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Interaction effect of different levels of phosphorus and biofertilizers on growth and yield of vegetable cowpea [*Vigna unguiculata* (L.) Walp.]

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Abstract

A field experiment was carried out at Vegetable Research Farm, Regional Horticultural Research Station, ASPEE College of Horticulture, Navsari Agricultural University, Navsari during summer season of 2024 and 2025 to study the “Interaction effect of different levels of phosphorus and biofertilizers on growth and yield of vegetable cowpea [*Vigna unguiculata* (L.) Walp.]”. The experiment was laid out in factorial randomized block design with twelve combinations. The results revealed that among various treatment combinations, 100% RDP +1% PSB (T₈) significantly improved growth parameters and promoted early flowering (44.40) with lower flowering node (3.73) and recorded maximum plant height (25.95, 51.77, 95.53 cm), number of branches per plant (3.97, 6.07, 7.63), number of leaves per plant (26.60, 52.40, 86.87) at 30 DAS, 45 DAS and at final harvest. In terms of yield parameters, significantly maximum values for pod width (1.12 cm), pod weight (3.38 g), number of seeds per pod (11.72), number of pods per plant (20.26), number of pods per cluster (4.33) and green pod yield (5.64 kg plot⁻¹ and 8.70 t ha⁻¹) were recorded with the same treatment. This treatment combination also remained statistically at par with T₅ as compared to other treatments. However, pod length and harvest index were found to be non-significant. The results of overall study emphasizes that optimized level of phosphorus with biofertilizer application can serve as effective strategy to enhance growth, productivity and sustainability of cowpea under South Gujarat conditions.

Keywords: Vegetable cowpea, phosphorus levels, PSB, VAM, growth, yield attributes

Introduction

Cowpea [*Vigna unguiculata* (L.) Walp.], one of the members of family Fabaceae, with a chromosome number of 2n = 22, is an important annual legume crop grown for manifold uses such as vegetable, pulse, fodder and green manure (Saraviya *et al.*, 2014) [14]. It is commonly defined as lobia, black-eyed pea, crowder pea or southern pea. The crop is believed to have originated in Central Africa and is widely cultivated in tropical and subtropical regions of the world. Compared to other legume crops, cowpea is known for its short duration, which enables crop to evade the impacts of climatic changes and exhibit better adaptability to wide range of abiotic stresses (Herniter *et al.* 2020) [8]. Cowpea is also recognized as a “poor man’s protein” due to its high protein content, ranging from around 23-25 per cent on dry weight basis, along with appreciable amounts of carbohydrates, vitamins and minerals (Aremu *et al.* 2007) [2]. In India, this crop occupies an area of about 13.3 million hectares with a total production of 8.06 million tonnes and an average productivity of 596 kg ha⁻¹ (GOI, 2023) [6]. In Gujarat, it is cultivated over an area of 0.34 lakh hectares with a production of about 3.53 million tonnes (Anon., 2022) [11].

The integrated use of inorganic nutrient sources and organic fertilizers not only enhances nutrient supply and maintains overall soil health, but also increase the crop yield (Kumar and Singh, 2010) [11]. Indian soils are generally low to medium in available phosphorus and plants absorb approximately only 25% of phosphate that is soluble in water, with the remaining becomes converted into insoluble forms. Phosphorus is the second most important macronutrient after nitrogen (Halder and Panda, 2014) [7] and plays a crucial role in the development of roots for better nutrient and water uptake. It also promotes the *Rhizobium* bacterial activity enhancing biological nitrogen fixation and improving the efficacy of soil restorers and biomass.

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Biofertilizers are beneficial microbial product that are used to enhance the soil microbial activity in the *Rhizosphere* and improves the nutrient availability for easy assimilation by plants (Sudhakar and Ranganathan, 2020) [17]. Being ecologically, cost effective and renewable, they have become an important part of integrated nutrient management in order to improve crop productivity (Shrotri *et al.* 2018) [16]. Biofertilizers such as *Rhizobium*, PSB and VAM act as key factors in improving the availability of nitrogen and phosphorus and increasing their uptake by plants. Inducing effective strains of *Rhizobium* in legume crops helps to improve soil fertility (Shekawat *et al.* 2018) [15] and root nodulation, thereby supporting better growth performance under nitrogen deficit soils.

