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Integrated Organic Nutrient Management with Biofertilizers Enhances French Bean (Phaseolus vulgaris L.) Growth and Yield under Temperate Conditions of Kashmir

Parmeet Singh
Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir
Shayista Fayaz
shayista027@gmail.com

SKUAST-KASHMIR
Moneesa Bashir
SKUAST-KASHMIR
Rifat Un Nisa
SKUAST-KASHMIR
Mehraj Ud Din Sofi
SKUAST-KASHMIR

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ABSTRACT

The indiscriminate use of agrochemicals and their associated environmental risks have intensified the need for sustainable and eco-friendly nutrient management strategies. Organic nutrient sources such as Rhizobium Phaseolus, farmyard manure (FYM), vermicompost, have emerged as viable alternatives for maintaining soil health and crop productivity. A two-year field investigation was conducted to assess the effects of bio-organic inputs applied alone or in combination with vermicompost/FYM on the growth performance, yield, quality attributes, and nutrient uptake of French bean (*Phaseolus vulgaris* L.). The experiment consisted of seven treatments arranged in a randomized block design with three replications. T1: Control, T2: FYM 4t ha^{-1}, T3: V.C @5t ha^{-1}, T4: FYM @ 2.5 t ha^{-1}+V.c @ 2.5 t ha^{-1},T5: Poultry manure @ 5 t ha^{-1}, T6: FYM @ 5 t ha^{-1} + Azospirillum + PSB + KSB, T7: Poultry Manure @ 5 t ha^{-1} + Azospirillum + KSB. The results revealed that the application of FYM @ 5 t ha^{-1} along with Azospirillum, PSB, and KSB significantly improved growth and yield parameters, recording the maximum plant height (58.15 & 62.58cm), leaf area index ((4.29 & 5.10**),** and dry matter accumulation **(**12.87 & 16.51 g $plant^{-1}$) during both cropping seasons.

Keywords: French bean, organic farming, FYM, vermicompost, biofertilizers, Azospirillum, PSB, KSB, yield, nutrient uptake.

Introduction: Beans are among the most extensively grown and consumed food crops worldwide, contributing more than 5% to total global vegetable intake. They possess high nutritional significance, as they are excellent sources of proteins, dietary fiber, vitamins, and essential minerals (Maphosa and Jideani, 2017; Manzoor *et al*., 2019). However, in recent years, the productivity of beans, along with other major crops, has declined in several parts of the world due to the combined effects of climate variability and declining soil fertility (Ayisi *et al*., 2019). FAO reports indicate that global bean yields declined by more than 5% between 2017 and 2021. This downward trend has been particularly evident over the last two decades in regions such as Europe, Africa, and East Asia, where yield reductions of approximately 34%, more than 37%, and 24%, respectively, have been recorded (FAO, 2023). Common beans prefer well-drained, sandy-loam or sandy-clay soils, but they are sensitive to soil pH and develop best at a pH between 5.8 and 6.5. They are moderately demanding in terms of soil nutrient content, but the primary macronutrients such as nitrogen (N), phosphorus (P) and potassium (K) are essential for their normal growth and development (Smith and Rao, 2021). Several studies have

reported that organic fertilization improves nutrient availability, enhances soil microbial populations, and positively influences the physical, chemical and biological properties of degraded or low-fertility soils (Demiraj *et al*., 2018). Although the complete exclusion of mineral fertilizers from commercial agriculture is not feasible, their balanced and integrated use with organic and alternative nutrient sources is essential for sustaining crop productivity (Dar *et al*., 2014). An effective nutrient management system therefore emphasizes ensuring a continuous and adequate nutrient supply to crops by synergistically utilizing the benefits of all available nutrient sources to achieve desired yield targets.

