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Effect of combined application of phosphatic fertilizers and organic adjuvants on growth and yield of green gram (*Vigna radiata* L.)

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Abstract
A field experiment was conducted at Research farm of the Maharishi Markandeshwar (Deemed to be University), Mullana, Ambala during Summer season of 2023 to determine the "Effect of combined application of phosphatic fertilizers and organic adjuvants on growth and yield of green gram (*Vigna radiata* L.)". The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three replications and five treatments (Control, 100% RDF (N - 20 Kg through urea, P_2O_5 - 40 Kg through SSP, K_2O – 20 Kg through MOP, 25 Kg Zn through $ZnSo_4$), 100% RDF + 25% higher P_2O_5, 100% RDF + 25% P_2O_5 through vermicompost, and 100% RDF + 25% P_2O_5 through vermicompost + *Rhizobium* + PSB) applied to two varieties PDM-139 and MH-421. The data was recorded on plant growth, yield attributes and yield. The results revealed that highest plant height (cm), number of leaves plant^{-1}, number of branches plant^{-1} and dry weight (g plant^{-1}) was recorded with the application of 100% RDF+25% P_2O_5 through vermicompost + *Rhizobium* +PSB and the lowest was recorded in control. Maximum grain yield (q ha^{-1}), stover yield (q ha^{-1}), biological yield (q ha^{-1}) and harvest index (%) was recorded with 100% RDF+ 25% P_2O_5 through vermicompost + *Rhizobium* + PSB while the minimum was recorded in Control. Highest gross return (₹ ha^{-1}), net return (₹ ha^{-1}) and B:C was recorded in 100% RDF + 25% P_2O_5 through vermicompost + *Rhizobium* + PSB and the lowest was recorded in control.

Keywords: Green gram, MH-421, vermicompost, *Rhizobium*, PSB etc.

Introduction

The Green gram, scientifically known as *Vigna radiata* L., is a versatile legume with various names such as mung, moong, and green gram in India, and mungo in the Philippines. In India, it holds immense agricultural significance as it is extensively grown in dry and semi-dry regions. Green gram is a highly valued pulse crop due to its abundant protein content, easy digestibility, and widespread culinary usage. With its nutrient composition, which includes protein, fat, minerals, fiber, and carbohydrates, provides a balanced nutritional profile.

According to the Green Gram Outlook from December 2022 by the Agricultural Market Intelligence Centre of PJTSAU, India's green gram cultivation area in 2022-23 was 33.45 lakh ha (82.65 lakh acres), significantly less than 34.80 lakh ha (85.98 lakh acres) in the previous year (2021-22). Notable Indian states that contribute significantly to green gram production include Rajasthan (20.54 lakh ha or 50.75 lakh acres), Madhya Pradesh (1.58 lakh ha or 3.90 lakh acres), Odisha (2.03 lakh ha or 5.02 lakh acres), Maharashtra (2.78 lakh ha or 6.86 lakh acres), Telangana (0.27 lakh ha or 0.66 lakh acres), and Karnataka (4.14 lakh ha or 10.24 lakh acres).

Phosphorus is essential for plant physiological activities. It is an essential component of several enzymes that transform energy in carbohydrate metabolism across different plant kinds. According to Arya and Kalra (1988) [1], applying phosphorus had no effect on green gram growth, but it enhanced the number of grains pod^{-1} and the weight of 1000 seeds with greater phosphorus levels.

Phosphate Solubilizing Bacteria (PSB) play a significant role in soil P solubilization by secreting various organic acids (oxalic, malic, maleic, and lactic acids, butyric, formic, acetic, glucomic, succinic, citric, and propionic acid) that are then accessible to plants. PSB increase the availability of soil phosphorus to plants, thus promoting plant growth.

Rhizobium within the community of bacteria found in the soil, the existence of distinct group known as rhizobia that possess advantageous qualities for the growth of legumes. It forms symbiotic relationships with the root nodules of leguminous plants. *Rhizobium* culture used to different legumes is a common agronomic technique for increasing pulse yield, according to (Patel *et al*., 2016) [5].

