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RESEARCH ARTICLE

Effect of organic nutrient sources on growth, yield and quality of French bean (*Phaseolus vulgaris* L.) under hill conditions of Himachal Pradesh, India

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Abstract

Vermicompost (VC), Farmyard manure (FYM), poultry manure (PM) and liquid sources of organic nutrients such as Panchgavya (PG) and Jeevamrut (JV) are rich in essential macronutrients (N, P, K) and micronutrients (Zn, Cu, Fe and Mn), making them valuable for sustainable farming system. In the present study, French beans were cultivated under organic management to evaluate the impact of various organic nutrient combinations on growth and yield. Ten treatment variations were set up in a randomized format at the Department of Soil Science and Water Management experimental farm in Nauni, Solan, Himachal Pradesh during summer months of March to May. The experiment included two liquid organic inputs, PG and JV and three substantial organic manures (FYM, VC and PM). Experimental results revealed that, highest plant height (38.20 cm), pod length (11.93 cm), number of pods/plant (34.77), pod width (1.26 cm), pod yield/plot (2.88 kg), pod yield/plant (71.67 g) and pod weight (2.34 g) were recorded under treatment T_4 with significant differences ($P<0.05$) under organic growing condition, which comprised 90 % RDN, PG at 5 % and JV at 5 % as a cost effective organic nutrient strategy to enhance yield and reduce input costs in sustainable French bean cultivation. The findings may lead to the conclusion that application of organic nutrient sources (FYM, VC and PM) and two liquid organic inputs (PG and JV) were crucial for nutritional management in this cultivation, as well as for attaining increased productivity, high-quality food, healthy soil and lower chemical dependence and move towards a more sustainable and regenerative farming model.

Keywords: french bean; jeevamrut; nutrient management; organic fertilizer; panchgavya; sustainable agriculture; vermicompost; yield attributes

Introduction

The French bean is a valuable vegetable crop from the Fabaceae family. It is among the most popular and commonly produced vegetables in India. It is sometimes referred to as kidney beans, string beans, snap beans, or bush beans. French bean is a superb vegetable crop for pods and seed and its worldwide relevance intended for direct human ingestion. A food supplement high in proteins, vitamins and minerals like calcium, phosphorus, iron and zinc, carotene, thiamine, riboflavin and vitamin A and C (1, 2). In India, French beans are grown on roughly 2.30 lakh hectares of land, with an annual production of approximately 22.49 lakh tons (3).

French beans (*Phaseolus vulgaris* L.) are a major leguminous vegetable. French bean has evolved in the highlands of middle America from a wild vine over a period of 7000- 8000 years. Mexico and Central America as primary and the Peruvian Ecuadorian-Bolivian region of South America as secondary places of origin of French beans (4). French beans are a nutrient-dense vegetable. 100 g of their edible pods contain 26 kcal of calories, 2 g of proteins, 50 mg of calcium, 132 mg of carotene, 28 mg of phosphorus, 0.08 mg of thiamine, 0.06 mg of riboflavin, 1 mg of iron, 2 g of fiber and 24.0 mg of vitamin C. It is a short duration crop (60 - 90 days) mainly cultivated in the *Kharif* season. However, with adequate irrigation it can be grown in the *rabi* and summer seasons as well. It is a warm-season vegetable that is delicate and intolerant of frost. Although French beans can be grown in a variety of well-drained, alluvial, friable soil types, beans are not able to tolerate very acidic or alkaline soils. Clay soils limit seed emergence, resulting in an uneven or poor stand. The optimum soil pH required for French beans is 5.5 - 6.8. Soil fertility is the main factor in achieving higher yields. Adding decomposed manure from a farm FYM during land preparation will enrich the soil fertility.

French bean is a valuable and widely regarded pulse crop that reacts well to fertilizer. Despite being a legume, it lacks nodules because of the NOD gene regulator absence (5) and is non-efficient in nitrogen fixation (6). For optimum nitrogen fixation, good soil aeration is required. Hence, it responds well to high nitrogen fertilization up to 120 kg per ha (7). Fertilizers play an important role in crop production. But these days, the inorganic fertilizers cause a toxic impact on soil properties, as well as they may also enter the food chain, causing harm to human beings. A self-sustaining agricultural system, such as organic farming, could provide solutions to many problems in Indian agriculture. Considering the above information, it has necessitated the concept of organic farming as modern technology, methodology and philosophy which rely on the conservation of natural resources, eco-friendly production technology and integrated crop management practices, etc., for sustainability in crop production.