By 2050, global cereal production must increase significantly to meet the food requirements of the projected world population of approximately 9.8 billion people (FASOSTAT 2019). Excessive or improper use of inorganic fertilizers can lead to adverse environmental impacts that threaten the long-term sustainability of agricultural systems (Shi *et al*., 2008; Zhou *et al*., 2013). These environmental concerns have driven the adoption of sustainable alternatives that regulate rhizosphere biotic interactions within the broader framework of integrated soil fertility management (Mahmood *et al.,* 2017; Nwite and Alu, 2018). These concerns have highlighted the need for sustainable alternatives capable of regulating rhizosphere biotic interactions within the framework of integrated soil fertility management. To overcome constraints related to soil fertility and plant nutrition, there is a pressing need for the development of innovative fertilizer formulations and improved application techniques. In commercial agriculture, the use of mineral fertilizers cannot be completely excluded, but there is a need for their integrated use with alternative nutrient sources to maintain crop productivity (Dar *et al*., 2014). A key aspect of the nutrient management system is ensuring a constant supply of nutrients to plants to achieve a certain yield level by integrating the benefits of all potential nutrient sources.

The advantages of integrating organic and inorganic nutrient sources, as opposed to their individual application, have been widely reported in the literature (Mohanty *et al.,* 2018; Rasool *et al*., 2019). Several studies have shown that the application of organo-mineral fertilizers represents an effective approach for enhancing growth performance, yield, and produce quality in leguminous crops (Ghosh *et al.,* 2014; Fekadu *et al*., 2018).

Materials and methods: An on-farm research trial was carried out at Agronomic Research Farm, of the Faculty of Agriculture, Sher-e Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, India during Kharif season of 2024 and 2025. The soil of the

research trial had a silty-clay loam texture with pH of 6.60, 0.70% of soil organic carbon and 230.3 kg/ha, 18.5 kg/ha and 150.0 kg/ha of available nitrogen, phosphorus and potassium respectively. The experimental site is located at 34°17′ N latitude and 74°33′ E longitude, at an altitude of 1524 m above mean sea level. The experimental field was well-drained with uniform topography. The total precipitation received during the crop season was 232.7 mm. A total of 328 sunshine hours were recorded, while the mean maximum and minimum relative humidity were 79.75% and 56.04%, respectively. The soil of the experimental field was silty clay loam in texture, medium in organic carbon, available nitrogen, phosphorus, and potassium, with neutral pH and normal electrical conductivity (Table 1).

The experiment comprising of seven treatments including control was laid out in a Randomized Block Design with three replications. The seven treatments are T1: Control, T2: FYM 4t ha^{-1} , T3: V.C @5t ha^{-1} , T4: FYM @2.5 t ha^{-1}+V.c @ 2.5 t ha^{-1},T5: Poultry manure @ 5 t ha^{-1}, T6: FYM @ 5 t ha^{-1} + Azospirillum + PSB + KSB, T7: Poultry Manure @ 5 t ha^{-1} + Azospirillum + KSB. The field was prepared by giving 2–3 ploughings with a rotavator to break clods and loosen hard pans, ensuring a fine tilth. Crop residues, stubbles, and weeds were removed thoroughly, followed by harrowing to achieve proper pulverization of the soil. After levelling, the experimental field was laid out according to the design, and block/replication borders, plot bunds, and irrigation channels were constructed manually as per the layout plan. The required quantities of organic manures, namely farmyard manure (FYM), poultry manure, and vermicompost, as per the respective treatment details, were uniformly incorporated into the soil 15 days prior to sowing to allow adequate decomposition and nutrient mineralization. For recording growth and yield attributes, three plants were randomly selected and tagged from the penultimate rows of each plot to avoid border effects. Observations were recorded at 20-day intervals from the date of sowing up to harvest, and the mean values were computed for statistical analysis. Plant height was measured from the base of the plant to the tip of the uppermost fully expanded leaf. Leaf area was estimated by measuring the maximum length and breadth of representative leaves using a meter scale. The obtained value was multiplied by the correction factor 0.73309 (Chand and Sharma, 1976) to determine the actual leaf area. Leaf area index (LAI) was calculated as the ratio of total leaf area to the corresponding ground area. For determining dry matter accumulation, the selected plants at each sampling stage (15-day intervals from sowing to plucking stage) were first sun-dried and subsequently oven-dried at 70°C until a constant weight was achieved. The dry weight was recorded using an electronic balance and expressed on a per-plant basis.

