 9.58$	$51.81^{b} \pm 2.57$	$310.11^{ab} \pm 15.00$
T_5	$145.15^{bc} \pm 3.58$	$1291.91^{e} \pm 53.92$	$293.93^{cd} \pm 8.93$	$48.90^{bc} \pm 3.03$	$299.03^{bc} \pm 11.89$
T_6	$149.87^{b} \pm 2.77$	$1449.97^{d} \pm 69.16$	$302.03^{bcd} \pm 11.42$	$52.73^{b} \pm 3.81$	$306.17^{ab} \pm 13.39$
T_7	$170.31^{a} \pm 2.80$	$1925.38^{a} \pm 75.96$	$330.88^{a} \pm 14.53$	$60.76^{a} \pm 2.69$	$324.58^{a} \pm 12.58$
T_8	$162.53^{a} \pm 2.36$	$1744.05^{b} \pm 58.18$	$323.35^{ab} \pm 11.69$	$58.14^{a} \pm 3.80$	$319.26^{ab} \pm 13.66$
CV (%)	4.96	6.65	6.17	6.69	6.24

*Means with different letters are significantly different according to Duncan's multiple range test at p < 05.

**CV = Coefficient of variation.

Improvement in vegetative growth and an increase in fruit yield was noted in treatment T_7. The greater nutrient availability attributed to the use of vermicompost and jeevamrit during the critical growth stage might have led to a higher synthesis of carbohydrates, their translocation and absorption by the plants. Vermicompost increased the amount of nutrients in the soil and enhanced the physical health of the soil (13, 14). A notable increase in brinjal yield with the use of vermicompost was observed in earlier studies (15). A significant increase in the production of chilli by using vermicompost and poultry manure was also observed in another study (16). Jeevamrit treatment has shown to increase the yield of tomatoes and brinjal fruits as well as the bulb yield of onions when combined with other organic manures, biofertilisers, trap crops, biological pest management and Integrated Nutrient Management (INM) (17-26).

Available NPK content (kg/ha) in soil

The data presented in Table 3 for available N, P and K signifies the positive impact of various treatments on the available nutrient content of soil (Fig. 3). Maximum available N content of 330.88 kg/ha, P content of 60.76 kg/ha and K content of 324.58 kg/ha was found in T_7 followed by T_8 with 323.35 kg/ha N, 58.14 kg/ha P and 319.26 kg/ha K. Conversely, T_1 had the minimum available nitrogen content of 281.10 kg/ha, phosphorus 44.37 kg/ha and 277.77 kg/ha K.

The application of vermicompost might have raised the soil's bacterial population density which converts nitrogen from its organic form to an inorganic form. Increase in microbial density which might have contributed to increase in soil's available nitrogen concentration. An increase in soil N content after the addition of vermicompost was noted in another study (14). These results also align with the observations made in similar studies (27, 28).

It was observed from a study that an increase in P levels in the soil was most likely the result of the gradual release of P by vermicompost facilitated by soil microorganism activity (29). Similar results of an increase in soil P by the application of organic amendments were demonstrated (30, 31). An increase in phosphatase activity and material physical breakdown contributed to an increase in mineralisation (32). The addition of P leads to the formation of chelates with Fe and Al which upon decomposition produce a variety of organic acids that aid in the solubilization of native P. This might be the reason for enhanced P content in the soil after the supplementation of vermicompost and jeevamrit (33, 34).

The interaction of organic matter with clay particles reduces potassium fixation resulting in a direct release of potassium into the soil, which might be responsible for an increase in potassium concentration (35, 36). Another research also reported that an increase in soil organic matter led to a decrease in K fixation and an increase in K availability (37). Soil's potassium concentration rises with extended usage of mineral fertilisers, manure, compost and other ameliorants. The high K content of organic amendments raises CEC, which in turn leads to an increase in levels of soil potassium. The outcomes also align with the findings of previous investigations (38-47).

NPK uptake by plant

Data related to the uptake of NPK content across various treatments (T_1 to T_8) is presented in Table 4 (Fig. 3). The uptake of nitrogen was maximum in treatment T_7 followed by T_8 i.e., 2.20% and 2.11%, respectively, whereas uptake was minimum in treatment T_1 (1.92%). The maximum phosphorus uptake was recorded in treatments T_7 (0.58%) followed by T_8 (0.54%). On the other hand, T_1 showed a minimum mean uptake of P (0.38%). Treatments T_7 and T_8 had the maximum potassium uptake, with values of 2.07% and 2.04%