Organic farming is considered a farming system without the utilization of artificial fertilizers (soluble salts) with a view to having nutrient inputs and pesticides originating from organic or biotic sources. Organic farming is now well established as an alternative agriculture, which has been presented as a remedy to the problems connected with chemical fertilizer and pesticide inputs, as previously discussed. India is uniquely in favour of the organic production of different agricultural and horticultural crops. Addition of organic matter as source of nutrients is crucial to sustain soil health in long term basis and thus, organic farming plays a pivotal role in agricultural system in the country (1). The different agro-climatic conditions suitable to produce several potential organic products include available farm land which are not much exposed to chemical farming and farmers have been practicing traditional farming since time immemorial, particularly in Hill States like Himachal Pradesh, Jammu and Kashmir, Uttarakhand and Northern States, etc. Given the above, the mountain regions of the country that happen to be the hotspots of biodiversity, with varied flora and fauna, are the appropriate locations to adopt the alternative production systems, like organic farming technology. Moreover, most of the mountain regions and the hills of Himachal Pradesh are particularly suitable for this system and have vast potential for organic production of fruits, vegetables, pulses, cereals, oilseeds and medicinal plants, etc., in addition to the quality milk production etc. Organic farming envisions a complete management strategy to enhance soil health and ecosystems in a specific area and region as a whole. Organic foods are often seen as healthier than conventionally farmed items. The organic products market is gradually increasing. Organic manures improve productivity by enriching the soil's physical, chemical and biological attributes, hence enhancing fertility, yield and water retention capacity. Furthermore, as the input cost of chemical farming rises, small and marginal farmers in our country are finding it practically impossible to grow the crop. Organic farming, on the other hand, has a cheap input cost of production due to its intrinsic technology, which uses locally accessible resources to manufacture various organic liquid inputs (3). Manure is a unique component in organic farming that is entirely created from naturally occurring raw materials and does not require any chemical synthesis. Considering organic farming as a long-term investment in soil sustainability and health, it makes financial sense. Over time, larger net profits and lower financial risk are frequently the result of lower input costs, premium pricing and enhanced resilience, even though there may be an initial trade-off, particularly in yields.

Native sources such as VC, PM and FYM have become indispensable in crop management in recent years. FYM, VC, PM and liquid organic nutrient suppliers like PG and JV are excellent sources of organic manure, encompassing a majority of essential macro and micronutrients, thereby demonstrating efficacy in sustainable agricultural systems. Due to their rich nutritional value, French beans, produced in organic conditions, are a beneficial advancement for superior quality food manufacturing. Under this, each organic nutrient source (i.e. FYM, VC, PM) individually and in integration, is important for nutritional management, for attaining greater productivity, better food quality and soil health. There was no systematic research in these elements of French bean production, keeping these factors in mind, the present investigation was conducted to know the combined effect of FYM, vermicompost, poultry manure, panchgavya (PG) and jeevamruta (JV) on growth and yield of French bean.

Materials and Methods

A field experiment was conducted using RBD with three replications conducted on the experimental farm of the Dr. Y S Parmar University of Horticulture and Forestry (UHF), Nauni, Solan -173230 (HP), India's Department of Soil Science and Water Management (SSWM). The study area located in Himachal Pradesh's sub-temperate, sub-humid agro climatic zone II. Around 75 % of the region's 1115 mm of annual rainfall falls during the monsoon season, which runs from mid-June to mid-September. Only a few winter precipitations fall in January and February. The coldest months are December through January, while the hottest months are May through June. As per USDA Soil Taxonomy, the soil samples used in the study region belong to the subgroup Eutrochrept and the order Inceptisol. Ferromagnesian shales and dolomitic limestone are responsible for the formation of these soils. Soils derived from these parent materials are moderately to highly fertile. Nutrient supply is balanced, including Ca, Mg, Fe, K and micronutrients. The pH buffering property of limestone prevents high acidity and the clay concentration of shales has the potential for good nutrient retention.