In vermicomposting, earthworms are used to convert decomposing materials into nutrient-rich manure. Constant use of synthetic fertilizers poses threats to human health and the environment, including nitrate leaching that contaminates surfaces and groundwater, claim Eswaran and Arsalan *et al.* (2016) [2]. The application of vermicompost at increasing rates significantly improved the nutritional content of nitrogen (N), phosphorus (P), and potassium (K) in the green gram grain and stover Todawat *et al.* (2017) [8].

Materials and Methods

A field experiment was undertaken in Maharishi Markandeshwar Research Farm (Deemed to be University), Mullana, Ambala, which is located at 30°17'0" N latitude, 77°3'0" E longitude, and 264 meters above the average level of sea. To study the “Effect of combined application of phosphatic fertilizers and organic adjuvants on growth and yield of Green gram (*Vigna radiata* L.)”. This region situated in the sub-tropical zone. Mullana experiences a warm and dry summer, along with a notably cold winter. Winter temperatures can drop to as low as -1°C, while summer temperatures can reach up to 48°C. The primary source of rainfall, accounting for 70-80%, is the south-west monsoon occurring from July to September, with the remaining 20-30% occurring between December and February. The average annual rainfall in this area is approximately 650-750 mm, classifying it as a high rainfall region in Haryana. Rainfall amount and distribution exhibit various patterns in the region. Morning relative humidity averages around 80-90% from July to March, decreasing to 40-50% from April to June. The soil possesses a sandy loam texture. The experiment was conducted in FRBD with two varieties *viz*., PDM-139, MH-421 and five treatments *viz*., 1. Control 2. 100% RDF 3. 100% RDF + 25% Higher Phosphorus 4. 100% RDF + 25% P_2O_5 through vermicompost 5. 100% RDF + 25% P_2O_5 through vermicompost + *Rhizobium* + PSB. The PDM-139 and MH-421 green gram variety were sown at a seed rate of 20 kg ha^{-1}, 30 cm row to row, and 10 cm plant to plant spacing. The recommended dosage of chemical fertilizer (20 kg N. 40 kg P_2O_5, 20 kg K_2O, and 25 kg Zn ha^{-1}) through Urea, SSP, MOP, and zinc sulphate. Similarly, vermicompost and *Rhizobium* were included in the plot and added in accordance with treatment requirements. At the time of sowing, fertilizers were added as a basal dressing.

Results and Discussion

Growth Parameters

In comparison to PDM-139, MH-421 had the highest plant height at 45 days after sowing and at harvest (38.82 and 47.23, respectively). Treatment T_5 (100% RDF + 25% P_2O_5 through vermicompost + *Rhizobium* + PSB) had the highest plant height at 45 DAS (43.25 cm) and at harvest (50.66 cm) and the minimum plant height was reported in T_1 (Control) at 45 DAS (31.50 cm) and at harvest (40.75cm). When compared to PDM-139, MH-421 showed maximum number of leaves plant^{-1} at 45 DAS and harvest (19.97 and 22.95). At 45 DAS (21.91) and at harvest (25.00), treatment T_5 (100% RDF + 25% P_2O_5 through vermicompost + *Rhizobium* + PSB) showed the maximum number of leaves plant^{-1}, whereas at 45 DAS (16.41) and at harvest (18.09), treatment T_1 (Control) showed the lowest number of leaves plant^{-1}. MH-421 had a larger number of branches plant^{-1} at 45 DAS (6.45) and at harvest (8.14). PDM-139 had the lowest number of branches plant^{-1} at 45 DAS (5.13) and at harvest (7.09). However, at 45 DAS (6.91) and during harvest (9.39), treatment T_5 (100% RDF + 25% P_2O_5 through vermicompost + *Rhizobium* + PSB) demonstrated the maximum number of branches plant^{-1}, while treatment T_1 (Control) exhibited the minimum number of branches plant^{-1} at 45 DAS (4.56) and during harvest (5.56). Dry weight (g plant^{-1}) at 45 DAS and at harvest (10.96 and 17.29 g plant^{-1}), MH-421 showed a greater dry weight (g plant^{-1}) than PDM-139 (9.59 and 16.23 g plant^{-1}). Among the treatments, Treatment T_5 (100% RDF + 25% P_2O_5 through vermicompost + *Rhizobium* + PSB) had the highest dry weight at 45 DAS (12.61 g plant^{-1}) and at harvest (20.72 g plant^{-1}). Rathour *et al.* (2015) [6] found that fixation, dry matter accumulation, quick plant growth, increased nutrient uptake and utilization, and improved growth qualities were all beneficial outcomes. The lowest dry weight was recorded in Treatment T_1 control at 45 DAS (7.97 g plant^{-1}) and at harvest (12.66 g plant^{-1}) as shown in table 1.