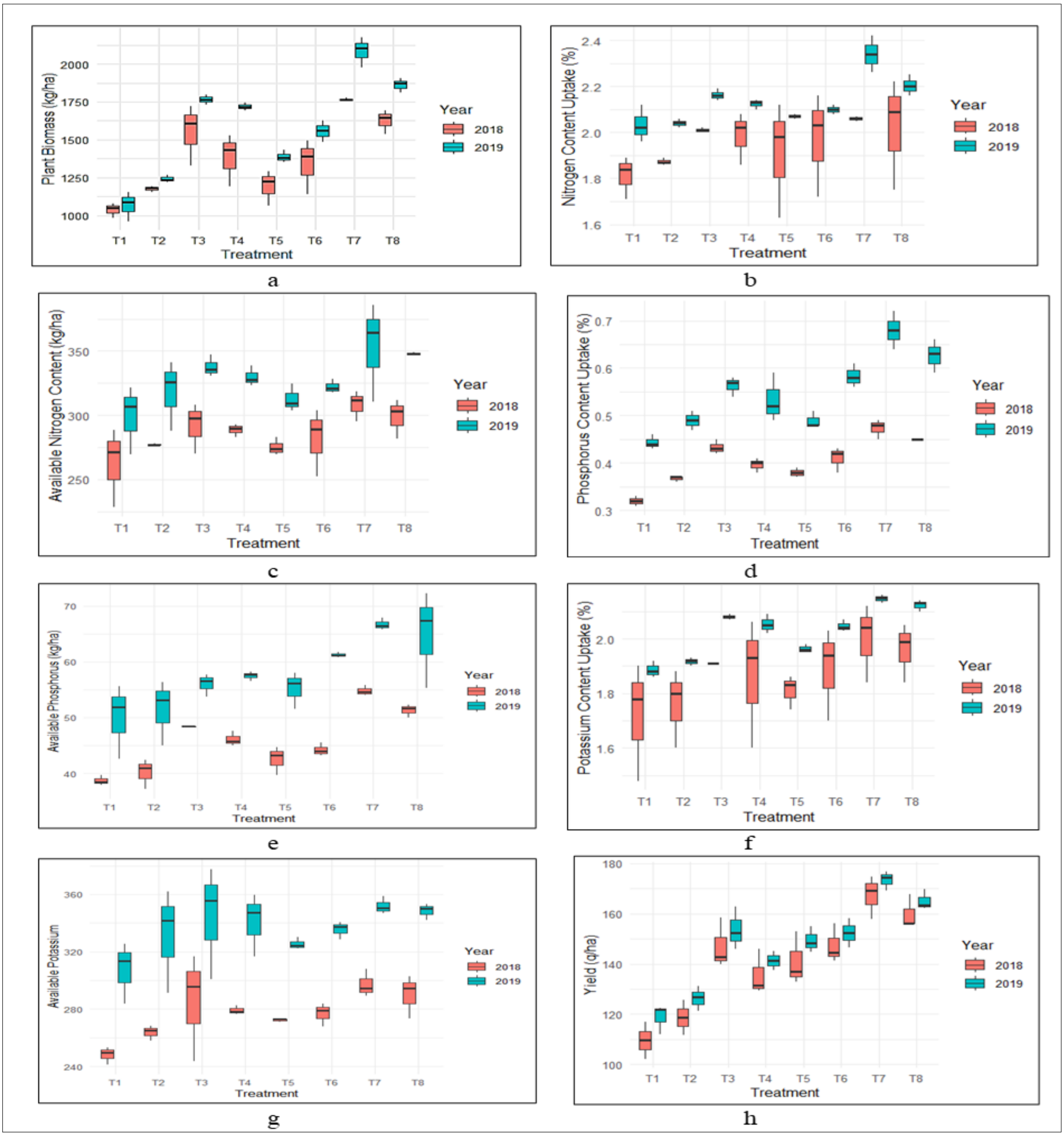

Fig. 3. Boxplot illustrating the plant biomass, yield, available soil nutrients and nutrients across eight treatments (T1 to T8) in brinjal cultivation during the years 2018 (red) and 2019 (blue). The boxes represent the interquartile range (IQR) with the median value shown by the black line. The different boxplots are labelled as: a. Plant biomass, b. Nitrogen uptake, c. Available Nitrogen, d. Phosphorus uptake, e. Available Phosphorus content, f. Potassium uptake, g. Available Phosphorus and h. Yield.