The bush-type French bean variety 'Contender' was selected for the experiment." A randomized block design (RBD) with three replications was adopted, where ten treatments combinations were randomly assigned to plots (2m×2m with spacing 50cm×20cm) within each block using a random number table. The bulky organic nutrient sources were FYM, VC and PM and those of liquid nature were PG and JV, applied according to the treatments. The suggested doses of nutrients (SDN), i.e. FYM: 20000 kg ha^{-1}; Urea: 50kg ha^{-1}; single super phosphate (SSP): 100 kg ha^{-1}; muriate of potash (MOP): 50 kg ha^{-1} (8) were administered using a 50:50 combination of VC and PM, calculated based on their nitrogen content. The quantity of VC and PM was quantified on the basis of nitrogen equivalence. The full amount of VC and PM was applied and mixed with the soil during land preparation before sowing. The PG (5 %) and JV (5 %) organic formulations were used two times as soil drench (250 mL/plant) at a 15-day duration after 14 days of sowing up to the third picking of the crop. The trial consisted of ten treatments, as listed in Table 1.

Table 1. Description of experimental treatments and nutrient application levels

Treatments	Conditions
T_1	100 % of the recommended nutrient dose
T_2	90 % RDN + PG (5 %)
T_3	90 % RDN + JV (5 %)
T_4	90 % RDN + PG (5 %) + JV (5 %)
T_5	80 % RDN + PG (5 %)
T_6	80 % RDN + JV (5 %)
T_7	80 % RDN + PG (5 %) + JV (5 %)
T_8	70 % RDN + PG (5 %)
T_9	70 % RDN + JV (5 %)
T_{10}	70 % RDN + PG (5 %) + JV (5 %)

Ingredients and flow chart for the preparation of PG and JV preparation

PG was prepared by dissolving the following ingredients (9).

Ingredients	Quantity
Cow dung	1 kg
Cow urine	1 L
Cow milk	2 L
Cow ghee	1 kg
Cow curd	2 kg
Jaggery	2 kg
Sugarcane juice	2 L
Coconut	1 fruit
Banana	1 dozen

5 L of PG was added in 100 L of water for its soil application

Flow chart of preparation of PG

Mix thoroughly the fresh cow dung + cow ghee
↓
Incubate for 2 days
↓
Add cow's urine
↓
Stir properly (morning and evening, daily for one week)
↓
Add sugarcane juice & jaggery
↓
Add cow's milk + cow curd + coconut water + 12 bananas
↓
Stir properly (morning and evening, daily for 3 week)
↓
PG is ready for soil drench

Preparation of JV

JV was prepared by dissolving the following ingredients (9).

Ingredients	Quantity
Cow dung	10 kg
Cow urine	10 L
Jaggery	2 kg
Pulse floor	2 kg
Live soil	1 kg
Water	200 L

For soil application dilution of 5 L of JV in 100 L of water is done

Flow chart of preparation of JV

Add fresh cow dung + cow urine in water
↓
Mix jaggery + pulse floor and live soil in water
↓
Mix the above both and stir properly (morning and evening)
↓
On fifth day filter the solution and filtrate is ready for soil drench

Plant growth parameters

Plant growth parameters were estimated at the maturity stage. For each treatment, observations were recorded from three randomly selected plants per plot for each parameter were taken in triplicates. An average was worked out for the estimation of traits, including plant height, pod weight, number of days until first harvest, length, width, yield/plant, yield/hectare, number of pods/plants and harvest duration. The final plant height was determined in centimetres (cm) from the ground to the apex of the mature plant. Plant height was taken using a meter scale. The total number of marketable green pods per plant was recorded from multiple harvests. Pod length was determined from the base of the pod to the tip of the pod and was averaged and reported in cm. Pod width, i.e. suture to suture end of pods, was determined using Vernier callipers and recorded in cm. Pod yield per plant (kg), i.e. the green pods were collected at optimal maturity and the average weight of pods/plant was determined using an electric weighing balance. Per-hectare pod yield (kg), the pod yield in quintals per hectare was determined by plant yield x plant population. Pod weight (g), the weight of randomly selected pods per plant at maturity was pooled and the calculated average pod weight in grams. Days to first harvest were recorded from the data of germination to the first picking. The harvest period was estimated by calculating the number of days from the initial to the last harvest and expressing the average result. French bean quality control includes the use of high-quality seeds, proper crop management and timely harvesting of tender, green pods. To remove any damaged or diseased produce, beans are sorted, washed and graded. Proper packaging and cold storage maintain freshness and reduce post-harvest losses.