Yield attributes and yield

The data in Table 2 showed that variety PDM-139 (19.56) had the lowest number of pods plant^{-1}, while MH-421 (20.48) had the highest number of pods plant^{-1}. Treatment T_5 (100% RDF + 25% P_2O_5 through vermicompost + *Rhizobium* + PSB) recorded a considerably higher number of pods plant^{-1} (22.14), whereas treatment T_1 control (16.86) recorded the lowest number of pods plant^{1}). The variety MH-421 had the most seeds pod^{-1} (9.32), whereas PDM-139 had the fewest (8.21). The treatment T_5 (100% RDF + 25% P_2O_5 through vermicompost + *Rhizobium* + PSB) produced a considerably higher number of seed pod^{-1} (10.29) than treatment control (6.41). Variety PDM-139 (4.45 g) had the lowest 100-seed weight, while MH-421 (4.65 g) had the highest 100-seed weight and treatment T_5 (100% RDF + 25% P_2O_5 through vermicompost + *Rhizobium*) had a considerably higher 100-seed weight (4.81 g), while treatment control had the lowest 100-seed weight (4.21 g). Among the two varieties MH-421 had a higher maximum grain yield (9.83 q ha^{-1}) than PDM-139 (7.77 q ha^{-1}) and treatment T_5 (100% RDF + 25% P_2O_5 through vermicompost + *Rhizobium* + PSB) had a noticeably greater grain yield (11.04 q ha^{-1}), while treatment T_1 control (5.37 q ha^{-1}) had the lowest grain yield. MH-421 had a much greater stover yield (23.23 q ha^{-1}) than PDM-139 (21.84 q ha^{-1}) among the two varieties. Treatment T_5 (100% RDF + 25% P_2O_5 through vermicompost + *Rhizobium* + PSB) produced a greater stover yield (27.13 q ha^{-1}) than treatment T_1 control (15.69 q ha^{-1}). MH-421 had a significant maximum biological yield (33.07 q ha^{-1}), while PDM-139 had a minimum biological yield of (29.62 q ha^{-1}). The treatment T_5 (100% RDF + 25% P_2O_5 through vermicompost + *Rhizobium* + PSB)) had a considerably higher biological yield (38.19 q ha^{-1}), while the T_1 control had the lowest (21.06 q ha^{-1}). The combination application of organic and inorganic fertilizer resulted in increased seed, stover, and biological yield. Inoculating seeds with *Rhizobium* significantly improved yield parameters such as no. of pods plant^{-1}, seeds pod^{-1}, and seed weight (Singh and Singh, 2021). MH-421 recorded a maximum harvest index of (29.56%), whereas PDM-139 recorded a minimum at (25.87%). The highest harvest index (28.91%) was obtained by treatment T_5 (100% RDF + 25% P_2O_5 through vermicompost + *Rhizobium* + PSB), while treatment control (25.08%) had the lowest harvest index. These results were also in finding of Verma *et al*. (2022) [9].