Phosphate Solubilizing Bacteria dissolve the inaccessible phosphates by bringing out more amount of unavailable fixed phosphates in soil into soluble forms (Elhaissoufi *et al.* 2022) [5] through the secretion of organic acids and enzymes.

VAM forms a symbiotic interaction between fungus and plant roots, enhances phosphorus transport and uptake in plants. This VAM fungi unlike PSB does not solubilize unavailable phosphorus, but stimulate phosphorus, zinc and other nutrients along with their own need and aids in defending plants against pathogens, salinity and drought stress (Beck-Nielsen and Madsen, 2001) [3].

Despite these benefits, the productivity of cowpea remains constrained due to imbalanced nutrient management, poor soil fertility and limited adoption of improved agronomic practices. The country's existing level of production of pulse crops, especially cowpea remains inadequate to meet the growing demand. There is a considerable potential to enhance the productivity of cowpea through improved nutrient availability and biofertilizers. Therefore, the present study was undertaken with the view of improving crop performance and ensure sustainable cowpea production.

Materials and Methods

The field investigation was conducted during summer

season 2024 and 2025 at Vegetable Research Farm, Regional Horticultural Research Station, ASPEE College of Horticulture, Navsari Agricultural University, Navsari under the South Gujarat agro-climate zone. The experiment was laid out in a Factorial Randomized Block Design concept comprising of twelve treatment combinations with four levels of phosphorus viz., P₁: 50% RDP, P₂: 75% RDP, P₃: 100% RDP, P₄: 125% RDP and three levels of biofertilizers viz., B₀: no biofertilizer application, B₁: PSB @ 1%, B₂: VAM @ 0.2% replicated thrice. The soil of experimental field was clayey in texture, slightly alkaline in nature (pH 7.8) with low nitrogen, moderate phosphorus and high potassium content. Crop was fertilized as per the recommended dose of nutrients with NPK dose of 20:40:00 kg/ha. FYM (25 t/ha) was applied at the time of land preparation, where half dose of nitrogen in the form of urea and full dose of phosphorus in the form of SSP was applied as per the treatment combinations as a basal dose. The remaining dose of nitrogen was given in split doses at 30 and 45 DAS. Novel organic liquid nutrient at 1.5 % was given as common foliar application to all treatments at 30 DAS and 45 DAS. Seeds of cowpea variety AVCP-1 was sown at 25 kg/ha by maintaining a spacing of 45 x 30 cm with gross plot area of 3.6 x 3 m and net plot area of 2.7 x 2.4 m. Before sowing, seeds were inoculated with strains of *Rhizobium* and PSB each at 10 ml/kg of seeds. In addition, VAM at 2 g/kg of seeds were also used in seed inoculation. The observations on growth parameters *i.e.*, days to first flowering, plant height (cm), number of branches per plant, number of leaves per plant, flowering node and yield parameters *i.e.*, pod length (cm), pod width (cm), number of seeds per pod, number of pods per plant, number of pods per cluster, harvest index (%) and green pod yield (kg/ha and t/ha) were recorded at different growth stages from randomly tagged five plants. The results were subjected to statistical analysis using standard ANOVA method as suggested by Panse and Sukhatme, 1985 [12].

Table 1: Details of experimental treatment

T ₁	50% RDP (NPK 20:40:00 kg/ha) + No Biofertilizer application
T ₂	50% RDP (NPK 20:40:00 kg/ha) + 1.0% of PSB
T ₃	50% RDP (NPK 20:40:00 kg/ha) + 0.2% of VAM
T ₄	75% RDP (NPK 20:40:00 kg/ha) + No Biofertilizer application
T ₅	75% RDP (NPK 20:40:00 kg/ha) + 1.0% of PSB
T ₆	75% RDP (NPK 20:40:00 kg/ha) + 0.2% of VAM
T ₇	100% RDP (NPK 20:40:00 kg/ha) + No Biofertilizer application
T ₈	100% RDP (NPK 20:40:00 kg/ha) + 1.0% of PSB
T ₉	100% RDP (NPK 20:40:00 kg/ha) + 0.2% of VAM
T ₁₀	125% RDP (NPK 20:40:00 kg/ha) + No Biofertilizer application
T ₁₁	125% RDP (NPK 20:40:00 kg/ha) + 1.0% of PSB
T ₁₂	125% RDP (NPK 20:40:00 kg/ha) + 0.2% of VAM

