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Impact of bioorganic nutrients and chemical fertilizers on sustainable production of French bean and soil health

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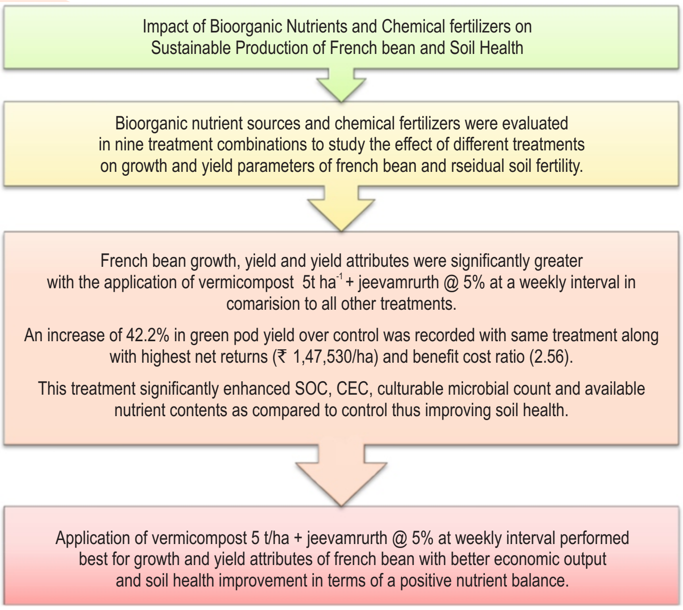
Abstract

Aim: To determine the impact of bioorganic nutrients and chemical fertilizers on sustainable production and profitability of french bean and soil health improvement.

Methodology: The effects of bioorganic nutrients (jeevamrurth, ghan-jeevamrurth, vermicompost, and FYM) and chemical fertilizers on french bean were studied during 2018 and 2019 with nine treatment combinations on growth parameters, yield attributes, productivity, and profitability of french bean. Residual soil fertility in terms of various soil properties was also assessed after the completion of the experiment. The economic analysis of different treatments was worked out to select the most profitable nutrient combination.

Results: Results showed that plant height, branches per plant, nodules per plant, green pod length, green pods per plant, pods weight per plant and total pod yield of french bean were significantly greater with the application of vermicompost 5t ha^{-1} + jeevamrurth @ 5% at a weekly interval as compared to all other treatments. This superior combination recorded 42.2% increase in green pod yield over control with the highest net returns (₹ 1,47,530 ha^{-1}) and benefit cost ratio (2.56). Also, this treatment significantly enhanced soil organic carbon, cation exchange capacity, culturable microbial count and available nutrient contents as compared to control thus improving soil health.



Interpretation: Application of vermicompost 5 t ha^{-1} + jeevamrurth @ 5% at weekly interval treatment performed best amongest all treatment combination for growth and yield attributes of French bean with better economic output and soil health improvement in terms of a positive nutrient balance.

Key words: French bean, Ghan-jeevamrurth, Organic manures, Soil nutrient balance

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Introduction

French bean (*Phaseolus vulgaris* L.) is an important leguminous vegetable crops of our country that is consumed as fresh green pods and dried seeds as pulse crop. It is likewise called snap bean, kidney bean, haricot bean, garden bean or string bean. French bean is grown appreciably due to its short duration and for nutritive values. For the successful cultivation of legume vegetables, appropriate quantities of nutrients are essential for their growth and development otherwise physiological deficiency symptoms can occur and hidden hunger can arrest the plant development (Takahashi, 1981). Fertilizers are routinely applied by most of the vegetable producers for higher production because of their easy availability and rapid release of nutrients for the plants (Thy and Buntha, 2005). However, the enduring uses of inorganic fertilizers either in single or combination form have contributed to innumerable forms of environmental degression, including air and water pollution, soil depletion and decreasing biodiversity and soil quality via means of diminishing natural soil organic content, increasing salinity, and disturbing local pH (Mahajan *et al.,* 2008; Wang *et al.,* 2008). Increasing concerns of ill-effects of agrochemicals on the environment and the health of human beings and animals have driven the interest in the production of chemical-free food for consumption and also for developing management strategies that maintain and protect soil resources (Ramesh *et al.,* 2009).