Statistical analysis

The data collected from the current investigation were statistically analysed using Microsoft Excel and OPSTAT. The level of significance was assessed for each variable at a 5 % level of significance (10). An outline for an analysis of variance using RBD with "t" treatments and "r" replications was prepared. Duncan's Multiple Range Test (DMRT) was used to determine the significant difference between treatment means.

Results

Plant height (cm)

The utilization of diverse organic materials registered a significant effect on different plant parameters, as shown within Table 2. The data presented revealed that maximum (38.20 cm) French bean plant height was observed in treatment T_4, significantly increased plant height by 16.57 % ($p<0.05$) than treatment T_1 and was comparable to treatments T_7 and T_{10} statistically. Minimum (32.77 cm) plant height was recorded in T_1 and was statistically at par with T_3, T_6 and T_9.

Table 2. Effect of organic nutrient sources on plant height (cm), number of pods and pod length (cm) of French bean

Treatments	Plant height (cm)	Number of pods per plant	Pod length (cm)
T_1 : 100 % RDN*	32.77	27.57	9.41
T_2 : 90 % RDN + 5 % PG	34.70	31.03	11.23
T_3 : 90 % RDN + 5 % JV	33.20	29.73	9.61
T_4 : 90 % RDN + 5 % PG + 5 % JV	38.20	34.77	11.93
T_5 : 80 % RDN + 5 % PG	34.67	30.80	10.35
T_6 : 80 % RDN + 5 % JV	33.17	28.30	9.52
T_7 : 80 % RDN + 5 % PG + 5 % JV	37.70	34.63	11.64
T_8 : 70 % RDN + 5 % PG	33.73	30.00	10.25
T_9 : 70 % RDN + 5 % JV	32.90	28.07	9.43
T_{10}: 70 % RDN + 5 % PG + 5 % JV	37.60	31.80	11.36
Mean	34.86	30.67	10.47
C.D $_{(0.05)}$	**0.69**	**0.65**	**0.21**
CV (%)	**1.68**	**1.80**	**1.70**

Pod count per plant

The experimental values presented in Table 2 further indicated that the maximum (34.77) number of pods per plants was also observed in treatment T_4, which is about 26.11 % ($p<0.05$) greater than treatment T_1 and was significantly at par with treatment T_7. Minimum (27.57) pod count per plant was reported in T_1.

Pod length (cm)

The use of various organic inputs had a significant effect on the French bean pod length, according to Table 2. The results showed that the longest (11.93 cm) pods were recorded in treatment T_4 ($p<0.05$), whereas the lowest (9.41 cm) pod length measured in T_1 was significantly comparable to those of treatments T_3, T_6 and T_9.

Pod width (cm)

The use of various organic inputs registered a substantial effect on the pod width of French bean, as displayed within Table 3. The data presented revealed that the maximum pod width of 1.26 cm was noted in T_4 treatment ($p<0.05$), which was not significantly different from treatments such as T_2, T_5, T_7 and T_{10}. Minimum width of the pod, however, was observed in T_1 with a value of 0.84 cm.

Yield (quintal per hectare)

The use of various organic inputs registered a significant effect on the French bean pod yield ($p<0.05$), as shown in Table 3. The results presented showed that the maximum yield (71.67 q ha^{-1}) was noted in treatment T_4 and the lowest pod yield (44.66 q ha^{-1}) was determined in T_1.

Pod weight

The use of various organic inputs registered a significant impact on the French bean pod weight ($p<0.05$), according to Table 4. The results presented revealed that maximum pod weight (2.34 g) was recorded in treatment T_4, whereas T_1 recorded a minimum pod weight of 1.44 g.

Table 3. Effect of organic nutrient sources on pod width and yield of French bean

Treatments	Pod width (cm)	Pod yield (q ha^{-1})
T_1 : 100 % RDN*	0.84	44.66
T_2 : 90 % RDN + 5 % PG	1.12	63.33
T_3 : 90 % RDN + 5 % JV	0.94	54.67
T_4 : 90 % RDN + 5 % PG + 5 % JV	1.26	71.67
T_5 : 80 % RDN + 5 % PG	1.11	63.00
T_6 : 80 % RDN + 5 % JV	0.93	52.33
T_7 : 80 % RDN + 5 % PG + 5 % JV	1.15	65.33
T_8 : 70 % RDN + 5 % PG	1.01	56.67
T_9 : 70 % RDN + 5 % JV	0.86	52.00
T_{10}: 70 % RDN + 5 % PG + 5 % JV	1.13	64.33
Mean	1.03	58.8
C.D $_{(0.05)}$	**0.17**	**3.51**
CV (%)	**14.0**	**5.06**

Number of days to first harvesting

The information displayed in Table 4 showed that the earliest harvest (59.18 days) was observed in T_1 ($p<0.05$). The maximum number of days (64.45 days) that the plant took for first harvesting was under treatment T_5.

