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Effect of phosphorous and zinc on growth and yield of cowpea (*Vigna unguiculata* L. walp)

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Abstract
A field experiment was conducted during kharif season of 2024 at Crop Research Farm Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Sciences and Technology. To determine “Effect of phosphorous and zinc on growth and yield of Cowpea”. The results revealed that treatment 7 (Phosphorous (50 kg/ha) and Zinc (10 kg/ha) at 60 DAS) recorded significantly higher plant height (78.19 cm), number of branches/plant (25.61), number of nodules/plant (25.80), dry weight (10.75 g), number of pods/plant (13.30), number of seeds/pod (17.73), seed yield (571.52 kg/ha), stover yield (3133.33 kg/ha), and harvest index (280.44%), maximum gross return (INR 100170.00), net return (INR 66740) and B: C ratio (1.99) was recorded in treatment 7 (Phosphorous (50 kg/ha) and Zinc (10 kg/ha) at 60 DAS) as compared to the other treatments was found to be productive as well as economically feasible.

Keywords: Cowpea, phosphorous, zinc parameters, growth parameters, yield attributes, economics

1. Introduction

Pulses play a significant role in our country's agriculture. They have three times more high-quality protein per serving than cereals. Pulses contain vitamin B, minerals, and a specific form of fiber, making them beneficial for health. Pulse crops increase soil quality by symbiotically fixing nitrogen from the environment. Protein-rich legumes are crucial for sustainable agriculture as they fix nitrogen in the soil, maintaining fertility. Pulses are known as the "Marvel of Nature" due to their ability to survive drought and prevent soil erosion through strong root systems and luxuriant flora. It contains 154 mg Ca, 385 mg P, 9.1 mg Fe, a tiny amount of vitamin B complex, 24% protein, 60% carbohydrate, 1.3% fat, 3.2% minerals, and 0.9% fiber. It contains high levels of vitamins A, B1, and B3, but only trace amounts of thiamine, riboflavin, niacin, and vitamin C. Albumin and globulin account for 78% to 80% of the nitrogen content. Cowpea grows best in moisture-retentive lights oil, although it is also excellent for loamy and clay loam cultivation. Loam to clay loam with neutral PH is ideal for cowpea growing. It is vulnerable to wets oil conditions. It is distinguished from other pulses by its mucilaginous pasty texture, which adds body to the mass created by the long polymeric chains of carbohydrates in the polysaccharide chain.

Cowpea output makes up around 10% of India's total pulse production. Globally, pulses covers an area of 959.68 lakh hectares with the production of 973.92 lakh tons with the productivity of 1015kg/ha (FAO, 2023).In India, Cowpea is grown over an area about 48.38 lakh hectares with a production of 27.28 lakh tons and productivity of 564 kg/ha. During 2022 total area coverage under Cowpea in Uttar Pradesh 5.72 lakh hectares with a production of 2.99 lakh tons and the productivity 522 kg/ha (GOI, 2023).

Levels of Phosphorus holds a critical position in enhancing the growth and productivity of leguminous crops. Phosphorus is a key element in energy transfer processes (ATP), root development, photosynthesis, and most importantly, biological nitrogen fixation — a process fundamental to legumes. In cowpea, adequate phosphorus availability is particularly important during early growth stages for promoting robust root growth, nodule formation, and efficient nutrient uptake.

However, phosphorus deficiency is a widespread constraint in Indian soils, especially in red, lateritic, and alluvial soils where phosphorus fixation limits its availability to plants. Under phosphorus-deficient conditions, cowpea exhibits stunted growth, delayed flowering, poor nodulation, and reduced yield. Conversely, appropriate phosphorus fertilization can significantly enhance vegetative growth, flowering, pod formation, and seed yied.

The productivity of cowpea remains suboptimal in many regions due to poor soil fertility and micronutrient deficiencies. Among the micronutrients, zinc is crucial for plant growth and development. Zinc is involved in various physiological and biochemical processes including enzyme activation, protein synthesis, auxin production, and maintenance of membrane integrity. It also plays a significant role in enhancing the efficiency of other nutrients, improving stress tolerance, and supporting reproductive development.