The hazards of agrochemicals and environmental footprint may be minimized via way of means of the use of bioorganic nutrient sources for fulfilling nutrient demand of the crops (Mahanta *et al.,* 2015). Conversely, organic sources may influence agricultural sustainability by improving soil quality (Saha *et al.,* 2010; Te Pas and Rees, 2014).Organic farming is increasingly becoming popular because of the perceived health and environment benefits (Zhao *et al.,* 2009). Organic systems may lead to more biological activity and improve soil quality than conventional systems (Gopinath *et al.,* 2009 and Mahanta *et al.,* 2017). Nutrient management is, therefore, one of the most critical management practices for organic growers. In hilly regions of India, organic materials such as forest and crop plant residues, cattle dung, cattle urine, are available in abundance, which can be utilized to prepare nutrient and micro-flora rich nutrient sources, *i.e.* vermicompost, jeevamrurth and ghan-jeevamrurth etc. (Bhattacharyya and Kumar, 2005: Shankar *et al.,* 2013; Sharma *et al.,* 2020), and their use as organic amendments for improving the soil productivity and health (Gopinath *et al.,* 2011; Moharana *et al.,* 2012; Kamble *et al.,* 2018; Hammad *et al.,* 2020).

Organic manure and compost are key to enhance soil quality and crop yield since they perform numerous functions in agroecosystems (Jones *et al.,* 2007). Their inputs are in general beneficial for the overall health of the agro-environment (Jedidi *et al.,* 2004). Integration of all bioorganic sources supply essential nutrients to the crops leading to increased crop yields and reduced environmental threats (Singh *et al.,* 2009). The research on various crops confirms that manures and composts improves seed germination, plant growth, flowering, fruiting, and quality of the economic produce (Gupta *et al.,* 2008; Premsekhar and Rajashree 2009; Thakur *et al.,* 2018; Yogananda *et al.,* 2020). In recent years, considerable attention has been paid to naturally fermented cattle urine and dung based formulations like jeevamrurth and ghan-jeevamrurth to replace agrochemical fertilizers apart from the use of conventional farm based products like manures and composts as nutrient source in organic cultivation which assist in the quick build-up and restoration of soil fertility through enhanced growth and activity of soil micro-flora and fauna (Khadse *et al.,* 2018). The use of liquid natural formulations such as jeevamrurth and beejamrit has led to better growth, yield, and quality of crops (Gowthamchand *et al.,* 2020) and improve soil physico-chemical and biological properties as they contain abundant microorganisms which accelerate the decomposition of organic material and results in the quick release of nutrients (Ram *et al.,* 2018). They additionally contain essential macro and micronutrients, vitamins, essential amino acids, growth-boosting substances like indole acetic acid and gibberellic acid which ultimately results in better growth and development of crops (Sharma and Verma, 2011; Kumbar *et al.,* 2016; Thakur, *et al.,* 2018).

French bean is an important leguminous vegetable cultivated in the North-western Himalayas of India and traditional organic french bean cultivation suffers from the slow release of nutrients and consequently led to low green pod yield (Mahanta *et al.,* 2015). Suitable combinations of different sources of organic and naturally fermented cattle urine and dung based formulations like jeevamrurth and ghan-jeevamrurth for enhancement of yield and profitability in french bean as a matter of scientific investigation hold a great importance. Considering the above facts, the present study was planned and undertaken with the objective to assess the effect of bioorganic nutrient sources (jeevamrurth, ghan-jeevamrurth, farmyard manure, and vermicompost) and chemical fertilizers on the growth, yield, and profitability of French bean cv. contender.

Materials and Methods

Experimental site: The field experiment was conducted on french bean cv. contender during 2018 and 2019 for two seasons at the experimental farm of the Department of Soil Science, College of Horticulture and Forestry, Neri (Hamirpur), Himachal Pradesh, India. The soil of the study area is Non calcic brown that manifests moderate profile development having argillic/cambic B_2 horizon and placed in soil order *Entisols*. The textural class of soil of experimental site is sandy clay loam (sand: 58.60%, silt: 14.60 %, clay: 26.80 %) with pH 7.09, 0.118 dS m^{-1} EC, 8.40 Cmol p^{+} kg^{-1} cation exchange capacity and 4.80 g kg^{-1} organic carbon content. The values of available nitrogen, phosphorus, and potassium contents in the soil before the start of the experiment were 192.72, 11.87, and 124.09 kg ha^{-1}, respectively.