Economics

The cost of cultivation were the same for both varieties i.e. PDM-139 (₹ 31135 ha^{-1}) and MH-421 (₹31135 ha^{-1}) as shown in Table 3. Treatment T_5 (100% RDF + 25% P_2O_5 through vermicompost + *Rhizobium* + PSB) had the highest cost of cultivation (₹38709 ha^{-1}), while treatment T_1 (control) had the lowest (₹31135 ha^{-1}). MH-421 had the highest gross return (₹78555 ha^{-1}), while PDM-139 had the lowest (₹62517 ha^{-1}) and treatment T_5 (100% RDF + 25% P_2O_5 through vermicompost + *Rhizobium*) had the highest gross return (₹88328 ha^{-1}), while treatment T_1 control had the lowest (₹ 43213). The maximum net return was obtained in variety MH-421 (₹47221 ha^{-1}), while the lowest was recorded in PDM-139 (₹31183 ha^{-1}). Treatment T_5 (100% RDF + 25% P_2O_5 through vermicompost + *Rhizobium* + PSB) had the highest net return (₹49619 ha^{-1}), whereas Treatment T_1 control had the lowest (₹12078 ha^{-1}). The variety MH-421 had the highest B:C (2.50) while variety PDM-139 had the lowest B:C (1.99) and treatment T_5 (100% RDF + 25% P_2O_5 through vermicompost + *Rhizobium* + PSB) had the highest B:C (2.28) while treatment T_1 control had the lowest B:C (1.39). Similar results were also found by Singh *et al*. (2022) [7].

Interaction effect

The interactions between varieties and fertilizer level were observed to be non-significant for all the characters. Similar results were collaborate the findings of Ghule *et al*. (2020) [4].

Table 1: Effect of combined application of phosphatic fertilizers and organic adjuvants on growth of green gram (*Vigna radiata* L.)

Treatments	Plant height (cm)			Number of leaves plant $^{-1}$			Number of branches plant^{-1}			Dry Weight (g plant ^{1})		
	30	45	Harvest	30	45	Harvest	30	45	Harvest	30	45	Harvest
Varieties												
V1: PDM-139	20.62	37.90	45.68	9.34	18.22	20.66	3.25	5.13	7.09	4.37	9.59	16.23
V2: MH-421	20.86	38.82	47.23	9.43	19.97	22.95	3.43	6.45	8.14	4.53	10.96	17.29
S.Em±	0.11	0.30	0.46	0.07	0.26	0.31	0.11	0.13	0.20	0.12	0.24	0.31
C.D at 5%	NS	0.90	1.39	NS	0.78	0.93	NS	0.39	0.61	NS	0.73	0.94
Fertilizer levels												
T_1	20.52	31.50	40.75	9.15	16.41	18.09	3.08	4.56	5.56	4.08	7.97	12.66
T_2	20.62	36.16	45.33	9.27	17.80	20.55	3.22	5.32	6.92	4.25	9.28	15.20
T_3	20.75	39.83	47.60	9.43	19.21	22.13	3.32	6.01	8.05	4.56	10.69	17.19
T_4	20.81	41.06	47.94	9.50	20.15	23.28	3.47	6.15	8.16	4.65	10.84	18.03
T_5	21.00	43.25	50.66	9.58	21.91	25.00	3.62	6.91	9.39	4.71	12.61	20.72
S.Em±	0.17	0.48	0.73	0.11	0.41	0.49	0.17	0.20	0.32	0.19	0.38	0.49
C.D at 5%	NS	1.43	2.21	NS	1.24	1.47	NS	0.62	0.96	NS	1.15	1.49
VxF interaction												
S.Em±	0.24	0.67	1.04	0.16	0.58	0.69	0.25	0.29	0.45	0.27	0.54	0.70
C.D at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note:
T_1: Control
T_2: 100% RDF (N - 20 Kg through urea, P_2O_5 - 40 Kg through SSP, K_2O – 20 Kg through MOP, 25 Kg Zn through $ZnSo_4$)
T_3: 100% RDF + 25% Higher Phosphorus
T_4: 100% RDF + 25% P_2O_5 through Vermicompost
T_5: 100% RDF + 25% P_2O_5 through Vermicompost + *Rhizobium* + PSB

Table 2: Effect of combined application of phosphatic fertilizers and organic adjuvants on yield attributes and yield of green gram (*Vigna radiata* L.)