In cowpea, zinc deficiency often leads to stunted growth, chlorosis, reduced leaf size, poor flowering, and low yield. Zinc-deficient soils are common in many agricultural regions of India, particularly in intensively cultivated and alkaline soils, where high pH limits zinc availability to plants. Application of zinc through soil or foliar methods has been shown to improve plant height, number of pods per plant, seed weight, and overall yield in legumes, including cowpea.

The zinc is an essential component of various dehydrogenases, proteases and peptidases (Fageria and Baligar, 2005) [26]. In this sense, biofortification of the crop with zinc fertilizers has increased the content of this element in legumes by 74.6%, it has increased the antioxidant capacity of the grain by 60%, and has reduced the content of anti-nutrients; likewise, it has been observed that when increasing the dose of zinc, the phosphorous content tends to decrease. In the seeds of various crops, most of the zinc is associated with proteins, peptides, enzynes and phytic acid. Broadely *et al*. (2012) [27]. Phosphorus is one of the most essential macronutrients required for the proper growth and development of leguminous crops. In legumes such as cowpea, phosphorus plays a pivotal role in energy transfer through the format ion of ATP, which is vital for various metabolic processes including photosynthesis, respiration, and nitrogen fixation. It promotes early root development, enhances nodulation, and increases the efficiency of symbiotic nitrogen fixation by rhizobia bacteria. Since legumes depend heavily on biological nitrogen fixation, adequate phosphorus availability is critical for maintaining effective root nodulation and nodule functioning. A deficiency of phosphorus not only hampers root and shoot growth but also reduces the plant's ability to form and maintain nodules, leading to poor nitrogen assimilation and ultimately lower yield. Therefore, balanced phosphorus nutrition is a key factor in realizing the full productive potential of leguminous crops under both irrigated and rainfed conditions Sapkota *et al*. (2015) [28]

2. Materials and methods

The field experiment was conducted on Cowpea during *kharif* season of 2024 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj (U.P.).To study the "Effect of Phosphorous and Zinc on Growth and Yield of Cowpea (*Vigna unguiculata*L. Walp)".The soil of experimental plot was sandy loam in texture, neutral in soil reaction (pH 7.1), organic carbon (0.452%), available N (178.48 kg/ha), available P (23.6 kg/ha) and available K (231.4 kg/ha). There were 9 treatments, each being replicated thrice and laid out in Randomized Block Design. The treatment combinations are treatment 1 Phosphorous 30kg/ha + Zinc 10kg/ha, treatment 2 Phosphorous 30kg/ha + Zinc 12kg/ha, treatment 3 Phosphorous 30kg/ha + Zinc 14kg/ha, treatment 4 Phosphorous 40kg/ha + Zinc 10kg/ha, treatment 5 Phosphorous 40kg/ha + Zinc 10kg/ha, treatment 6 Phosphorous 40kg/ha + Zinc 14kg/ha, treatment 7 Phosphorous 50kg/ha + Zinc 10kg/ha, treatment 8 Phosphorous 50kg/ha + Zinc 12kg/ha, treatment 9 Phosphorous 50kg/ha + Zinc 14kg/ha, and treatment 10 control (RDF)-NPK-20:50:20, Data was collected on growth parameters [Plant height (cm), Number of branches/plant, Number of nodules/plant, Plant dry weight (g), Crop growth rate (g/m2/day), Relative growth rate (g/g/day)], yield attributes and yield [Number of pods/plant, Number of seeds/pod, Test weight (g), Seed yield (t/ha), Stover yield (t/ha), Harvest index (%)] were subjected to statistical analyzed by analysis of variance method as reported by Gomez and Gomez (1976) [10]. Economics were also calculated [Cost of cultivation (INR/ha), Gross returns (INR/ha), Net returns (INR/ha) and benefit-cost ratio].