Experimental design and treatment details: The experiment was laid out with different bioorganic nutrient sources [*viz.,* vermicompost, farmyard manure (FYM), jeevamrurth, ghan-jeevamrurth] and inorganic fertilizers to assess the best treatment combination for sustainable production and profitability of french bean and soil health improvement. The treatments were replicated thrice in a randomized block design. Different input combinations of bioorganic sources and inorganic fertilizers, namely, vermicompost 5 t ha^{-1}, farmyard manure 20 t ha^{-1}; jeevamrurth @ 5% at weekly and fortnightly interval and ghan-jeevamrurth at weekly interval were applied in 9 different combinations (T_1-T_9). Different treatments comprised of the following combinations: T_1=Jeevamrurth @ 5% at weekly interval; T_2 = FYM 20t ha^{-1} + 100% NPK (Recommended dose of fertilizer; N:50; P:100; K:50 kg ha^{-1}); T_3 = FYM 20t ha^{-1} + Jeevamrurth @ 5% at weekly interval ; T_4 = FYM 20t ha^{-1} + Jeevamrurth @ 5% at fortnight interval; T_5 = Vermicompost 5 t ha^{-1} + 100% NPK; T_6 = Vermicompost 5 t ha^{-1} + Jeevamrurth @ 5% at weekly interval; T_7 = Vermicompost 5t ha^{-1} + Jeevamrurth @ 5% at fortnight interval; T_8 = Jeevamrurth @ 5% + Ghan-jeevamrurth 2t ha^{-1} at fortnight interval; T_9 = 100% NPK (Control). For each treatment combination, the requisite quantity of bioorganic nutrient sources and recommended dose of fertilizer were calculated and applied uniformly in each treatment plot. All the bioorganic sources of the nutrient were applied as basal as per the treatment 10 days prior to sowing. Ghan-jeevamrurth was applied as soil application near the root zone of the plant and jeevamrurth was drenched with irrigation water as per treatments under investigation. The nutrient composition and culturable microbial count of bioorganic nutrient sources (farmyard manure, vermicompost and ghan-jeevamrurth) on dry weight basis and jeevamrurth are presented in Table 1. The nitrogen, phosphorus, and potassium were supplied through urea, single super phosphate, and muriate of potash, respectively. The full dose of P, K, and half dose of N was applied as a basal, and the remaining half dose of N was applied at 30 days after sowing (DAS).

Crop management: French bean was sown at a seed rate of 75 kg ha^{-1} at a row spacing of 45 cm and seed to seed spacing of 15 cm (45 cm x 15 cm) to maintain the optimum plant population. Crop was irrigated at 10-15 days interval depending on the stage of crop and soil conditions. Necessary after-care and inter-cultural operations were followed as per the recommendations. No major pest and disease incidences were noticed during crop growth. The green pods were harvested at edible maturity. Response of treatments was recorded with respect to plant height (height of five plants was recorded from ground level to the base of the fully developed youngest leaf at 60 DAS in centimetres and the average height of plants was recorded by dividing the total plant height by five) and number of branches per plant (total number of primary branches of five plants were counted at 60 DAS and the average number was enumerated by dividing the total number by five), length of a green pod (length of ten randomly selected pods were measured from the base to the tip of the pod and the average pod length was worked out and expressed in centimetres), number of green pods per plant (total number of green pods were counted in five randomly chosen plants and then the mean number of pods per plant was enumerated) and weight of pods per plant (the green pods from selected five plants were weighed separately for total weight and mean weight was calculated as yield per plant and expressed in grams) and green pod yield ha^{-1} (the green pods from each treatment were harvested and weighed separately. The total weight of each treatment plot was recorded and converted per hectare basis and expressed in quintals) were recorded at harvest. Nodules per plant were calculated by dipping the plant root system in water to remove adhering soil and enough care was taken to keep the root system and nodules intact so that none of the nodules were lost. The nodules were separated from roots, washed, and counted. The average of five plants was recorded and finally considered as the number of nodules per plant.

Soil sampling and analyses: The composite surface (0-15 cm) soil samples were collected from each treatment plot at the end of two year experiment. The samples were shade dried and sieved through a 0.2 cm sieve, and used for analysis. Soil pH and EC were measured in 1:2.5 soil-water suspensions by standard methods (Jackson, 1973). Soil bulk density, and porosity were estimated as per the standard procedure outlined by Piper (1966). Cation exchange capacity in soil samples was determined by method suggested by Chapman (1965). Soil organic carbon (SOC) was analyzed using rapid titration method of Walkey and Black (1934), available nitrogen was estimated using alkaline potassium permanganate method (Subbiah and Asija, 1956), available phosphorus (0.5 M $NaHCO_3$ extractable) by Olsen *et al.* (1954), and available potassium estimated by flame photometry (Pratt, 1965). DTPA extractable Fe, Cu, Zn, and Mn, according to Lindsay and Norvell (1978) and then analyzed using atomic absorption spectrophotometer model AA-7000 (Lab India). The total culturable microbial count was estimated on nutrient agar medium using serial dilution standard spread plate technique and expressed as colony forming units per gram of dry soil (Foght and Aislabie, 2005).

