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Analysing the Nutrient Uptake and Economic Viability of Integrated Nutrient Management for French Bean (*Phaseolus vulgaris* L.) in Uttar Pradesh Gangetic Plain

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Abstract—A field experiment was carried out at the Krishi Vigyan Kindra-1 research plot in Kotwa, Azamgarh, Uttar Pradesh, India, to examine the nutrient absorption and economic feasibility of integrated nutrient management of French beans (*Phaseolus vulgaris* L.) during the Rabi season of 2022–2023 and 2023–2024.Treatments werea combination of five different levels of fertilizers and vermicompost viz. T_1(100% NPKS + 0% VC), T_2(75% NPKS + 25% VC), T_3(50% NPKS + 50% VC), T_4(25% NPKS + 75% VC) T_5 (0% NPKS + 100% VC) tofulfil the requirement of the recommended dose of fertilizers. This treatment was applied tofour genotypes of French bean i.e. Kashi Rajhans, Kashi Sampann, HUR-15, and HUR-137. Treatment (T_2) observed a significant maximum seed yield of 23.04 q $ha^{-1}$and straw yield(32.45 q ha^{-1}), harvest index (41.46%), and genotype Kashi sampan (41.93%).In the interaction treatment (T_2) 75% NPKS through fertilizers + 25% Vermicompost fertility levels with all genotypes achieved the highest B:C ratio and lowest through $T_5$100% RDF nutrient supply through vermicompost.Maximum cost of cultivation (₹140218.00 ha^{-1}) recorded by Treatment (T_5) to fulfil the 100% RDF nutrient through vermicompost and lowest gross return (₹ 423728.00 ha^{-1}).The lower grain yield with 100% RDF through vermicompost application compared to integrated fertilizers and vermicompostis due to the slower nutrient release, improving soil health and may not supply enough nutrients at the right time for optimal growth from vermicompost, whilefertilizers provide nutrients more quickly and in higher concentrations, leading to faster growth and better yields.In genotype Kashi sampan achieved the highest B: C ratio. This show T_2 more economically benefit to farmer then other treatments and genotype Kashi Sampann.According to the obtained output, it might be adopted to Kashi Sampann geno type for achieving potential yield for the Gangetic plains region and could be used alternate option for boosting productivity of French bean production.

Keywords: French bean, Integrated nutrient management, vermicompost, yield Economic.

I. INTRODUCTION

In India, cereals are the prominent source of protein in the daily diet (Swaminathan et al., 2012). However, the protein quality of cereals is suboptimal due to their lysine deficiency, and the digestion, absorption, and utilization of this protein may be incomplete. Despite this, substantial public funds are allocated to rights-based food subsidy programs that primarily distribute cereals, even though these grains provide low-quality protein.In water-scarce areas has also been observed that employment and wages are lower, highlighting the productivity-enhancing through irrigation (Verma, 1988, 1990, 1993). The Committee of Ashok Dalwaifor Doubling Farmers' Income (2017) projected the average monthly farmer income to be ₹6,498. The current Central government is working towards doubling farmers' incomes by 2022.

Green pod of French bean leguminous is one of the most important vegetables.It is popularly cultivated for its green pod and dry seed. Dry seeds are known as kidney beans. French bean grown throughout the world and contributesapproximately 30% of food legumes of the total production of pulse(Vasishtha and Srivastava, 2012). In India, is mainly grown in range Himalayan region, Indo-Gangetic plain, central Inda, andpeninsular region). 100 grams green pods contain aboutprotein1.7 g, carbohydrates4.5 g, 221 I.U. vitamin A, vitamin C11 mg, and calcium 50 mg (Gopalakrishnan, 2007; Kanwar et al., 2020) so, it may call a complete food.

In 2020-21, fertilizer consumption in India was 32.54 million tons, with a projected rise to 57.32 million tons by 2030, indicating a growing demand. To meet this need, promoting domestic fertilizer production is crucial to reduce reliance on imports (Jadhav &Ramappa, 2021). However, excessive fertilizer use may toxicwhen the accumulated heavy metals in soil like arsenic, cadmium, and uranium, which can enter the food chain and pose health risks (Das et al., 2023). Additionally, industrial emissions can degrade soil structure, impacting agricultural productivity and crop quality (Das et al., 2023). French beans, for example, thrive in soils with a pH of 5.5-6.5 and benefit from high-nitrogen fertilizers despite being legumes without nitrogen-fixing nodules (Choudhary, 2015).