Table 4. Effect of different treatments on nutrient uptake by plants

Treatments	N uptake (%)	P uptake (%)	K uptake (%)
T_1	$1.92^{d} \pm 0.06$	$0.38^{f} \pm 0.03$	$1.80^{d} \pm 0.07$
T_2	$1.96^{cd} \pm 0.04$	$0.43^{e} \pm 0.03$	$1.84^{cd} \pm 0.05$
T_3	$2.09^{abc} \pm 0.04$	$0.50^{c} \pm 0.03$	$2.00^{ab} \pm 0.04$
T_4	$2.06^{abcd} \pm 0.04$	$0.47^{d} \pm 0.03$	$1.96^{abc} \pm 0.08$
T_5	$1.99^{bcd} \pm 0.07$	$0.44^{e} \pm 0.02$	$1.89^{bcd} \pm 0.04$
T_6	$2.04^{bcd} \pm 0.06$	$0.50^{c} \pm 0.04$	$1.97^{abc} \pm 0.06$
T_7	$2.20^{a} \pm 0.07$	$0.58^{a} \pm 0.05$	$2.07^{a} \pm 0.05$
T_8	$2.12^{ab} \pm 0.08$	$0.54^{b} \pm 0.04$	$2.04^{a} \pm 0.05$
CV (%)	5.64	5.05	5.65

respectively, while treatments T_1 and T_2 had the minimum uptake of 1.80% and 1.84% respectively.

The application of vermicompost and jeevamrit enhances soil microbial activity, leading to increased nutrient content and uptake by crops. The results are in conformity with the observations made by (48-53).

Correlation

A considerable positive association between important factors in brinjal cultivation was revealed by the correlation matrix heatmap (Fig. 4). Notably, plant biomass, phosphorus, potassium and nitrogen absorption all have substantial correlations with plant yield. Strong relationships between yield and biomass and available nutrients (N, P and K) highlighted that these elements play vital roles in plant growth. The results highlighted the value of managing nutrients in a balanced way and the possible advantages of adding organic amendments to increase soil fertility. Brinjal productivity and soil health could be increased by optimising nutrient availability through sustainable techniques. Yield had strong positive correlations (0.90) with almost all variables except available Nitrogen, which had a slightly lower positive correlation (0.88). Available Nitrogen was strongly connected with available Potassium (0.97) and Plant Biomass (0.98), although the relationship with yield was significantly weaker. Nutrient absorption variables (N, P and K uptake) had perfect correlations among themselves (0.95-0.98), implying that increased absorption of one nutrient positively impacted the uptake of another. Available phosphorus and P uptake were exactly connected (1.00), which indicated that P uptake is dependent on the availability of phosphorus in the soil.

Economic analysis

Plants subjected to treatment 7 (T_7) recorded the highest net return of ₹357490 and ₹357760, respectively, demonstrating maximum profit while plants subjected to treatment (T_1) had the lowest net return (₹225645 and ₹253215) (Fig. 6). In addition, T_7 had recorded the maximum gross income (₹501810 in 2018 and ₹520080 in 2019) while, T1 had the

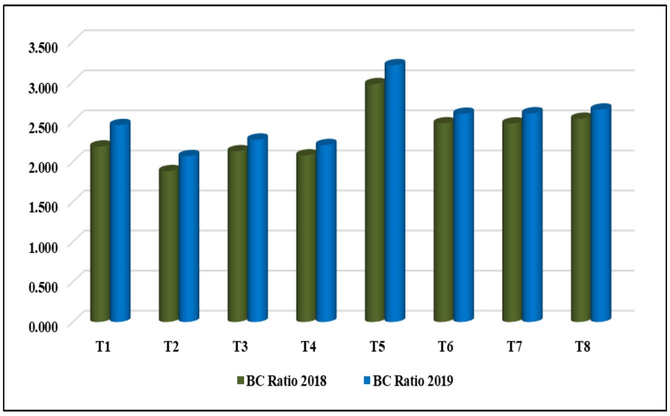

Fig. 5. BC ratio across different treatments in 2018 and 2019.

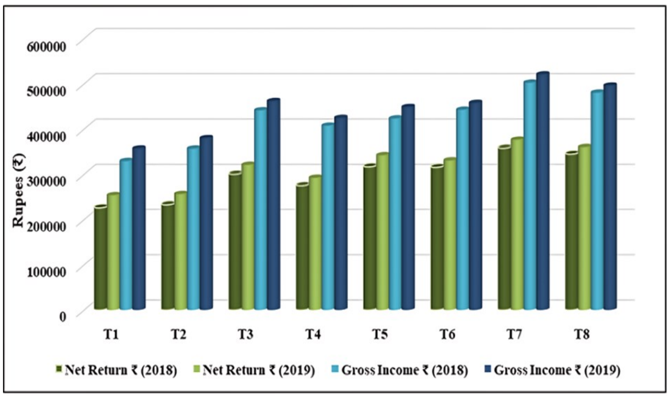

Fig. 6. Average net return and gross income across different treatments in 2018 and 2019.