Statistical and economic analyses: The data on the analysis of soil and plant samples were subjected to analysis of variance (ANOVA) as suggested by Gomez and Gomez (1984) to find out the magnitude of treatment effect on various plant and soil parameters. For statistical analysis of data, Microsoft Excel software (Microsoft Corporation, USA) was used. Economic analysis was based on the prevailing cost of input/ operations of different treatments and price of produce. The benefit : cost ratio (B/C ratio) was calculated by dividing net returns by the total cost of cultivation.

Results and Discussion

Plant height, number of branches and nodules per plant, green pod length, green pods per plant, pods weight per plant and total pod yield (q ha^{-1}) were significantly influenced by treatment combinations of bioorganics *viz.* vermicompost, farmyard manure, jeevamrurth, ghan-jeevamrurth and inorganic fertilizers as compared to the control (Table 2). The plant height and number of branches per plant varied significantly among the treatments

Table 1: Nutrient content and culturable microbial count of bioorganic inputs

Parameters	Jeevamrurth	Ghan-jeevamrurth	Farmyard manure	Vermicompost
N (%)	0.12	0.69	0.50	1.38
P (%)	0.36	0.58	0.22	0.73
K (%)	0.15	0.67	0.48	1.13
Total culturable microbial count (cfu ml^{-1} and cfu g^{-1})	68.67×10^6	81.67×10^7	40.00×10^6	101.00×10^6

Table 2: Growth attributes of French bean as influenced by different nutrient sources (pooled data)

Treatments	Plant height at 60 DAS (cm)	No. of branches per plant at 60 DAS	Length of green pod (cm)	Nodules per plant
T_1 (Jeevamrurth @ 5% at weekly interval)	35.65	4.92	11.07	119.67
T_2 (FYM @ 20t ha^{-1} + 100% NPK)	38.70	5.75	12.52	178.00
T_3 (FYM @ 20t ha^{-1} + Jeevamrurth @ 5% at weekly interval)	41.28	5.89	13.72	283.33
T_4 (FYM @ 20t ha^{-1} + Jeevamrurth @ 5% at fortnight interval)	38.98	5.86	12.97	274.33
T_5 (Vermicompost @ 5t ha^{-1} + 100% NPK)	38.65	5.85	12.87	209.33
T_6 (Vermicompost @ 5t ha^{-1} + Jeevamrurth @ 5% at weekly interval)	41.30	6.11	14.21	235.00
T_7 (Vermicompost @ 5t ha^{-1} + Jeevamrurth @ 5% at fortnight interval)	39.10	5.88	13.51	203.00
T_8 (Jeevamrurth @ 5% + Ghanjeevamrurth at fortnight interval)	38.53	5.71	12.4	187.67
T_9 100% NPK (Control)	37.11	5.24	12.02	97.00
CD (0.05)	1.106	0.084	0.743	36.81

and the maximum plant height (41.30 cm) and number of branches per plant (6.11) were recorded in treatment T_6 (vermicompost @ 5 t ha^{-1} + jeevamrutha at weekly interval). The corresponding lowest values (35.65 cm and 4.92) were observed in sole application of jeevamrurth @ 5% at weekly interval. Similarly, significantly higher green pod length (14.21 cm) in french bean was recorded in T_6 treatment, followed by FYM @ 20t ha^{-1} + jeevamrurth @ 5% at weekly interval (T_3) in comparison to other treatments. Treatments T_3 and T_4 did not vary much from each other but registered significantly higher nodules per plant in comparison to all other treatments.