Sole reliance on chemical fertilizers is unsustainable; INM, combining fertilizers, manures, and bio-fertilizers, that is essential for maintaining crop production and soil health. INM enhances nutrient efficiency, improves soil structure, and reduces environmental impact (Ghosh et al., 2004; Roy et al., 2006). This study explores INM's impact on French bean yield, assessing the role of vermicompost as a sustainable alternative to traditional fertilizers in eastern Uttar Pradesh.

II. METHOD AND MATERIALS

The field experiment was carried out at Krishi Vigyan Kindra-1, Kotwa, Azamgarh, Uttar Pradesh (26° 0.5824'Nand 83° 11.4212'E)during Rabi season years 2022-2023 and 2023-24. Azamgarh district falls under the 8thEastern PlainArgo-climatic zone of India. This region comes under a subtropical climate (semi-arid and sub-humid type), experiencing 1081.5 mm rainfall and subjected to extreme weather conditions i.e., extremely hot in summer and cold in winter. A sandy clay loam soil texture was found under experimental field (typical Ustochrepts) deep, well-drained, flat, low organic carbon (0.42%) content, and available nutrient i.e. nitrogen 338 kgha^{-1} (medium), phosphorus15 kgha^{-1} (low) and potassium189 kgha^{-1} (medium). Soil reaction varies from neutral to mildly alkaline that pH gives good response to NPK fertilizers for various crop.The conducted field experiment comprised 20 treatments combined with four varieties i.e. Kashi Rajhans, Kashi Sampann, HUR-15, and HUR-137 of French beans, and five integrated nutrient management levels of inorganic fertilizer and vermicompost (VC) to supply the recommended dose of nutrients100% RDF through fertilizers; 75% RDF via fertilizers with 25% from vermicompost; 50% RDF from fertilizers and 50% vermicompost; 25% RDF through fertilizers with 75% vermicompost; and 100% RDN via vermicompost.The experiment plotlayoutdesign was arranged in a split plot with 3 replications for all treatments. Each combination of fertilizers and vermicompost is applied to the respective genotype. The vermicompost ofthe market was analyzed for content of NPKS in thelaboratory, and accordingly itspercentage in manures, the particular manures were applied in the experimental plotaccordingly to treatments. The N, P and K content vermicompost (1.71%, 1.15% and 1.06%). The certified seeds of Kashi sampan and Kashi Rajhansweretaken from the Indian Institute of Vegetable Science, Varanasi and HUR- 15 and HUR- 137 from Banaras Hindu University, Varanasi.A shallow furrow was opened for sowing of seeds by line to line with row-to-row 45 cm and plant-to-plant15 cm spacing, first year on November 02nd, 2022 and second-year November 03^{rd,} 2023. The fernch bean seeds were treated with Rhizobium, PSB and Trichoderma @ 250 grams/10 kg of seeds before sowing. The treated seed was dried at room temperature and the shade then utilized for sowing.

III. RESULT AND DISCUSSION

Yield and yieldattribute

French bean grain yieldsignificantlyincreased up to 10% through the application of 75% NPKSby fertilizers + 25%vermicompostmanure treatments.Nitrogen playsa direct role in seed growth and indirectly helps in obliging osmotic imbalances present during the ultimate stage of seed filling (Kushwaha 1994, Dahatonde and Nalawar 1996). Vermicompost has a beneficial effect along withenvisaged mineralsby its high and longer availability of nutrients as per the needof the crop demand (Hegde and Dwivedi 1993). Thelower productivity of grain and straw was recorded with 100% NPKSapplied through vermicompost(Table 1). Probably, it might be due to non or less and both the availability of nitrogen at critical stages of crop growth (Shivananda et al. 1998). A maximum harvest index of approximately 41.46% was recorded in treatment (T2)than the furthertreatments. This is due to the proper availability of nutrients to crop roots with increased sink capacity.