Table:1. Physiochemical properties of experimental field

Soil texture	EC ds/m	pH	O.C	N	P	K
Silty clay loam	0.39	6.60	0.70	230.3	18.5	150

Result and Discussion:

Growth parameters

As depicted the growth attributes in **Table 2**. The plant height 58.15 & 62.58cm was significantly taller with the application of FYM @ 5 t ha^{-1} along with Azospirillum, PSB, and KSB treatment (T6) during both years at harvest stage than other treatments. The use of 100% organic nutrient management provided a conducive environment for the proliferation and activity of nitrogen-fixing microorganisms during later stages of crop growth. The increase in plant height may be attributed to the combined application of vermicompost and easily available nutrients supplied through organic formulations. This integrated nutrient supply likely promoted vigorous seedling growth, as vermicompost is a rich source of essential nutrients, organic matter, growth-promoting substances, and beneficial enzymes. These components enhance nutrient availability and stimulate physiological processes such as cell division and elongation, ultimately supporting improved plant growth and development. Our results are in line with results of Rana *et al*.,2025.

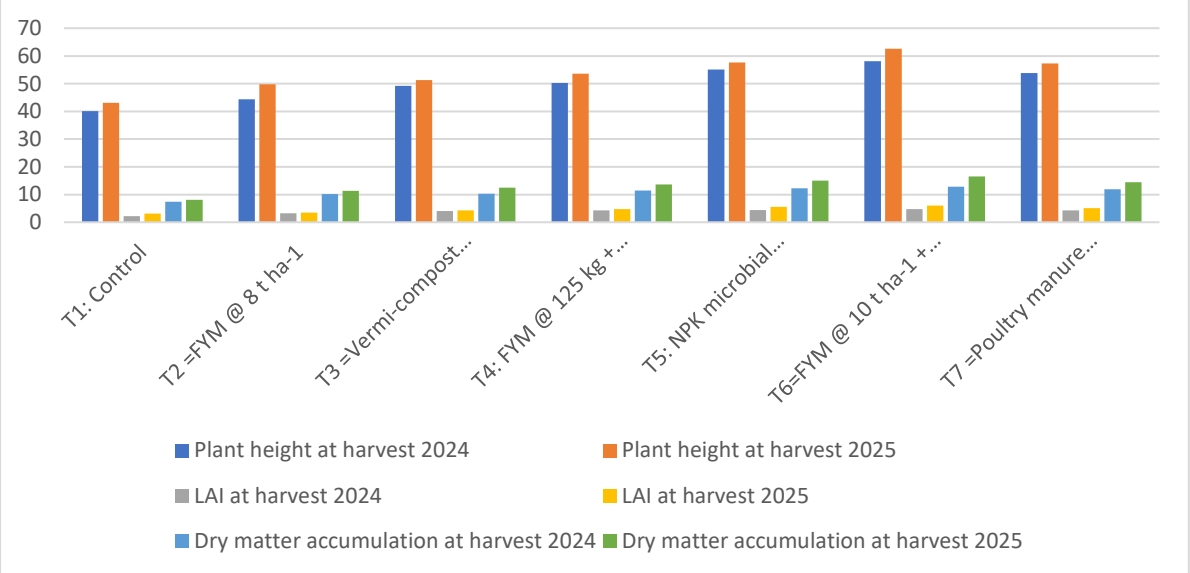
Leaf Area Index: During two growing seasons at 60 DAS maximum leaf area index of (4.29 & 5.10) was recorded in T6 (FYM @ 5 t ha^{-1} along with Azospirillum, PSB, and KSB treatment) than other treatments. The second assessment indicated that the application of organic nutrient sources created favourable conditions for the growth and activity of Azospirilium,PSB,KSB fixing bacteria, thereby enhancing micronutrient ailability and uptake by the plants.

Dry matter accumulation: The maximum plant dry weight 12.87 16.51g) was observed in T6 (FYM @ 5 t ha^{-1} along with Azospirillum, PSB, and KSB treatment), whereas the lowest dry weight was recorded in T1 (control). Enhanced plant dry matter accumulation may be attributed

due to the application of organic nutrient sources, which improved nutrient availability and supported better plant growth. Similar findings have also been reported by Ramana *et al.* 2011.