The highest nodules per plant (283.33) was recorded in FYM @ 20t ha^{-1} + Jeevamrurth @ 5% at weekly interval and lowest (97.0) was in 100% recommended NPK (T_9). The better growth in terms of plant height, number of branches per plant and green pod length in treatment T_6 (vermicompost @ 5 t ha^{-1} + jeevamrutha at weekly interval) could be ascribed to accelerated proliferation of beneficial soil microbes and better availability of nutrients through rapid mineralization and increased solubilisation of native soil nutrients and cumulative effect of continuous supply of nutrients and growth promoting substances present in vermicompost and jeevamrurth lead to better absorption of nutrients resulted into synthesis of nucleic acid, amino acid, amide substances in growing region and meristematic tissue ultimately enhancing cell division and differentiation (Jaipaul *et al.,* 2011; Jidhu and Jeyakumar, 2016; Thakur, *et al.,* 2018). Also, cow urine present in jeevamrutha provides nitrogen which is the constituent of protein and protoplasm, vigorously induces the vegetative development of the plant. Jeevamrutha is well thought-out to be a gifted source of natural carbon, N, P, K and lot of other micro nutrients required for the crops (Somdutt *et al.,* 2021). Since plant height is an important yield attribute, any practice to alter plant height would influence crop yield (Valdez, 2011).

Significantly higher pods per plant (9.70) was obtained in T_6 (vermicompost 5 t ha^{-1} + jeevamrutha at a weekly interval) treatment in comparison to other treatments (Table 3). Increased green pod numbers might be due to fact that vermicompost and jeevamrutha contains growth promoting substances such as humic acids and growth regulators like auxins, gibberellins, and cytokinins etc. (Tomati *et al.,* 1988) which are liable for enhanced growth and yield of numerous crops (Atiyeh *et al.,* 2002; Patil and Udmale, 2016). Treatment T_6 remained at par with T_3 but produced a significantly higher weight of pods per plant (51.45 g)

Table 3: Influence of nutrient sources on yield attributes of French bean (pooled data)

Treatments	No. of green pods per plant	Weight of pods per plant (g)	Pod yield (q ha^{-1})
T_1 (Jeevamrurth @ 5% at weekly interval)	6.69	24.90	33.1
T_2 (FYM @ 20t ha^{-1} + 100% NPK)	8.23	44.26	58.9
T_3 (FYM @ 20t ha^{-1} + Jeevamrurth @ 5% at weekly interval)	8.93	50.26	66.8
T_4 (FYM @ 20t ha^{-1} + Jeevamrurth @ 5% at fortnight interval)	8.6	46.89	62.4
T_5 (Vermicompost @ 5t ha^{-1} + 100% NPK)	8.33	46.07	61.3
T_6 (Vermicompost @ 5t ha^{-1} +Jeevamrurth @ 5% at weekly interval)	9.70	51.45	68.4
T_7 (Vermicompost @ 5t ha^{-1} + Jeevamrurth @ 5% at fortnight interval)	8.90	47.41	63.1
T_8 (Jeevamrurth @ 5% + Ghanjeevamrurth at fortnight interval)	7.93	41.91	55.7
T_9 (100% NPK) (Control)	6.83	36.17	48.1
CD (0.05)	0.595	1.610	2.14

Table 4: Impact of nutrient sources on soil physico-chemical properties and culturable microbial count

Treatments	Bulk density (mg m^{-3})	Porosity (%)	pH	Organic carbon (g kg^{-1})	CEC (Cmol p^{+} kg^{-1} soil)	Total culturable microbial count (x 10^{5} cfu g^{-1})
T_1 (Jeevamrurth @ 5% at weekly interval)	1.371	39.03	6.90	5.90	9.87	36.33
T_2 (FYM @ 20t ha^{-1} + 100% NPK)	1.375	39.97	6.85	9.90	13.40	39.67
T_3 (FYM @ 20t ha^{-1} + Jeevamrurth @ 5% at weekly interval)	1.372	39.83	6.85	11.10	13.53	65.00
T_4 (FYM @ 20t ha^{-1} + Jeevamrurth @ 5% at fortnight interval)	1.377	39.27	6.87	10.80	13.33	59.33
T_5 (Vermicompost @ 5t ha^{-1} + 100% NPK.)	1.365	40.43	6.87	10.00	13.63	47.00
T_6 (Vermicompost @ 5t ha^{-1} +Jeevamrurth @ 5% at weekly interval)	1.328	40.77	6.85	11.20	14.47	72.67
T_7 (Vermicompost @ 5t ha^{-1} + Jeevamrurth @ 5% at fortnight interval)	1.347	40.53	6.89	10.20	13.83	59.00
T_8 (Jeevamrurth @ 5% + Ghanjeevamrurth at fortnight interval)	1.349	39.27	6.91	8.80	13.13	37.67
T_9 (100% NPK) (Control)	1.382	37.83	6.79	4.90	9.60	25.00
CD (0.05)	NS	NS	NS	0.60	0.26	2.52