75% NPKS application of the recommended dose of inorganic fertilizers and remaining through vermicompostincreased the grain yield by 11.54% during the first year and 9.77% second year,then100% NPKSthrough vermicompost application only (Table 1). The vermicompost's enhanced developed microbial population, along with Rhizobium, phosphobacteria, and Pseudomonas,may explain the positive effect of combining vermicompost with inorganic fertilizers on crop grain yield.As evident given in the Table 1;maximum cost of cultivation was incurred in treatment T_5 (Rs. 140218/-) followed by T4

(Rs.1,33,106/-) while maximum gross return T_2 (Rs. 507275/-) than T_3 ((Rs. 488435/-).Therefore, the highest B: C ratio value was obtained from T_2 (3.29) followed by T_1 (3.26). The highest expenditure under treatment T_5 might be due to the high rate ofvermicompost. This aligns with other investigators (Longmatula*et al*.,2021; Reddy et al., 2011). Maximum gross return was obtained in genotype Kashi Sampan (Rs. 515578/-) followed by Kashi Rajhans (Rs. 491125/-), HUR 15 (Rs. 455765/-)and lowest HUR-137 (Rs. 427867/-).

Interaction of INM and genotypes on yield attributesand yield

The flower number per plant is significantly affected by INM treatments and genotypes. T_2 (75% NPKSby fertilizers + 25% NPKS by vermicompost) observed maximum flower per plant and Kashi Sampann (50.14), followed by Kashi Rajhans (47.97), HUR 15 (47.26). Lowest observed $T_5$with the HUR-137 genotype (Table 2).Flowers are vital for the reproduction of French beans, enabling pollination, pod formation, and seed development. Healthy flowers lead to better pod sets, and higher yields, and support overall plant growth.Maximum grain per pod was recorded with T_2 and Kashi Sampann (6.81), followed by Kashi Rajhans (6.73), and HUR 15 (6.38). Lowest observed $T_5$with HUR-137 genotype.The number of grains per pod in French beans directly impacts yield, with a higher grain count boosting overall production and crop productivity.

Maximum grain yield was recorded with T_2 and Kashi Sampann (25.07 kg ha^{-1}), followed by Kashi Rajhans (23.53 kg ha^{-1}), genotype HUR 15 (23.11 kg ha^{-1}). $T_5$and HUR-137 genotypes recorded lowest (17.10 kg ha^{-1}).

Nutrient uptake

The nutrient uptake is significantly affected by INM treatments. T_2 (75% NPKS by fertilizers + 25% NPKS by vermicompost) was observed with maximum nitrogen uptake 70.77 kg ha^{-1} and 34.07 kg ha^{-1}, phosphorus 17.28 kg ha^{-1} and 2.54 kg ha^{-1}, potassium 40.31 kg ha^{-1} and 42.35 kg ha^{-1}, and sulfur 6.91 kg ha^{-1} and 3.33 kg ha^{-1} by grain and straw, respectively (Table:3).Higher biological production at these fertility levels was the primary cause of this (Prasad 1999).Furthermore, soil organic matter plays a major role in providing agricultural plants with nitrogen, phosphorous, and sulfur since it is the storage of these nutrients. It enhanced the soil's other chemical characteristics. Increased cation exchange capacity, for instance, aids in the trapping of potassium and other nutritional cations.In addition to providing nutrients, SOM facilitates the soil's nutrient release.All of these promote nutrient availability and, consequently, increased crop uptake.Cultivar Kashi Sampann has the highest nutrient uptake, followed by Kashi Rajhans,HUR-15, and HUR- 137. It resulted from the highest grain yield production.

Interaction of INM and Genotype on Economics

The Benefit-Cost (B/C) ratio is important as it helps assess the profitability of agricultural practices. In the present investigation the interaction of 75% NPKS through fertilizers + 25% Vermicompostfertility and genotypes positively affected B:C ratio(Fig 1). In genotype Kashi Sampannrecorded highest B: C ratio (3.63) withINM treatment(75% NPKS through fertilizers + 25% Vermicompostfertility levels). Treatment 100% RDF (0.0% NPKS through fertilizers + 100% Vermicompost) nutrient supply through vermicompostwith genotype HUR 137recorded lowest B: C ratio (1.69).It might be high cost of cultivation (₹140218.00ha^{-1}) to fulfil the 100% RDF nutrient through vermicompost and lowest gross return (₹ 423728.00 ha^{-1}).A higher B: C ratio indicates greater returns for each unit of investment, guiding farmers and policymakers in making cost-effective decisions to maximize economic benefits.