3. Results and discussion

3.1 Growth attributes

3.1.1 Plant height (cm)

The data recorded that significant and taller plant height (78.19 cm) was recorded in treatment 7 Phosphorous 50kg/ha + Zinc 10kg/ha. However, treatment 4 Phosphorous 40kg/ha + Zinc 10kg/ha, were statistically at par with treatment 7 Phosphorous 50kg/ha + Zinc 10kg/ha (Table 1).Significant and taller plant height was observed with application of Phosphorous (50 kg/ha) might be due to presence phosphorous application may be ascribed to its favourable effect on cell division and enlargement, which ultimately reflected in terms of increased plant height resulted taller plant height. Similar results was earlier reported by Kumar *et al*. (2018) [29]. Further, the application of zinc (10 kg/ha) recorded taller plant height might be due to availability of zinc in soil and its absorption and translocation in plants is influenced by all other plant nutrients resulted taller plant height. Similar finding was recorded by Rathore *et al.* (2015) [1].

3.1.2 Number of branches/plant

The data showed that significant and maximum number of branches/plant (9.50) was recorded in treatment 7 Phosphorous 50kg/ha + Zinc 10kg/ha. However, treatment 5 Phosphorous 40kg/ha + Zinc 10kg/ha were statistically at par with treatment 7 Phosphorous 50kg/ha + Zinc 10kg/ha (Table 1).Significant and maximum number of branches was observed with application of Phosphorous (50 kg/ha) might be due to adequate phosphorus availability likely supported the vigorous development of lateral buds, leading to increased branching, phosphorus is a key constituent of ATP, which facilitates various metabolic processes essential for cell division and expansion. Similar results was earlier reported by Tijjani *et al.* (2025) [30]. Further, the application of zinc (10 kg/ha) might be due to the auxin metabolism and increased photosynthetic rate by zinc nutrition. Similar finding was recorded by Kumar *et al*. (2016) [1].

3.1.3 Number of nodules/plant

The data revealed that significant and maximum number of nodules/plant (25.17) was recorded in treatment 7 Phosphorous 50kg/ha + Zinc 10kg/ha. However, treatment 6

Phosphorous 40kg/ha + Zinc 14kg/ha were statistically at par with treatment 7 Phosphorous 50kg/ha + Zinc 10kg/ha (Table 1).Significant and maximum number of nodules was observed with application of Phosphorous (50 kg/ha) might be due to phosphorus stimulate growth and initiate nodules formation due to increase in phosphorous application, it may enhance the proliferation and activity of *Rhizobium* in the rhizosphere, indirectly promoting nodule initiation, by affecting the synthesis and transport of plant hormones such as auxins and cytokinins, which are involved in nodule formation. Similar results was earlier reported by Tijjani *et al.* (2025) [30]. Further, the application of zinc (10 kg/ha) recorded maximum number of nodules might be due to zinc activates several enzymes that are involved in protein synthesis and metabolic regulation, these enzymes are vital for the energy-intensive process of nodule formation and functioning. Similar finding was recorded by Dhaliwal *et.al* (2022) [31].

3.1.4 Plant dry weight (g)
The data showed that significant and higher plant dry weight (10.75g) was recorded in treatment 7 Phosphorous 50kg/ha + Zinc 10kg/ha. However, treatment 4 Phosphorous 40kg/ha + Zinc 10kg/ha, treatment 6 Phosphorous 40kg/ha + Zinc 14kg/ha, treatment 8 Phosphorous 50kg/ha + Zinc 12kg/ha and treatment 9 Phosphorous 50kg/ha + Zinc 14kg/ha were statistically at par with treatment 7 Phosphorous 50kg/ha + Zinc 10kg/ha (Table 1).Significant and higher plant dry weight was observed with application of Phosphorous (50 kg/ha) might be due to phosphorus-induced increase in dry weight also reflects improved photosynthetic activity and better partitioning of assimilates into plant tissues, as cowpea is a nitrogen-fixing legume, the enhanced nodulation due to phosphorus could have contributed indirectly to higher dry matter accumulation by improving internal nitrogen supply. Similar results was earlier reported by Mohammed *et.al* (2021) [32]. Further, the application of zinc (10 kg/ha) recorded higher plant dry weight might be due to zinc positively influences vegetative growth when applied within an optimal range, this can be attributed to improved chlorophyll synthesis and photosynthetic efficiency. Similar finding was recorded by Kumar *et.al* (2016) [1].