Results and Discussion

Plant height at 30, 45 DAS and at final harvest showed significant variation, where maximum plant height at 30 DAS (25.95 cm), 45 DAS (51.77 cm) and at final harvest (95.53 cm) was recorded with combined application of 100 % RDP + 1 % PSB (T₈). Plant height at 30 DAS and 45 DAS remained statistically at par with T₅ (23.45, 49.08 cm), while at final harvest, it remained at par with both T₅ (93.57 cm) and T₁₂ (91.75 cm), respectively. Contrarily, the lowest plant height at 30 DAS (18.53 cm), 45 DAS (38.75) and

final harvest (68.10 cm) was recorded under 50 % RDP + no biofertilizer application (T₁).

Growth parameters

Observations were recorded on various growth parameters such as days to first flowering, plant height, number of branches per plant, number of leaves per plant at 30, 45 DAS, final harvest and flowering node under different levels of phosphorus and biofertilizer application, as elucidated in Table 1 and 2.

Significant effect on earliness with respect to days taken for first flowering was observed with the combined application of 100% RDP + 1% PSB (T_8) indicated by least number of days (44.40), which remained statistically at par with T_5 (46.70) over rest of the treatments, whereas the maximum number of days to first flowering (53.07) was noted with 50% RDP + no biofertilizer application (T_1).

Plant height at final harvest showed significant variation, while it remained non-significant at 30 and 45 DAS. Besides non-significance, maximum plant height at 30 DAS (25.95 cm), 45 DAS (51.77 cm) and at final harvest (95.53 cm) was recorded with combined application of 100% RDP + 1% PSB (T_8). Plant height at 30 DAS remained statistically at par with T_5 (23.45, 49.08 and 93.57 cm), whereas the lowest plant height at 30 DAS (18.53 cm), 45 DAS (38.75) and final harvest (68.10 cm) was recorded under 50% RDP + no biofertilizer application (T_1).

Number of branches per plant exhibited significant variation and increased progressively at 30 DAS (3.97), 45 DAS (6.07) and at final harvest (7.63) under combined application of 100% RDP + 1% PSB (T_8), which was at par with T_5 at 30 DAS (3.70), 45 DAS (5.37) and final harvest (6.85). With regard to lowest range, number of branches were recorded lower with 50% RDP + no biofertilizer application (T_1) at 30 DAS (2.13), 45 DAS (3.33) and at final harvest (4.10) respectively.

Number of leaves per plant at 30 DAS (26.60), 45 DAS (52.40) and at final harvest (86.87) was observed significantly higher with the combined application of 100% RDP + 1% PSB (T_8). This treatment remained statistically at par with T_5 at 30 DAS (24.17), 45 DAS (49.23) and at final harvest (83.43) as well as with T_{12} at 45 DAS (47.53) and final harvest (80.60). Further minimum number of leaves per plant at 30 DAS (16.60), 45 DAS (39.10) and at final harvest (55.70) were recorded with treatment receiving, 50% RDP + no biofertilizer (T_1).

Flowering node observations showed that significantly minimum node number at which flower initiated (3.73) was recorded with combined application of 100% RDP + 1% PSB (T_8), remaining at par with T_5 (4.23), while flower initiation at maximum node number (6.07) was associated with treatment, consisting of 50% RDP + no biofertilizer application (T_1).

The application of phosphorus with PSB significantly improved the growth parameters of vegetable cowpea. Higher values were recorded with the treatment, 100% RDP along with 1% PSB. This improvement is attributed to essential role of phosphorus in plant metabolic processes such as energy transfer, cell division and root development. Adequate phosphorus nutrition also enhances photosynthetic efficiency and carbohydrate metabolism, which contributes to higher vegetative growth and reproductive development. In addition, phosphate solubilizing bacteria improves the availability of phosphorus in the rhizosphere by converting insoluble forms into available forms through the production of organic acids and phosphatase enzymes. The synergistic effect of phosphorus and PSB enhances nutrient uptake, microbial activity and overall nutrient use efficiency, leading to increased synthesis and translocation of assimilates to plant parts. Consequently, improved nutrient availability and efficient utilization of nutrients resulted in increased plant height, number of branches and leaves with earlier flowering. These findings are in close agreement with Surya Kant *et al.* (2016) ^[18] in Urdbean, Kothiyari *et al.* (2017) in garden pea, Punarabati Heisnam *et al.* (2017) ^[13], Jayshree and Umesha (2021) ^[9] in cowpea and Danish *et al.* (2025) ^[4] in green gram.