than the remaining treatments. Significantly higher number of green pods per plant and higher weight of pods per plant was observed with organic nutrient supply (Mahanta *et al.,* 2015; Yogananda *et al.,* 2020). The highest green pod yield (68.4 q ha^{-1}) was recorded in plots receiving vermicompost @ 5 t ha^{-1} + jeevamrutha at weekly interval, followed by FYM @ 20t ha^{-1} + jeevamrurth @ 5% at weekly interval, while the lowest yield (33.1 q ha^{-1}) was recorded in sole application of jeevamrurth @ 5% at weekly interval treatment. Variability in the management of soil fertility under organic production system affect soil dynamics and plant metabolism, which result in differences in plant composition and yield (Worthington, 2001). Improvement in green pod yield of French bean may be attributed to better and steady supply of all major and micro-nutrients at vital growth period of the crop (Kamble *et al.,* 2018; Sutar, 2019). The augmented soil aeration and water retention capacity manifested by lower soil bulk density and higher organic carbon with vermicompost, farmyard manure and jeevamrutha application might have resulted in greater synthesis of carbohydrate with higher photosynthetic activity, and their proper translocation, and accumulation of photosynthates towards sink (Thakur *et al.,* 2018; Yogananda *et al.,* 2020).

The results in Table 4 and 5 revealed that the application of different bioorganic nutrient sources resulted in positive effects virtually on all soil nutrients and properties. The obtained data indicated a positive but in significant effect of treatments on soil bulk density and porosity of the soil (Table 4). The lowest bulk density was recorded with the application of T_6 and mean decrease in bulk density was 3.91% as compared to the control. The observed reduction in bulk density might be due to improved microbial population and activity by the addition of vermicompost and jeevamrutha which produce polysaccharides providing a

Table 5: Effect of different nutrient sources on soil macro and micronutrients

Treatments	Available nitrogen (kg ha^{-1})	Available phosphorous (kg ha^{-1})	Available potassium (kg ha^{-1})	Zn (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})
T_1 (Jeevamrurth @ 5% at weekly interval)	208.72	19.47	141.61	1.06	7.62	9.10	1.57
T_2 (FYM @ 20t ha^{-1} + 100% NPK)	235.89	19.53	179.70	1.71	8.94	9.63	2.02
T_3 (FYM @ 20t ha^{-1} + Jeevamrurth @ 5% at weekly interval)	256.80	32.97	180.83	1.92	9.92	10.58	2.55
T_4 (FYM @ 20t ha^{-1} + Jeevamrurth @ 5% at fortnight interval)	256.80	24.69	180.11	1.88	9.25	9.80	2.20
T_5 (Vermicompost @ 5t ha^{-1} + 100% NPK.)	241.12	20.25	178.31	1.73	9.01	9.75	2.15
T_6 (Vermicompost @ 5t ha^{-1} + Jeevamrurth @ 5% at weekly interval)	288.16	28.39	187.56	2.05	10.01	10.76	2.71
T_7 (Vermicompost @ 5t ha^{-1} + Jeevamrurth @ 5% at fortnight interval)	267.25	25.57	182.69	1.91	9.67	9.93	2.31
T_8 (Jeevamrurth @ 5% + Ghanjeevamrurth at fortnight interval)	230.67	17.34	173.95	1.65	8.05	9.54	1.91
T_9 (100% NPK) (Control)	209.76	15.09	170.72	1.57	7.43	8.82	1.61
CD (0.05)	34.85	1.79	8.05	0.051	0.072	0.191	0.042

cementing action between soil particles resulted in the formation of aggregates, increased root growth and bioprocesses (Manivannan *et al.,* 2009). Further, the decrease in bulk density of soil during the study due to addition of organic matter and low-density fibers from the organic manures was also evident which corroborates with the reports of by Abbas and Fares (2009) and Hammad *et al.* (2020). The highest porosity (40.77%) was obtained under T_6 treatment which was higher by 7.78% as compared to the control. Improvement in porosity in response to the addition of bioorganic nutrients is due to improved organic matter status and soil aggregation (Bhatacharyya *et al.,* 2008). The use of bioorganic amendments is accompanied with many beneficial soil characteristics including lowering of bulk density and raising porosity (Bulluck *et al.,* 2002; Gopinath *et al.,* 2009).