Table.2: Effect of organic source of nutrients on growth parameters in common Beans

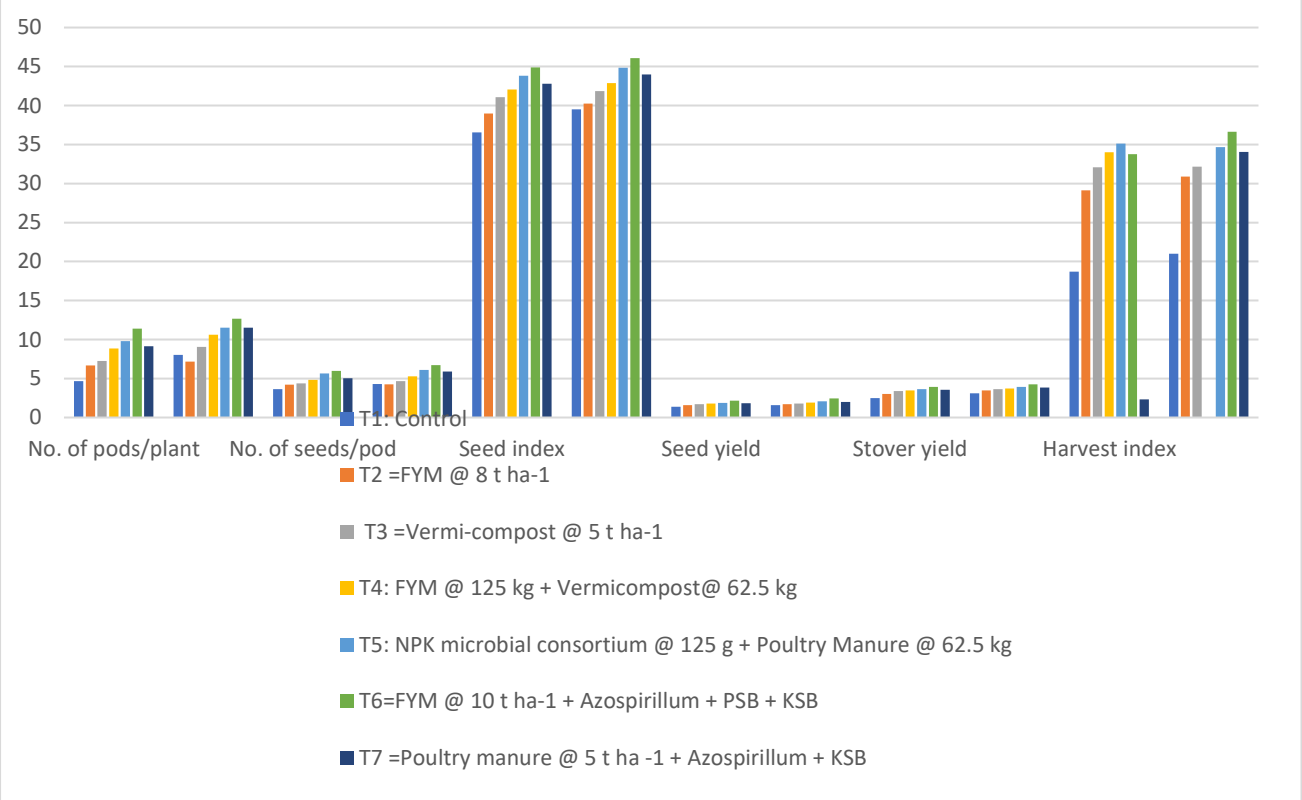
Treatment details	Plant height at harvest		LAI at harvest		Dry matter accumulation at harvest	
	2024	2025	2024	2025	2024	2025
T1: Control	40.05	43.05	2.25	3.11	7.38	8.15
T2 =FYM @ 8 t ha^{-1}	44.41	49.81	3.22	3.45	10.17	11.35
T3 =Vermi-compost @ 5 t ha^{-1}	49.15	51.26	4.10	4.30	10.34	12.51
T4: FYM @ 125 kg + Vermicompost@ 62.5 kg	50.28	53.57	4.23	4.74	11.44	13.61
T5: NPK microbial consortium @ 125 g + Poultry Manure @ 62.5 kg	55.15	57.61	4.36	5.54	12.23	15.08
T6=FYM @ 10 t ha^{-1} + Azospirillum + PSB + KSB	58.15	62.58	4.74	6.07	12.87	16.51
T7 =Poultry manure @ 5 t ha $^{-1}$ + Azospirillum + KSB	53.83	57.31	4.29	5.10	11.91	14.50
SEM±	2.74	2.19	0.079	0.069	0.88	1.23
CD(0.5)	8.45	6.76	0.24	0.293	2.72	3.79