IV. CONCLUSION

A balanced combination of fertilizers and vermicompost offers significant benefits in terms of growth, yield, and economic viability. Among the different treatments, the combination of 75% NPKS + 25% Vermicompost (T_2) resulted in the highest seed yield and straw yield although the harvest index was significantly higher than the treatment with 100% vermicompost (T_5), which achieved the lowest harvest index.The treatment T_2, which included 75% NPKS + 25% vermicompost, provided the best cost-benefit ratio, indicating that it offers greater economic returns related to the other treatments. The higher cost of cultivation associated with using 100% RDF through vermicompost and the lower gross return make it a less economically viable option. Furthermore, the genotype Kashi Sampann performed excellently, achieving the highest B:C ratio and harvest index (41.93%), indicating its potential as a high-yielding and economically beneficial genotype for cultivation in the Gangetic Plains region.Based on these findings, it can be concluded that the treatment combining 75% NPKS with 25% vermicompost (T_2) offers the most economically viable solution for French bean cultivation. Additionally, the genotype Kashi Sampann is a promising variety that could be recommended for increased French bean production in the region.

Table 1: Effect of fertility levels, vermicompost, and genotype on yield and economics of French bean (pooled data of 2 years)

Treatment of INM	**Grain yield (q ha^{-1})**			**Straw Yield (q ha^{-1})**	**Harvest Index**	**Cost of cultivation (Rs. ha^{-1})**	**Gross return (Rs. ha^{-1})**	**Net return (Rs. ha^{-1})**	**B:C ratio**
	2022-23	2023-24	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	Pooled
T_1 (100% NPKS + 0% VC)	20.96	20.67	20.82	30.35	40.65	111772	472823	361052	3.265
T_2 (75% NPKS + 25% VC)	23.38	22.69	23.04	32.45	41.46	118883	507275	388393	3.295
T_3 (50% NPKS + 50% VC)	21.80	21.53	21.67	30.75	41.29	125995	488435	362440	2.895
T_4 (25% NPKS +75% VC)	19.81	18.72	19.27	28.15	40.57	133106	470658	337552	2.555
T_5 (0% NPKS + 100% VC)	17.53	17.01	17.27	26.80	39.12	140218	423728	283511	2.035
SEm±	0.20	0.22	0.21	0.45	0.47		2629	2629	0.02
CD(P=0.05)	0.65	0.72	0.68	1.47	1.53		8574.5	8574.5	0.07
Cultivars									
V_1 (Kashi Rajhans)	21.31	20.59	20.95	29.86	41.16	125995	491125	365131	2.96
V_2 (Kashi Sampann)	22.79	22.37	22.58	31.21	41.93	125995	515578	389584	3.155
V_3 (HUR- 137)	18.74	18.40	18.57	28.61	39.32	125995	427867	301874	2.45
V_4 (HUR -15)	19.96	19.14	19.55	29.12	40.05	125995	455765	329771	2.67
SEm±	0.22	0.22	0.22	0.19	0.32		2853	2853	0.025
CD(P=0.05)	0.63	0.63	0.63	0.55	0.93		8239.5	8239.5	0.065

Note:VC is vermicompost manure

Table 2: Interaction effect of treatments on yield attributes and yield of French bean (pooled data of 2 years)

Interaction (V×T)	T1 (100% NPKS+ 0% VC)	T2 (75% NPKS + 25% VC)	T3 (50% NPKS + 50% VC)	T4 (25% NPKS +75% VC)	T5 (0% NPKS +100% VC)
No. of flower/plant					
Kashi Rajhans	45.85	47.97	46.66	44.63	41.22
Kashi Sampan	47.76	50.14	48.40	46.63	43.16
HUR137	43.71	45.85	44.45	42.68	39.45
HUR15	44.99	47.26	45.72	43.89	40.62
Two sub-plot means at the same main plot treatment					0.33
Two main plotsmeans at same or different sub-plot treatments					0.67
No. of grain /pod					
Kashi Rajhans	5.86	6.73	6.34	5.51	5.00
Kashi Sampan	6.05	6.81	6.55	5.64	5.17
HUR137	5.40	6.27	5.77	5.10	4.73
HUR15	5.50	6.38	5.90	5.16	4.89
Two sub-plot means at the same main plot treatment					0.22
Two main plotsmeans at same or different sub-plot treatments					0.26
Grain yield (q/ha)					
Kashi Rajhans	21.63	23.53	22.46	19.74	17.40
Kashi Sampan	23.00	25.07	23.77	21.86	19.21
HUR-137	19.18	20.43	19.49	17.89	15.85
HUR-15	19.46	23.11	20.95	17.59	16.63
Two sub-plot means at the same main plot treatment					1.41
Two main plotsmeans at same or different sub-plot treatments					1.40