Yield attributes							
Treatments	No. of pods plant^{-1}	No. of seeds pod $^{-1}$	Test weight (g)	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
Varieties							
V1: PDM-139	19.56	8.21	4.45	7.77	21.84	29.62	25.87
V2: MH-421	20.48	9.32	4.65	9.83	23.23	33.07	29.56
S.Em±	0.21	0.12	0.03	0.16	0.23	0.29	0.40
C.D at 5%	0.65	0.36	0.11	0.49	0.69	0.88	1.20
Fertilizer level							
T_1	16.86	6.41	4.21	5.37	15.69	21.06	25.08
T_2	19.35	8.41	4.52	8.48	22.12	30.59	27.57
T_3	20.71	9.11	4.57	9.35	23.71	33.07	28.15
T_4	20.88	9.57	4.63	9.77	24.04	33.82	28.85
T_5	22.14	10.29	4.81	11.04	27.13	38.19	28.91
S.Em±	0.34	0.19	0.06	0.25	0.36	0.46	0.63
C.D at 5%	1.03	0.57	0.17	0.77	1.09	1.40	1.90
VxF interaction							
S.Em±	0.49	0.27	0.08	0.36	0.51	0.66	0.89
C.D at 5%	NS	NS	NS	NS	NS	NS	NS

Note:
T_1: Control
T_2: 100% RDF (N - 20 Kg through urea, P_2O_5 - 40 Kg through SSP, K_2O – 20 Kg through MOP, 25 Kg Zn through $ZnSo_4$)
T_3: 100% RDF + 25% Higher Phosphorus
T_4: 100% RDF + 25% P_2O_5 through Vermicompost
T_5: 100% RDF + 25% P_2O_5 through Vermicompost + *Rhizobium* + PSB

Table 3: Effect of combined application of phosphatic fertilizers and organic adjuvants on economics of green gram (*Vigna radiata* L.)

Varieties	Economics			
	Cost of cultivation (₹ ha^{-1})	Gross Return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C
V1: PDM-139	31335	62517.9	31183	1.99
V2: MH-421	31335	78555.65	47221	2.50
Fertilizer levels				
T_1	31135	43213	12078	1.39
T_2	35629	67974	32345	1.91
T_3	36230	74880	38650	2.07
T_4	37902	78170	40268	2.06
T_5	38709	88328	49619	2.28

Note:
T_1: Control
T_2: 100% RDF (N - 20 Kg through urea, P_2O_5 - 40 Kg through SSP, K_2O – 20 Kg through MOP, 25 Kg Zn through $ZnSo_4$)
T_3: 100% RDF + 25% Higher Phosphorus
T_4: 100% RDF + 25% P_2O_5 through Vermicompost
T_5: 100% RDF + 25% P_2O_5 through Vermicompost + *Rhizobium* + PSB

Conclusion
Between two varieties, PDM 139 and MH-421, MH-421 recorded notably superior growth parameters, yield parameters, and yield. Among all treatments, treatment T_5 (100% RDF+25% P_2O_5 through vermicompost + *Rhizobium* + PSB) showed the highest values for growth parameters, yield parameters, and yield. In the economics of treatments, treatment T_5, comprising (100% RDF+25% P_2O_5 through vermicompost + *Rhizobium* +PSB) obtained the highest gross return, net return and B:C compared to other treatments. Hence it can be recommended to the farmer's that cultivation of MH-421 with application of RDF (Recommended dose of fertilizer) in combination with T_5 (100% RDF+25% P_2O_5 through vermicompost + *Rhizobium* +PSB) would be worth by to achieved sustainable and economically viable green gram production.

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