3.1.5 Crop growth rate (g/m2/day)
The data recorded that during 45-60 DAS, highest crop growth rate (21.67 g/g/day) were recorded in treatment 8 Phosphorous 50kg/ha + Zinc 12kg/ha and though there was no significant difference among the treatments (Table 1).

3.1.6 Relative growth rate (g/g/day)
The data recorded that during 45-60 DAS, highest relative growth rate (0.021 g/g/day) were recorded in treatment 8 Phosphorous 50kg/ha + Zinc 12kg/ha and though there was no significant difference among the treatments (Table 1).

3.2 Yield attributes and yield
3.2.1Number of pods/plant
The data showed that significant and maximum number of pods/plant (13.30) was recorded in treatment 7 Phosphorous 50kg/ha + Zinc 10kg/ha. However, treatment 8 Phosphorous 50kg/ha + Zinc 12kg/ha were statistically at par with treatment 7 Phosphorous 50kg/ha + Zinc 10kg/ha (Table 2).Significant and Significant and maximum number of pods/plant was observed with application of Phosphorous (50 kg/ha) might be due to phosphorus is a fundamental component of nucleic acids, phospholipids, and ATP, all of which are crucial for energy transfer, cell division, and meristematic activity. Similar results was earlier reported by Sapkota *et.al* (2015) [28]. Further, the application of zinc 10 kg/ha) recorded maximum number of pods/plant might be due to zinc plays a vital role in enzyme activation, protein synthesis, and hormone regulation, especially in the synthesis of auxins which influence flower initiation, fruit set, and pod development. Similar results was earlier reported by Quiroz *et.al* (2018) [33].

3.2.2 Number of seeds/pod
The result revealed that significant and maximum number of seeds/pod (17.73) was recorded in treatment 7 Phosphorous 50kg/ha + Zinc 10kg/ha. However, treatment 6 Phosphorous 40kg/ha + Zinc 14kg/ha, treatment 8 Phosphorous 50kg/ha + Zinc 12kg/ha and treatment 9 Phosphorous 50kg/ha + Zinc 14kg/ha were statistically at par with treatment 7 Phosphorous 50kg/ha + Zinc 10kg/ha (Table 2).Significant and maximum plant seeds/pod was observed with application of Phosphorous (50 kg/ha) might be due to phosphorus enhances photosynthetic efficiency and translocation of assimilates from source to sink tissues, during the pod-filling stage, efficient mobilization of photosynthates to developing seeds is critical for seed number and size. Similar results was earlier reported by Sapkota *et.al* (2015) [28]. Further, the application of zinc (10 kg/ha) recorded maximum seeds/pod might be due to zinc is a key component of several enzymes and proteins involved in auxin metabolism, cell division, and reproductive organ development. Similar results was earlier reported by Quiroz *et.al* (2018) [33].

3.2.3 Test weight (g)
The data showed that highest test weight (97.33 g) was recorded in treatment 7 Phosphorous 50kg/ha + Zinc 10kg/ha and though there was no significant difference among the treatments (Table 2).

3.2.4 Seed Yield (t/ha)
The data showed that significant and higher seed yield (1.06 t/ha) was recorded in treatment 7 Phosphorous 50kg/ha + Zinc 10kg/ha. However, treatment 6 Phosphorous 40kg/ha + Zinc 14kg/ha were statistically at par with treatment 7 Phosphorous 50kg/ha + Zinc 10kg/ha (Table 2). Significant and higher seed yield was observed with application of Phosphorous (50 kg/ha) might be due to phosphorus is essential for nodulation and biological nitrogen fixation in legumes, which may have indirectly contributed to higher seed yield by improving the plant's nitrogen nutrition. Similar results was earlier reported by Poudel *et.al* (2023) [34]. Further, the application of zinc (10 kg/ha) recorded higher seed yield might be due to application of zinc resulted in a notable increase in the number of pods per plant, seeds per pod, and 100-seed weight, this can be attributed to zinc's involvement in pollen viability and fertilization, which enhances pod setting and seed filling. Similar results was earlier reported by Sheta *et.al* (2024) [35].