Harvest duration

The use of various organic inputs registered a significant effect on the harvest duration of the crop, as displayed in Table 4. Maximum harvest duration (46.49 days) was observed in treatment T_8 and it was comparable to treatments T_1 (43.56 days), T_4 (45.62 days), T_9 (45.33 days) and T_{10} (43.50 days) ($p<0.05$). A minimum harvest duration of 41.02 days was recorded in treatment T_2.

Discussion

Plant height

The increase in plant height could be due to the conjunctive use of vermicompost and readily available nutrients through organic formulations, which produced vigorous seedlings because vermicompost contains growth hormones and enzymes, essential nutrients and organic matters, which favours rapid cell elongation and division and favours better growth and development.

Additionally, these outcomes are consistent with those of previous works who reported that the height of the French bean plant was considerably raised by using organic manures like FYM and VC (11). A significant development in capsicum plant height because of the incorporation of PG has also been documented (12) and of application of vermicompost and JV (13). According to early findings, applying PG and JV increased the height of the tomato plants (14); the highest plant height was achieved with 3 % PG (15) also noted that applying PG increased plant height. Additionally, these findings are consistent with previous work (1).

Number of pods

This could be because organic nutrition improves the soil environment for nodule development, root growth and nutrient availability and absorption, all of which directly result in more pods being produced by the plants. The findings corroborate early findings, who stated that the French bean's pod count per plant was significantly improved by the use of organic manures, which had been used to minimize the use of inorganic fertilizers

Table 4. Effect of organic nutrient sources on pod weight, number of days to first harvesting and harvest duration in French bean

Treatments	Pod weight (g)	Number of days to first harvesting	Harvest duration (days)
T_1 : 100 % RDN*	1.44	59.18	43.56
T_2 : 90 % RDN + 5 % PG	1.94	60.82	41.02
T_3 : 90 % RDN + 5 % JV	1.90	62.50	41.66
T_4 : 90 % RDN + 5 % PG + 5 % JV	2.34	60.51	45.62
T_5 : 80 % RDN + 5 % PG	1.93	64.45	42.06
T_6 : 80 % RDN + 5 % JV	1.86	62.86	42.97
T_7 : 80 % RDN + 5 % PG + 5 % JV	2.08	63.51	41.70
T_8 : 70 % RDN + 5 % PG	1.91	60.18	46.49
T_9 : 70 % RDN + 5 % JV	1.70	61.43	45.33
T_{10}: 70 % RDN + 5 % PG + 5 % JV	2.06	63.34	43.50
Mean	1.92	61.88	43.39
C.D $_{(0.05)}$	**0.24**	**0.90**	**3.45**
CV (%)	**10.6**	**1.23**	**6.74**

under irrigated conditions (16). These findings are similarly consistent with previous work, who investigated the effects of PG, JV and other farm yard manure sources on the growth and yield of French beans (*Phaseolus vulgaris* L. var. *Paulista*) (1).

Pod length

These findings also concur with early works, who investigated the effects of various farm yard manure sources, including JV and PG, on the development and yield of French beans (*Phaseolus vulgaris* L) var. *Paulista* (1) (Fig. 1).

Pod width

These results are also in line with early findings, who studied the impact of PG on *Abelmoschus esculentus* (cv. Arka Anamika) growth and yield (17) and who studied the impact of PG on the development of Black gram (*Vigna mungo* L.) and its yield, where the effect of manures in conjunction with PG and JV has been found to increase the pod width of beans (Fig. 2) (18).

Yield

This may be because organic manures (FYM, VC, PM) and other liquid inputs (PG and JV) enhanced the soil's physical characteristics (water and nutrient holding capacity), increasing the amount of nutrients available to plants. They would have also adequately supplied both macro and micronutrients, creating an environment that is conducive to crop growth and development. Many early works observed similar results with French beans (5, 19-21). These observed results (Fig. 3) were also consistent with previous results, who investigated the impact of PG on the development and yield of black gram (*Vigna mungo* L.) (12).