Table 3: Nutrient uptake (kg ha^{-1}) by grain and straw yield

Treatment of INM	Nitrogen		Phosphorus		Potassium		Sulpher	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1 (100% NPKS + 0% VC)	70.77	31.87	15.61	2.38	36.43	39.60	6.24	3.10
T_2 (75% NPKS + 25% VC)	78.32	34.07	17.28	2.54	40.31	42.35	6.91	3.33
T_3 (50% NPKS + 50% VC)	73.67	32.39	16.2					5
T_4 (25% NPKS +75% VC)	67.21	29.56	14.8					9
T_5 (0% NPKS +100% VC)	62.97	26.51	13.8					9
SEm±	3.71	0.47	0.16					5
CD(P=0.05)	2.32	1.55	0.51					6
Cultivars								
V_1 (Kashi Rajhans)	77.42	30.98	15.9					3
V_2 (Kashi Sampann)	77.97	32.40	17.2					7
V_3 (HUR-137)	64.32	29.68	14.1					7
V_4 (HUR-15)	67.65	30.21	14.9					5
SEm±	0.74	0.20	0.16					2
CD(P=0.05)	2.14	0.58	0.47					5

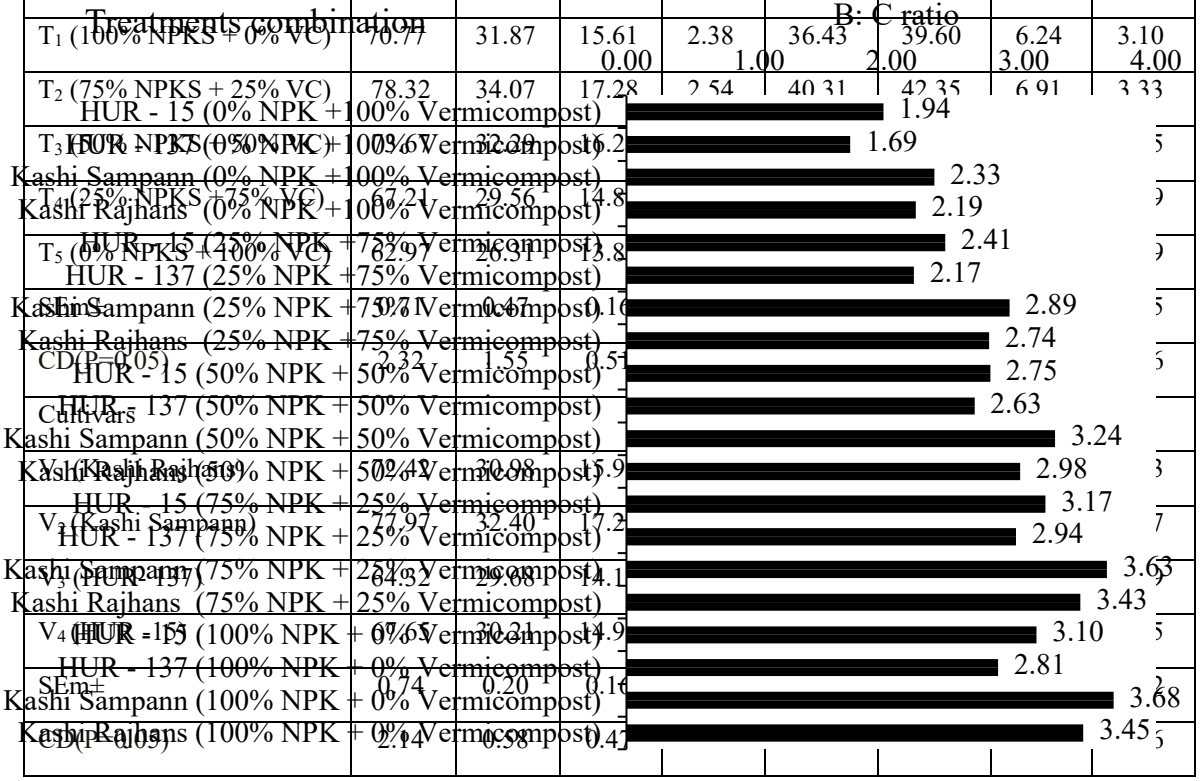

Fig. 1: B:C ratio under different treatment combinations (pooled data of 2 years)

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