Soil porosity tended to increase in the organic systems, whereas the conventional systems had lower porosity values (Clark *et al.,* 1998). Our results are in accordance with the findings of Hampton *et al.* (2011) and Datt *et al.* (2013) who reported that favourable changes in soil bulk density and porosity could be seen only after continuous application of bioorganic inputs. There was no significant difference in soil pH among different treatment combination of nutrient sources (Table 4). In the present experiment, though non-significant but slightly higher pH was recorded in bioorganic nutrient applied treatments. The soil pH was within the neutral range and it varied between 6.90 (T_1) and 6.79 (T_9). The soil pH increased in all the treatments compared to control (T_9). Our results are in line with earlier reports Gopinath *et al.,* 2008; Yogananda *et al.,* 2020) where organic production systems had slightly higher pH values than their conventional counterparts. This elucidates the vital role of organic nutrient sources and other fermented organic inputs can have in buffering the soil (Stroo and Alexander, 1986; Arden-Clarke and Hodges, 1988) and pH of rhizosphere depend on organic substances produced during decomposition of added organic materials, humus and soil parent material (Fliessbach *et al.,* 2007). The nutrient management practices exerted significant influence on build up of soil organic carbon, cation exchange capacity and total culturable microbial count (Table 4). The maximum SOC content (11.20 g kg^{-1}) and CEC (14.47 C mol p^{+} kg^{-1}) was recorded in T_6 treatment and minimum (4.9 g kg^{-1} and 9.60 C mol p+ kg^{-1}) in T_9 treatment, respectively.

This rise in SOC and CEC might be due to the addition of vermicompost, farmyard manure and jeevamrutha which increased the microbial and enzymatic activity in soil, resulting in increased soil organic matter, total carbon, and cation exchange capacity and ultimately improving the soil quality (Bulluck *et al.,* 2002). These findings corroborates with the studies undertaken by Jaipaul *et al.* (2011) and Hammad *et al.,* (2020). The highest total culturable microbial count was recorded in T_6 treatment, whereas the lowest was obtained in T_9 treatment. This increase in microbial population in jeevamrurth containing treatments might be due to promt buildup of microflora with the addition of fermented organics whereas lower microbial population in control treatment might be due to smothering effect of inorganic fertilizers on living organisms (Ravusaheb *et al.,* 2010). Jeevamrurth contains higher amount of growth promoting substances, vitamins and enzymes coupled with addition of compost and FYM caused a significant increase in the microbial population (Parthasarathi *et al.,* 2008) because these substrate offers sufficient particulate surface area for microbial growth and

Table 6: Benefit-cost ratio of french bean as influenced by nutrient sources

Treatments	Total cost of cultivation (₹ ha^{-1})	Yield (q ha^{-1})	Gross income (₹ ha^{-1})	Net returns (₹ ha^{-1})	B/C ratio
T_1 (Jeevamrurth @ 5% at weekly interval)	33170	33.1	99300	56630	1.71
T_2 (FYM @ 20t ha^{-1} + 100% NPK)	53170	58.9	176700	123530	2.32
T_3 (FYM @ 20t ha^{-1} + Jeevamrurth @ 5% at weekly interval)	57670	66.8	200400	142730	2.47
T_4 (FYM @ 20t ha^{-1} + Jeevamrurth @ 5% at fortnight interval)	52990	62.4	187200	134280	2.53
T_5 (Vermicompost @ 5t ha^{-1} + 100% NPK)	53170	61.3	183900	130730	2.46
T_6 (Vermicompost @ 5t ha^{-1} +Jeevamrurth @ 5% at weekly interval)	57670	68.4	205200	147530	2.56
T_7 (Vermicompost @ 5t ha^{-1} + Jeevamrurth @ 5% at fortnight interval)	53420	63.1	189300	136380	2.54
T_8 (Jeevamrurth @ 5% + Ghanjeevamrurth at fortnight interval)	47430	55.7	167100	120180	2.53
T_9 (100% NPK) (Control)	38170	48.1	114300	76130	1.99

activities (Shi-wei and Fu-zhen, 1991). A phenomenal difference existed among the treatments with respect to available N, P and K in post-harvest soil (Table 5). It was clearly visible from the data obtained from 2 year study, that all the treatments contained higher N content over control and maximum (288.16 kg ha^{-1}) was recorded in T6 followed by T_7, T_3 = T_4 treatments (Table 5). The residual soil N was recorded more in the plots treated either with vermicompost or farmyard manure along with jeevamrurth at varying intervals, which might be due to favourable rhizosphere environment and lower C/N ratio of vermicompost and farmyard manure under bioorganic treatments, which helped in the rapid mineralization and augmented the residual soil nitrogen fertility (Gopinath *et al.,* 2011; Yogananda *et al.,* 2020). Further, there was a pronounced multiplication of microbes in soil with incorporation of bioorganics (vermicompost, farmyard manure, jeevamrurth, ghan-jeevamrurth) and these organics during mineralization converted organically bound nitrogen to inorganic form to the available pool resulting in higher availability of nitrogen in soil (Rai *et al.,* 2014; Sharma *et al.,* 2020).