3.2.5 Stover yield (t/ha)
The data showed that significant and higher stover yield (3.13 t/ha) was recorded in treatment 7 Phosphorous

50kg/ha + Zinc 10kg/ha. However, treatment 2 Phosphorous 30kg/ha + Zinc 12kg/ha were statistically at par with treatment 7 Phosphorous 50kg/ha + Zinc 10kg/ha (Table 2). Significant and higher stover yield was observed with application of Phosphorous (50 kg/ha) might be due to phosphorus's critical role in enhancing root development, nodulation, and overall plant vigor, which in turn supports better biomass accumulation. Similar results was earlier reported by Poudel *et.al* (2023) [34]. Further, the application of zinc (10 kg/ha) recorded higher stover yield might be due to application of adequate zinc in legumes such as cowpea, supports healthy root development and may indirectly improve nitrogen fixation by supporting nodule function, these effects collectively enhance the overall plant growth, resulting in increased stover yield. Similar results was earlier reported by Sheta *et.al* (2024) [35].

3.2.6 Harvest index (%)

The result revealed that significant and higher harvest index (28.44%) was recorded in treatment 7 Phosphorous 50kg/ha + Zinc 10kg/ha. However, treatment 2 Phosphorous 30kg/ha + Zinc 12kg/ha and 9 Phosphorous 50kg/ha + Zinc 14kg/ha were statistically at par with treatment 7 Phosphorous 50kg/ha + Zinc 10kg/ha (Table 2). Significant and higher harvest index was observed with application of Phosphorous (50 kg/ha) might be due to phosphorus application positively influences the harvest index of cowpea by supporting reproductive development and efficient resource allocation. Similar results was earlier reported by Poudel *et.al* (2023) [34]. Further, the application of zinc (10 kg/ha) recorded higher stover yield might be due to application of zinc supported vegetative growth did not excessively overshadow reproductive growth, allowing for a favorable balance between grain and total biomass. Similar results was earlier reported by Sheta *et.al* (2024) [35].

3.3 Economic analysis

The maximum benefit cost ratio (1.99 INR/ha) was recorded in treatment 7 Phosphorous 50kg/ha + Zinc 10kg/ha (Table 3). Maximum benefit cost ratio was observed with phosphorous (50 kg/ha) might be due to comparatively lower investment cost and higher grain and stover yield in comparison to other treatments, resulted maximum benefit cost ratio.

Table 1 Effect of phosphorous and zinc on growth attributes of Cowpea

S. No.	Treatment combinations	Plant height (cm)	Number of branches/	Number of nodules/	Plant dry weight (g)	CGR (g/m2/day)	RGR (g/g/day)
			plant	plant		45-60 DAS Interval	45-60 DAS Interval
1.	Phosphorous (30 kg/ha) + Zinc (10 kg/ha)	59.86	7.00	22.37	4.55	18.08	0.018
2.	Phosphorous (30 kg/ha) + Zinc (12 kg/ha)	70.62	7.33	22.57	8.05	17.06	0.016
3.	Phosphorous (30 kg/ha) + Zinc (14 kg/ha)	74.63	7.67	22.07	7.90	17.35	0.016
4.	Phosphorous (40 kg/ha) + Zinc (10 kg/ha)	72.92	6.00	22.06	8.85	17.25	0.016
5.	Phosphorous (40 kg/ha) + Zinc (12 kg/ha)	70.94	8.83	21.20	8.20	18.25	0.017
6.	Phosphorous (40 kg/ha) + Zinc (14 kg/ha)	70.75	7.00	25.17	9.91	18.38	0.017
7.	Phosphorous (50 kg/ha) + Zinc (10 kg/ha)	78.19	9.50	25.80	10.75	18.56	0.018
8.	Phosphorous (50 kg/ha) + Zinc (12 kg/ha)	72.91	7.33	24.87	9.85	21.67	0.021
9.	Phosphorous (50 kg/ha) + Zinc (14 kg/ha)	73.03	7.67	23.53	8.73	15.48	0.015
10.	Control (RDF) 20:50:20 kg NPK/ha	73.16	7.00	22.07	8.33	16.15	0.016
	F-test	S	S	S	S	NS	NS
	S.Em (±)	1.36	0.62	0.74	0.82	2.75	0.01
	CD (p=0.05)	3.93	1.78	2.14	2.36	-	-

Table 2: Effect of phosphorous and zinc on yield attributes and yield of Cowpea.