Pod weight

This could be because organic sources of nutrients have accelerated the soil's decomposition process, which may have led to a comparatively rapid release of nutrients. These outcomes are consistent with early research in French bean and (1, 22). Additionally, these findings are consistent with previous works, who investigated the effect of PG on *Abelmoschus esculentus* on development and productivity (11). French bean growth attributes appear to benefit from the improved nutrition and moisture regimes under the organic treatments.

Number of days

These findings are consistent with early findings who revealed that the number of days to first harvesting in French bean cv. Lakshmi, in the lower hills of northern India, was considerably impacted by the incorporation of organic manure (23). The control treatment seems to have led to the early onset of the reproductive phase in the plants, which was delayed in the case of the organic nutrient treatments with PG and JV.

Harvest duration

These findings are in conformity with those of early results, who reported that the harvest duration in French bean cv. Lakshmi, in the lower hills of northern India, was notably affected by the utilization of organic manure (14) (Fig. 4). Although no definite trend was observed, the treatment effects were found to be significant. The similar findings also reported in previous findings (24).

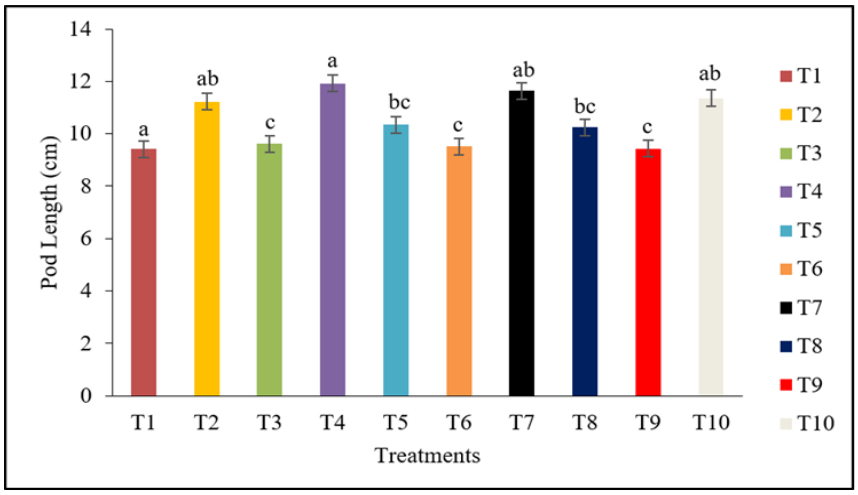

Fig. 1. Effect of organic nutrient sources on pod length (cm).

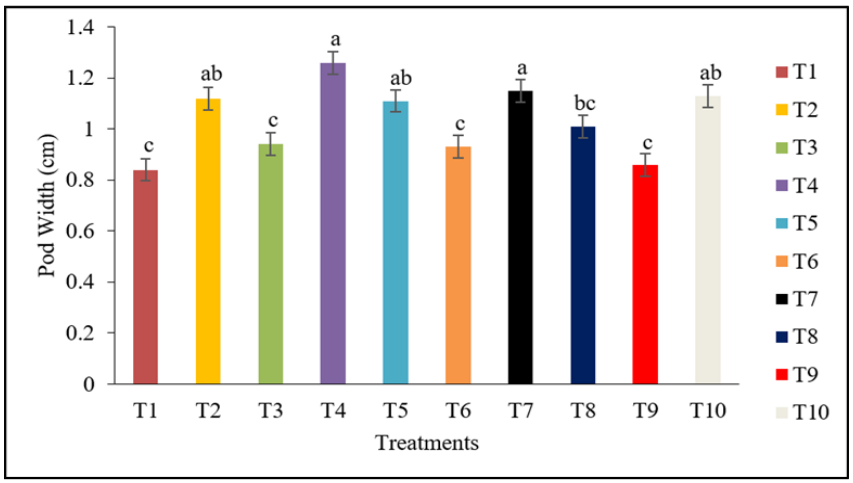

Fig. 2. Effect of organic nutrient sources on pod width (cm).