Effect on yield attributes and yields: Among yield attributes, maximum pods/plant (11.41&12.68) & no. of seeds/pod (5.98 & 6.71), seed index (44.88 & 46.07), seed yield (2.14 & 2.45 t ha^{-1}), Stover yield (2.45 3.91t ha^{-1}) and Harvest index(%) were found T6:FYM @ 10 t ha^{-1} + Azospirillum + PSB + KSB (Table. 3). Higher crop productivity might be attributed to the beneficial microorganisms with organic manure (FYM), which assured better crop establishment. Balanced supplied of beneficial nutrients during cropping period that helps increase in efficiency of micro-organisms in rhizoshphere results in better crop productivity as well as yield attribute compared to control treatment.The present results are in agreement with findings of Kumari *et al*. (2012), Kumawat *et al.* (2015).

Table.3: Effect of organic source of nutrient on yield attributes in common Beans

Treatment details	No. of pods/plant		No. of seeds/pod		Seed index		Seed yield (t/ha)		Stover yield (t/ha)		Harvest index(%)	
	2024	2025	2024	2025	2024	2025	2024	2025	2024	2025	2024	2025
T1: Control	4.68	8.03	3.63	4.31	36.57	39.51	1.39	1.58	2.50	3.10	18.72	20.99
T2 =FYM @ 8 t ha^{-1}	6.69	7.16	4.23	4.27	38.99	40.25	1.59	1.70	3.00	3.48	29.13	30.90
T3 =Vermi-compost @ 5 t ha^{-1}	7.25	9.05	4.36	4.65	41.05	41.86	1.69	1.80	3.38	3.62	32.08	32.15
T4: FYM @ 125 kg + Vermicompost@ 62.5 kg	8.86	10.62	4.83	5.29	42.05	42.88	1.80	1.92	3.49	3.72	33.40	34.17
T5: NPK microbial consortium @ 125 g + Poultry Manure @ 62.5 kg	9.78	11.51	5.64	6.11	43.81	44.85	1.88	2.07	3.62	3.94	34.02	34.65
T6=FYM @ 10 t ha^{-1} + Azospirillum + PSB + KSB	11.41	12.68	5.98	6.71	44.88	46.07	2.14	2.45	3.91	4.24	35.13	36.63
T7 =Poultry manure @ 5 t ha^{-1} + Azospirillum + KSB	9.15	11.51	5.04	5.89	42.80	44.00	1.82	2.00	3.55	3.86	33.75	34.06
SEM±	0.49	0.87	0.19	0.20	1.72	2.17	0.056	0.065	0.22	0.22	2.31	2.25
CD (0.5)	1.51	2.70	0.59	0.63	5.31	6.70	0.17	0.20	0.68	0.69	7.16	6.82



Conclusion: The findings of the two-year field investigation demonstrate that the application of organic manures and biofertilizers is an effective and sustainable nutrient management strategy for French bean cultivation. Among the different nutrient management practices evaluated, the combined application of FYM @ 5 t ha^{-1} along with *Azospirillum*, phosphate-solubilizing bacteria (PSB), and potassium-solubilizing bacteria (KSB) proved to be the most effective in enhancing crop growth, yield, quality attributes, and nutrient uptake. This treatment consistently recorded superior plant height, leaf area index, and dry matter accumulation across both cropping seasons, indicating improved nutrient availability and better crop performance. Therefore, the integrated use of FYM with *Azospirillum*, PSB, and KSB can be recommended as a viable, environmentally friendly, and economically sustainable nutrient management practice for achieving higher productivity and maintaining soil health in French bean cultivation**.**

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