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Impact of Phosphorus Levels and Spacing on Growth, Yield and Development of Cowpea (*Vigna unguiculata* L. Walp.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during *Zaid* 2022 at Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology And Sciences, Prayagraj (U.P). To determine the "Impact of phosphorus levels and spacing on growth, yield and development of cowpea (*Vigna unguiculata* (L.) Walp)". To study treatment consisting of three phosphorus concentrations *viz.* 30, 40, 50 kg/ha and three levels of spacing 20cm×20cm, 30cm×30cm, 40cm×40cm. There were 10 treatments, each of which was replicated three times and laid out in a random block design. The results showed that treatment 8 [Phosphorus (50kg/ha) + (30cm×30cm)] recorded significantly higher plant height (60.3 cm), higher number of branches/plant (7.40), higher plant dry weight (16.47 g), higher number of nodules/plant (10.00). Whereas, maximum number of

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pods/plant (15.07), maximum number of seeds/pod (10.87), higher seed yield (1.05 t/ha), higher stover yield (1.60 t/ha), was recorded in treatment 8 [Phosphorus (50kg/ha) + (30cm×30cm)]. Similarly, maximum gross returns (89,050.00 INR/ha), higher net returns (57,832.40 INR/ha) and highest benefit cost ratio (1.85) was also recorded in treatment 8 [Phosphorus (50kg/ha) + (30cm×30cm)] as compared to other treatments.

Keywords: Phosphorus; spacing; growth; yield and development.

1. INTRODUCTION

Cowpea (*Vigna unguiculata* L.) is one of the most important vegetable crops grown as pulse, vegetable and fodder. Cowpea is annual herbaceous plant known for its drought hardy nature with large tap root system and alternate trifoliate leaves with ovate leaflets. It can either be short and bushy or act like a vine by climbing supports or trailing along the ground. Generally, colours of cowpea flowers are purple, pink, yellow, white and blue [1]. It can be consumed in all stages of its growth and can be used to prepare delicious dishes and animal feed. It is well-known for its smothering nature, drought tolerant character, soil restoring properties and multiple uses. It is also known as “vegetable meat”, because it is a rich source of protein and other nutrients and minerals like calcium and iron. On dry weight basis, cowpea seeds contain 23.4% protein, 1.8% fat, 60.3% carbohydrate, 3.4% fibre, 3.3% ash and 9 to 11% moisture [2].

The world’s total production of cowpea covers around 3 million tons, of which Nigeria is the leading producer contributing 2.1 million tons. Highest cowpea production nations are Nigeria, India and Brazil. Annual global production is 2 million tons from an area of 5 million ha. In India, cowpea is grown in almost 1.3 million ha area with an average productivity of 600-700 Kg grains/ha, particularly in western, central and peninsular region (FAO, 2012). It is an annual multipurpose grain legume [3].

In India pulses are grown nearly in 25.43 m ha with an annual production of 17.28 m t and productivity of 679 kg/ha. The per capita availability of pulses in India is 35.5g/day as against the minimum requirement of 7g/day/capita as advocated by Indian council of Medical Research. Cowpea grown across the world on an area 14.5 m ha of land planted each year and the total annual production is 6.2 m t. In India during 2020-21 cowpea is grown in about 13.3 m ha with an annual production of 8.06 m t and productivity of 596 kg/ha. Some of the states like Uttar Pradesh is about 2.38 m ha with an annual production of 2.56 and productivity of 1079 kg/ha major producer of cowpea in India as advocated by Ministry of Agriculture & Farmers welfare [4].

The yield potential for cowpea crop is very low and plaughed with number of diseases and pests. The production of pulse crop in our country including cowpea is not enough to meet the domestic demand of population. There is a scope to enhance the productivity of cowpea by proper agronomic practices and fertilizers. In India problems of cowpea such as low flowering and poor pod set in pulse crops [5].

Legumes are phosphorus loving plants. They require phosphorus for growth and seed development and most especially in nitrogen fixation which is an energy-driving process. For sustainable food production to meet the increasing population in developing countries, need for phosphorus fertilizer application is expected to increase yield. Phosphorus is known to cause multiples effects on nutrition, increase in seed yield and nodulation process [6]. Some researchers also reported that phosphorus application will affects the other nutrients in seed and leaves because of its multiple effects on plant nutrition [7].