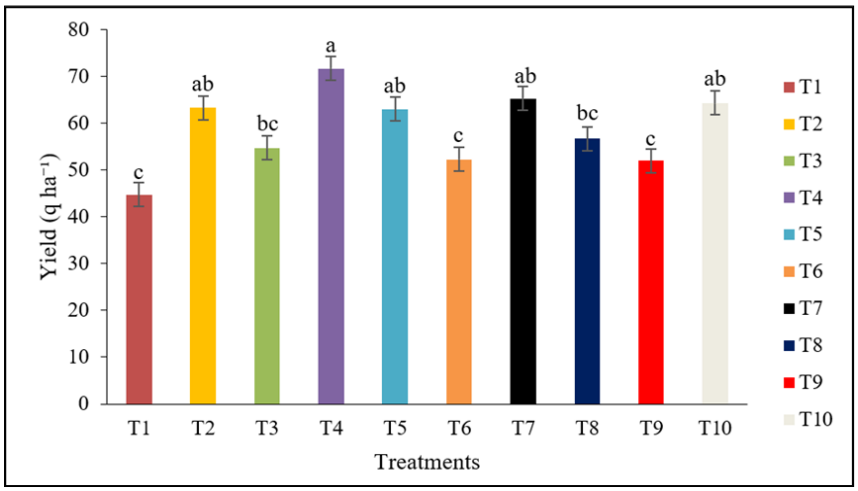

Fig. 3. Effect of organic nutrient sources on yield (q ha^{-1}).

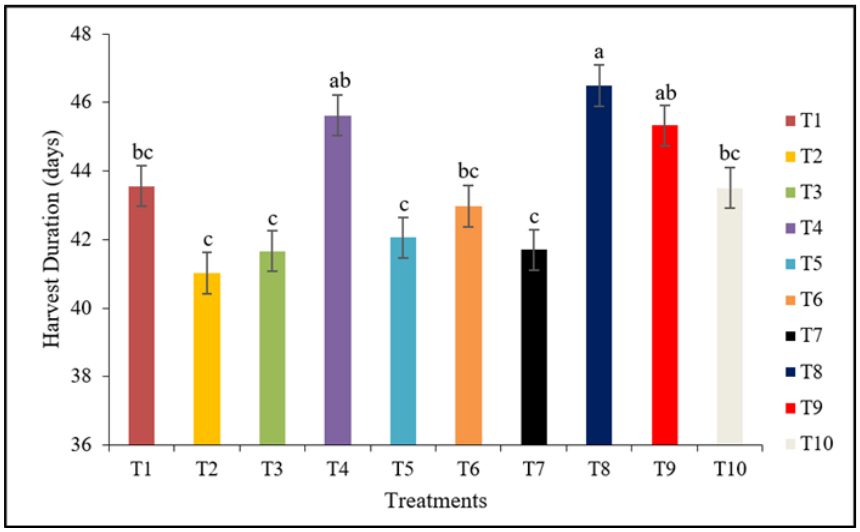

Fig. 4. Effect of organic nutrient sources on harvest duration (days).

Conclusion

The current investigation concludes that incorporating 90 % of the recommended nutrient doses (based on nitrogen equivalence) through a 50:50 combination of vermicompost and poultry manure significantly improved growth, yield and pod quality parameters. This effect was further enhanced by the application of liquid organic formulations, namely PG and JV, each applied at 5 %. The full amount of VC and PM should be applied and mixed with the soil in the first week after sowing. The PG (5 %) and JV (5 %) organic formulations should be administered twice as a soil drench (250 mL per plant) at a 15 - day gap after two weeks of sowing up to the third picking of the crop. The results showed that the organic treatment with 90 % RDN + 5 % PG + 5 % JV was economically viable as compared to other treatments. The combination of 90 % RDN, 5 % PG and 5 % JV has shown encouraging results in improving plant growth, yield and soil health in French bean production. Multilocation trials are necessary to evaluate its best performance under various agro climatic conditions. These trials will assist analyse how this treatment adapts to changes in soil type, rainfall, temperature and management approaches, ensuring region-specific recommendations for sustainable production. Therefore, the developed nutrient module may be suggested, after completing multi-location testing, for enhance productivity of French bean and sustaining and improving the soil health.

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Authors' contributions

AR contributed to conceptualization, methodology and writing the original draft. US supervised the work, contributed to writing the review, original draft and editing. AV, MD, YK, G, M, AS, AM and KW contributed to writing, editing and designing the experiments. All authors read and approved the final manuscript.

Compliance with ethical standards

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

Ethical issues: None

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