S. No.	Treatment combinations	Number of Pods/plant	Number of Seeds/pod	Test weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest Index (%)
1	Phosphorous (30 kg/ha) + Zinc (10 kg/	ha) 11.03	13.07	91.33	0.50	2.53	25.54
2	Phosphorous (30 kg/ha) + Zinc (12 kg/	ha) 10.60	13.67	96.00	0.49	2.70	26.36
3	Phosphorous (30 kg/ha) + Zinc (14 kg/	ha) 11.20	13.67	93.00	0.51	2.17	24.83
4	Phosphorous (40 kg/ha) + Zinc (10 kg/	ha) 10.73	13.57	92.67	0.48	2.07	25.59
5	Phosphorous (40 kg/ha) + Zinc (12 kg/	ha) 11.30	13.77	91.33	0.49	2.27	23.08
6	Phosphorous (40 kg/ha) + Zinc (14 kg/	ha) 11.03	15.03	91.33	0.48	2.23	25.06
7	Phosphorous (50 kg/ha) + Zinc (10 kg/	ha) 13.30	17.73	97.33	0.63	3.13	28.44
8	Phosphorous (50 kg/ha) + Zinc (12 kg/	ha) 12.93	14.23	96.33	0.60	2.03	25.18
9	Phosphorous (50 kg/ha) + Zinc (14 kg/	ha) 11.20	17.27	88.00	0.51	2.03	26.28
10	Control (RDF) 20:50:20 kg NPK/ha	9.33	10.60	90.67	0.43	2.07	20.38
	F-test	S	S	NS	S	S	S
	S.Em (±)	0.64	1.32	2.67	0.01	0.17	0.90
	CD (p=0.05)	1.85	3.82	_	0.04	0.48	2.59

Table 3: Effect of phosphorous and zinc on economics of Cowpea.

S.N	Treatment combinations	Cost of cultivation (INR/ha)	Gross returns (INR/ha)	Net returns (INR/ha)	B:C ratio
1	Phosphorous (30 kg/ha) + Zinc (10 kg/ha)	32,830.00	85,890.00	53,060.00	1.61
2	Phosphorous (30 kg/ha) + Zinc (12 kg/ha)	33,010.00	85,450.00	52,440.00	1.50
3	Phosphorous (30 kg/ha) + Zinc (14 kg/ha)	33,190.00	86,490.00	53,300.00	1.60
4	Phosphorous (40 kg/ha) + Zinc (10 kg/ha)	33,130.00	83,350.00	50,220.00	1.51
5	Phosphorous (40 kg/ha) + Zinc (12 kg/ha)	33,310.00	84,890.00	51,580.00	1.54
6	Phosphorous (40 kg/ha) + Zinc (14 kg/ha)	34,940.00	84,030.00	50,540.00	1.50
7	Phosphorous (50 kg/ha) + Zinc (10 kg/ha)	34,340.00	100,170.00	66,740.00	1.99
8	Phosphorous (50 kg/ha) + Zinc (12 kg/ha)	33,610.00	96,230.00	62,620.00	1.86
9	Phosphorous (50 kg/ha) + Zinc (14 kg/ha)	33,790.00	86,810.00	53,020.00	1.56
10	Control (RDF) 20:50:20 kg NPK/ha	78,850.00	78,850.00	45,420.00	1.35

4. Conclusion
It can be concluded that the application (Phosphorous 50kg/ha + Zinc 10kg/ha) recorded higher yield and benefit cost ratio in cowpea.

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6. Competing Interests
Authors have declared that no competing interests exist.

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