Phosphorus deficiency in soil is widespread and crops grown under deficient situation show significant response to fertilizer phosphorus. At several places normal yield of crops could not be achieved despite judicious use of NPK fertilizers due to deficiency of micronutrients in soil, in general, that of Zn in particular. The knowledge regarding the use of optimum dose of nutrients especially Phosphorus and Zinc is of serious concern [8].

It is not possible to recommend a generalized optimum spacing since the crop is grown in different seasons with different management practices in different soil type. So, optimum spacing differs depending on the environmental conditions and plant type.

Optimum spacing is necessary to obtain maximum yield in any crop by reducing the competition among the plants for light, nutrient, moisture, etc. It depends on size of plant, elasticity, nature of the plant, capacity to reach optimum leaf area at an early date and seed rate used. Optimum spacing for any crop varies considerably due to environment under which it is grown [9]. Keeping in view the above facts, the present investigation was undertaken to find out "Impact of phosphorus levels and spacing on growth, yield and development of cowpea (*Vigna unguiculata* L.).

2. MATERIALS AND METHODS

The experiment was conducted during the *Zaid* season 2022 at the Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology And Sciences, Prayagraj (U.P.). The soil of the field constituting a part of central gangetic alluvium is neutral and deep. The soil of the experimental field was sandy loamy in texture, nearly neutral in soil reaction (pH 7.8), low level of organic carbon (0.62%), available N (225 kg/ha), P (38.2 kg/ha), K (240.7 kg/ha). The treatment consists of three Phosphorus levels *viz.* 30, 40, 50 kg/ha with three different spacing 20cm×20cm, 30cm×30cm, 40cm×40cm. The experiment was laid out in Randomized Block Design (RBD) with 10 treatments each replicated thrice. The treatment combinations are T1 – Phosphorus (30kg/ha) + (20cm×20cm), T2 – Phosphorus (30kg/ha) + (30cm×30cm), T3 – Phosphorus (30kg/ha) + (40cm×40cm), T4 – Phosphorus (40kg/ha) + (20cm×20cm), T5 – Phosphorus (40kg/ha) + (30cm×30cm), T6 – Phosphorus (40kg/ha) + (40cm×40cm), T7 – Phosphorus (50kg/ha) + (20cm×20cm), T8 – Phosphorus (50kg/ha) + (30cm×30cm), T9 – Phosphorus (50kg/ha) + (40cm×40cm), T10 – (control) Phosphorus (40kg/ha) + (45cm×15cm).

All agronomic practices are followed in order in the crop period. Experimental data collected was subjected to statistical analysis of variance (ANOVA) as outlined by Gomez and Gomez [10]. Critical Difference (CD) values were calculated wherever the 'F' test was found significant at 5 percent level.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Plant height (cm)

The data recorded that significant and higher plant height (60.3 cm) was observed in treatment 8 [Phosphorus (50kg/ha) + (30cm×30cm)]. However, treatment 4 [Phosphorus (40kg/ha) + (20cm×20cm)], treatment 5 [Phosphorus (40kg/ha) + (30cm×30cm)], treatment 6 [Phosphorus (40kg/ha) + (40cm×40cm)], treatment 7 [Phosphorus (50kg/ha) + (20cm×20cm)], and treatment 9 [Phosphorus (50kg/ha) + (40cm×40cm)] were statistically at par with the treatment 8 [Phosphorus (50kg/ha) + (30cm×30cm)] [Table 1]. Significant and higher plant height was observed with application of phosphorus (50kg/ha) might be due to a sufficient quantity of phosphorus can stimulate biological activity. Similar findings have been reported by Sonet et al. [11] in lentil. Further, higher plant height was observed with spacing (30cm×30cm) might be due to plant get sufficient space under wider spacing for light, air and nutrition for better growth and development. Similar results have been reported by Kasula et al. [12] in chickpea.