Yield parameters

Different levels of phosphorus and biofertilizer combinations influenced the yield contributing parameters viz., pod length, pod width, number of seeds per pod, weight of pod, number of pods per plant, number of pods per cluster and green pod yield as depicted in Table 3.

Pod length recorded at the time of 6th picking did not differ significantly. However, numerically higher pod length (14.35 cm) was observed under 100% RDP coupled with 1% PSB, while the lowest pod length (11.02 cm) was being observed under the treatment consisting of 50% RDP + no biofertilizer application (T_1).

Relative to pod width, significant difference was observed at 6th picking with maximum pod width (1.12 cm) recorded under the application of 100% RDP + 1% PSB (T_8), which remained statistically at par with treatments, T_5 (1.00 cm) and T_{12} (0.89 cm), whereas the minimum pod width (0.54 cm) was exhibited by the application of 50% RDP + no biofertilizer (T_1).



Fig 1: General view of experimental plot

Number of seeds per pod increased significantly with the combined application of 100% RDP + 1% PSB (T_8) and remained statistically at par with T_5 (11.35) and T_{12} (11.07),

while the minimum number of seeds per pod (7.16) was noted under, 50% RDP + no biofertilizer application (T_1). Pod weight (3.38 g) was recorded significant and maximum

with combined application of 100% RDP +1% PSB (T₈), which was found statistically at par with T₅ (3.27 g) and T₁₂ (3.22 g), whereas the treatment, 50% RDP + no biofertilizer application (T₁) recorded the lowest range of pod weight (2.50 g).

Number of pods per plant was observed significantly maximum with the treatment combination, 100% RDP +1% PSB (T₈), remaining statistically at par with T₅ (19.25) and T₁₂ (18.75), while number of pods per plant was recorded minimum (15.93) under the treatment receiving, 50% RDP + no biofertilizer application (T₁).

Significantly number of pods per cluster (4.33) was observed maximum with the treatment combination, 100% RDP + 1% PSB (T₈), which remained statistically at par with T₅ (3.95), whereas minimum number of pods per cluster (2.15) was recorded under 50% RDP + no biofertilizer application (T₁).

Harvest index remained non-significant with numerically higher values (39.02%), recorded under treatment combination, 100% RDP +1% PSB (T₈), while the treatment, 50% RDP + no biofertilizer application (T₁) recorded the lower values for harvest index (30.99%).

Significant differences in green pod yield indicated that treatment combination, 100% RDP +1% PSB (T₈) recorded

the highest yield (5.64 kg plot⁻¹ and 8.70 t ha⁻¹), which was statistically at par with T₅ (5.39 kg plot⁻¹, 8.32 t ha⁻¹) and T₁₂ (5.32 kg plot⁻¹, 8.22 t ha⁻¹). In contrast, lowest value for green pod yield (3.06 kg plot⁻¹, 4.72 t ha⁻¹) was obtained with the treatment, 50% RDP + no biofertilizer application (T₁).

Higher yield attributes recorded under the interaction treatment, 100% RDP with 1% PSB may be due to improved reproductive efficiency and better conversion of assimilates into economic yield. Adequate phosphorus supply at critical growth stages promotes flower initiation, reduces flower drop and improves pod setting, which ultimately increases the number of pods formed per plant and per cluster. The presence of PSB further enhances phosphorus availability in the rhizosphere, ensuring a continuous nutrient supply during the reproductive phase ensuring better partitioning of photosynthates towards developing pods and seeds, resulting in improved pod development and high yield. Similar beneficial interaction of phosphorus and biofertilizers were also reported by Kothiyari *et al.* (2017) in garden pea, Punarbati Heisnam *et al.* (2017) [13], Jayshree and Umesha (2021) [9] in cowpea, Danish *et al.* (2025) [4] and Umeed *et al.* (2024) [9] in green gram.