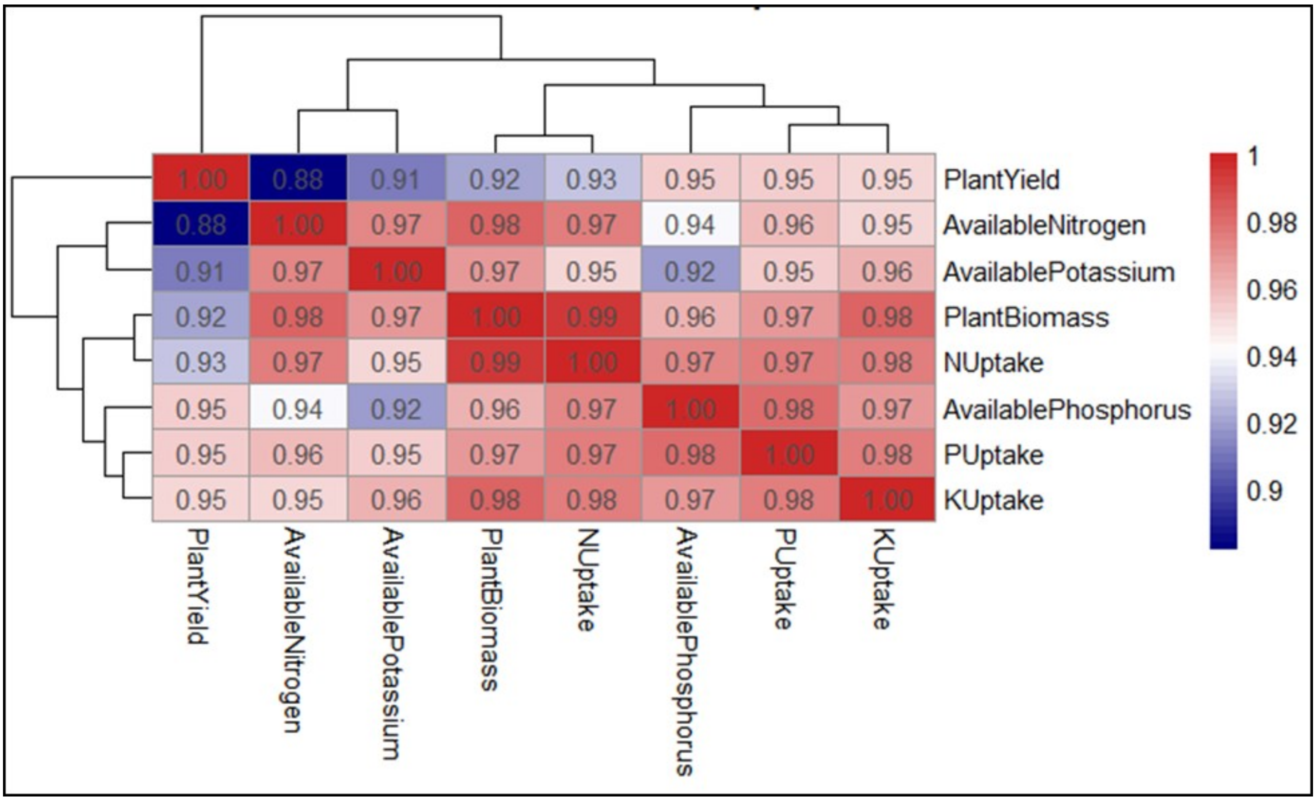

Fig. 4. Correlation heatmap depicting the relationships between plant yield, available soil nutrients and nutrient uptake variables in an experimental brinjal cultivation study. Each cell represents a Pearson correlation coefficient ranging from 0.88 (blue *i.e.,* weaker correlations) to 1.00 (dark red *i.e.,* stronger correlations). Hierarchical clustering on both axes groups similar factors together.

lowest gross income in 2018 and 2019 (₹328710 and ₹356280, respectively) (Fig. 5, 6).

Conclusion

This study presents data designed with the aim of developing an effective approach for farmers to get enhanced brinjal production. The application of treatment T_7 enhanced the availability and uptake of essential nutrients like potassium (K), phosphorus (P) and nitrogen (N), which in turn significantly increased brinjal yield, plant biomass and soil fertility. T_7 was observed to be the best treatment option for farmers based on the high economic value measured in terms of the high Benefit-Cost (BC) ratio, net return and gross income.

Crop quality, yield and soil health can be improved by farmers by adopting organic nutrient management techniques, such as the addition of supplements like vermicompost and biostimulants like Beejamrit and Jeevamrit. These sustainable techniques support long-term soil and environmental health in addition to improving economic returns. The use of organic nutrient sources can provide farmers with a viable and affordable way to increase productivity while maintaining ecological sustainability.

Acknowledgements

The authors thank the Department of Vegetable Science, Dr. YSP UHF Nauni Solan for providing financial assistance to carry out the research work.

Authors' contributions

SB[1] carried out the research work in the field and lab and drafted the manuscript. KST, SK and AC carried out the framework of research. SB[2], ND, ID and N designed the study and performed the statistical analysis. SB[1] conceived of the study and participated in its design and coordination. All authors read and approved the final manuscript. [SB[1] stands for Suraj Bhan and SB[2] stands for Simran Bhatia].

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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