The highest available phosphorus content was recorded in T_3 treatment. Higher content of phosphorus was probably due to release of organic acids during microbial breakdown of organic manure (FYM) that have helped in solubility of native phosphorus. The intricate organic anions and hydroxyl acids liberated during decomposition of farmyard manure might have chelated Al^{+}, Fe^{+3} and Ca^{+2} and decreased the phosphate fixing power of these cations thereby increased the phosphorus availability (Reddy *et al.,* 1990). Available K was significantly higher in plots treated with T_6. Enhancement of soil K content was recorded in about all the bioorganic nutritional treatments over sole application of NPK fertilizer (Table 5). The maximum K content in soil was obtained in T_6 treatment which was statistically at par with T_7 and T_3 treatments. The available potassium content increased due to addition of vermicompost and farmyard manure along with jeevamrurth which helped in the release of slowly exchangeable form of potassium to available form in the soil solution and increased the potassium content of soil (Chatterjee and Bandyopadhyay, 2014). The positive soil nutrients balance perceived in the plots treated with jeevamrurth either with vermicompost or farmyard manure combinations may be ascribed to the plethora of these sources in terms of organic matter and improved microbial growth. Bioorganic sources not only supply macro and micronutrients but are also a store house of beneficial microorganisms. Application of bioorganic and fermented organic (jeevamrurth and ghan- jeevamrurth) sources might have helped in enhanced mineralization of native nutrients by creating favourable soil environment and offer sufficient particulate surface areas for microbial activities as well as for the secured retention of nutrients and most of the nutrients are present in bio-available forms (Edwards, 1998; Rajkhowa *et al.,* 2017).

Similar results of positive effect of bioorganic input application on soil nutrient balance has been also reported by Saha *et al.* (2010) and Singh *et al.* (2014). The available data on DTPA extractable micronutrients of soil under various treatments showed that significant difference was observed in Zn, Fe, Mn and Cu content (Table 5). The highest Zn, Fe, Mn and Cu content was obtained in T_6 treatment when applied at weekly interval. The increased availability of micronutrient in bioorganically treated plots may be due to chelating agents that was released from microbial disintegration of farmyard manure, biocompost and fermented organics (jeevamrurth and ghan- jeevamrurth) which might have prevented the precipitation, oxidation, and leaching of micronutrients (Sharma *et al.,* 2001). Several researchers have also recorded an increase in soil micronutrients due to application of bioorganic nutrient sources in different ecosystems which may be ascribed to narrow C : N ratio of farmyard manure and vermicompost along with jeevamruth which encourages rapid mineralization of native nutrients in the rhizosphere (Panwar *et al.,* 2010; Hampton *et al.,* 2011; Sharma *et al.,* 2020). The adoption of technology in modern agriculture can only be feasible and acceptable to farmers if it is economically viable. The treatment-wise cost of cultivation and return analysis (B : C ratio) has been depicted in Table 6. The economic analysis showed that the highest net return of Rs. 1,47,530 ha^{-1} was obtained from treatment T_6 which also recorded highest benefit cost (B/C) ratio of 2.56. The high profitability in T_6 was on account of the highest yield (68.4 q ha^{-1}) recorded in this treatment after incurring Rs. 57,670 towards cost of cultivation. Yogananda *et al.* (2020) observed the highest annual net returns in cowpea through treatment comprising of 100% N equivalent compost + beejamrutha + jeevamrutha over the recommended practice (100% NPK + 10 t FYM ha^{-1}). Similar returns through conjoint use of bioorganic nutrient sources have also been reported by Thakur *et al.* (2018) in cauliflower in the Indian Himalayas.

Traditional organic French bean cultivation suffers from the slow release of nutrients, consequently resulting in low green pod yield. On the basis of two years of study, the results indicate that jeevamrurth @ 5% at weekly interval with vermicompost 5 t/ha can be used as a cost-effective bioorganic nutrient module for sustainable yield, profitability and soil health improvement in french bean cultivation in north-western Himalayas.

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