Table 2: Pooled interaction effect of phosphorus and biofertilizers on growth parameters of vegetable cowpea

Treatments	Days to first flowering	Plant height (cm)			No of branches plant ⁻¹		
		30 DAS	45 DAS	Final harvest	30 DAS	45 DAS	Final harvest
T ₁	53.07	18.53	38.75	68.10	2.13	3.33	4.10
T ₂	52.23	19.58	39.52	69.24	2.37	3.50	4.33
T ₃	51.33	20.20	40.83	71.61	2.73	3.87	4.83
T ₄	51.73	19.80	39.92	70.15	2.50	3.67	4.53
T ₅	46.70	23.45	49.08	93.57	3.70	5.37	6.85
T ₆	51.13	20.36	41.21	73.25	2.80	3.93	4.87
T ₇	52.03	19.91	40.31	70.65	2.63	3.73	4.63
T ₈	44.40	25.95	51.77	95.53	3.97	6.07	7.63
T ₉	50.13	20.96	42.96	81.33	3.20	4.40	5.43
T ₁₀	52.60	20.02	40.59	71.35	2.70	3.83	4.73
T ₁₁	50.80	20.62	42.11	75.38	3.00	4.13	5.17
T ₁₂	48.37	22.08	45.95	91.75	3.43	5.00	6.20
SEm (±)	1.33	0.96	1.74	3.69	0.11	0.24	0.32
CD (p = 0.05)	3.91	2.82	5.09	10.81	0.34	0.71	0.92
C.V.%	4.59	7.93	7.03	8.22	6.80	9.86	10.34

Table 3: Pooled interaction effect of phosphorus and biofertilizers on growth parameters of vegetable cowpea

Treatments	No of leaves plant ⁻¹			Flowering node
	30 DAS	45 DAS	Final harvest	
T ₁	16.60	39.10	55.70	6.07
T ₂	18.00	40.00	57.47	5.77
T ₃	19.70	41.03	61.67	5.53
T ₄	18.77	40.17	58.47	5.70
T ₅	24.17	49.23	83.43	4.23
T ₆	20.27	41.30	68.93	5.33
T ₇	18.90	40.27	59.73	5.50
T ₈	26.60	52.40	86.87	3.73
T ₉	21.10	43.57	74.93	4.97
T ₁₀	19.54	40.67	60.53	5.73
T ₁₁	20.53	42.27	72.80	5.10
T ₁₂	22.07	47.53	80.60	4.67
SEm (±)	0.84	1.72	3.02	0.18
CD (p = 0.05)	2.48	5.03	8.87	0.54
C.V.%	7.13	6.89	7.65	6.11

Table 4: Pooled interaction effect of phosphorus and biofertilizers on yield parameters of vegetable cowpea

Treatments	Pod length (cm)	Pod width (cm)	No of seeds per pod	Weight of pod (g)	No of pods per plant	No of pods per cluster	Harvest Index (%)	Green pod yield (kg plot ⁻¹)	Green pod yield (t ha ⁻¹)
T ₁	11.02	0.54	7.16	2.50	15.93	2.15	30.99	3.06	4.72
T ₂	11.31	0.60	8.45	2.58	16.77	2.29	31.95	3.15	4.86
T ₃	12.34	0.74	9.73	2.67	17.23	2.75	33.87	3.36	5.18
T ₄	11.54	0.69	9.03	2.61	16.87	2.45	32.27	3.17	4.89
T ₅	14.21	1.00	11.35	3.27	19.25	3.95	38.01	5.39	8.32
T ₆	12.84	0.75	10.16	2.74	17.63	2.90	34.58	3.53	5.48
T ₇	11.62	0.69	9.44	2.63	17.03	2.55	32.91	3.30	5.09
T ₈	14.35	1.12	11.72	3.38	20.26	4.33	39.02	5.64	8.70
T ₉	13.20	0.80	10.58	2.92	18.15	3.27	36.64	4.80	7.40
T ₁₀	11.77	0.72	9.54	2.66	17.12	2.56	33.56	3.33	5.14
T ₁₁	13.03	0.76	10.40	2.80	17.93	3.10	35.87	4.11	6.35
T ₁₂	13.71	0.89	11.07	3.22	18.75	3.62	37.22	5.32	8.22
SEm (±)	0.46	0.04	0.34	0.10	0.53	0.13	2.60	0.24	0.32
CD (P = 0.05)	NS	0.12	0.98	0.29	1.56	0.39	NS	0.69	0.94
C.V.%	6.31	9.02	5.87	6.10	5.18	7.78	12.98	10.19	8.92

Conclusion

From the results of present investigation, it can be concluded that 100% RDP combined with 1% PSB was observed to be the best treatment with respect to earliness and in enhancing the growth and yield parameters of vegetable cowpea.

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