3.1.2 Number of branches/plant

The data revealed that significant and higher number of branches/plant (7.40) was observed in treatment 8 [Phosphorus (50kg/ha) + (30cm×30cm)]. However, treatment 5 [Phosphorus (40kg/ha) + (30cm×30cm)], treatment 7 [Phosphorus (50kg/ha) + (20cm×20cm)] and treatment 9 [Phosphorus (50kg/ha) + (40cm×40cm)] were statistically at par with the treatment 8 [Phosphorus (50kg/ha) + (30cm×30cm)]. The significant and maximum number of branches/plant was with application of phosphorus (50kg/ha) might be due to efficient utilization of nutrients, which resulted in attaining better crop canopy and simulation of root growth. Similar results have been reported by Sirisha et al. [1]. Further, maximum number of branches/plant was observed with spacing (30cm×30cm) might be due to optimum plant spacing between plants resulted in enhanced space, sunlight, nutrients and soil moisture for increased photosynthesis, and metabolic activities which resulted in higher number of branches. Similar results have been reported by Jasper et al. [13] in black gram.

3.1.3 Number of nodules/plant

Data was found that significantly higher number of nodules/plant (10.00) was obtained in treatment 8 [Phosphorus (50kg/ha) + (30cm×30cm)]. However, treatment 9 [Phosphorus (50kg/ha) + (40cm×40cm)] were statistically at par with the treatment 8

[Phosphorus (50kg/ha) + (30cm×30cm)]. Application of phosphorus (50kg/ha) showed that maximum number of nodules/plant that increase in nodulation might be due to stimulates the root and plant growth, initiates nodule formation as well as influence the general efficiency of the rhizobium- legume symbiosis, thereby optimizes the Biological Nitrogen Fixation system of legume. Similar results have been reported by Ndor et al. [14]. Further, higher number of nodules/plant was observed with spacing (30cm×30cm) might be due to wider spacing there is less competition for space, moisture and nutrient might have probably increased root nodule as compared to close spacing. Similar results have been reported by Murade et al. [15] in urdbean.

3.1.4 Plant dry weight (g)

Significant and higher plant dry weight (16.47 g) was recorded in treatment 8 [Phosphorus (50kg/ha) + (30cm×30cm)]. However, treatment 9 [Phosphorus (50kg/ha) + (40cm×40cm)] were statistically at par with the treatment 8 [Phosphorus (50kg/ha + 30cm×30cm)]. Significant and maximum plant dry weight was observed with application of phosphorus (50kg/ha) might be due to the increase in vegetative development and reproductive attributes under proper availability of phosphorus and better physical condition of soil.

Similar results have been reported by Singh et al. [16] in summer green gram. Further, higher plant dry weight was observed with spacing (30cm×30cm) might be due to greater exposure to light and increased availability of nutrients to plants have also resulted in higher root dry weight on the plants. Similar results have been reported by Wali et al. [17] in green gram.

3.1.5 Crop growth rate (g/m2/day)

The data revealed that during 45-60 Days After Sowing, treatment 7 [Phosphorus (50kg/ha) + (20cm×20cm)] recorded significantly higher crop growth rate (1.95 $g/m^{2/}$day), However, treatment 4 [Phosphorus (40 kg/ha) + (20cm×20cm)] were statistically at par with the treatment 7 [Phosphorus (30kg/ha) + (20cm×20cm)]. The significant and higher crop growth rate with the application of phosphorus (50kg/ha) might be due to superior nodulation and its weight/plant, these result in better acquisition of phosphorus and other nutrients, thereby increasing the crop growth. Similar results have been reported by Singh et al. [18] in lentil. Further, increase in crop growth rate was observed with spacing (20cm×20cm) might be due to closer crop geometry with more population/unit area. Similar results have been reported by Kumar et al. [19] in black gram.

3.1.6 Relative growth rate (g/g/day)

The data revealed that during 45-60 Days After Sowing, treatment 5 [Phosphorus (40kg/ha) + (30cm×30cm)] recorded higher relative growth rate (0.0060 g/g/day) and though there was no significant difference among the treatments.

3.2 Yield Attributes

3.2.1 Number of pods/plant

The data showed that treatment 8 [Phosphorus (50kg/ha) + (30cm×30cm)] recorded significantly higher number of pods/plant (15.07). However, treatment 7 [Phosphorus (50kg/ha) + (20cm×20cm)], and treatment 9 [Phosphorus (50kg/ha) + (40cm×40cm)] were statistically at par with the treatment 8 [Phosphorus (50kg/ha) + (30cm×30cm)] [Table 2]. The significant and increase in number of pods/plant was observed with application of phosphorus (50kg/ha) might be due to enhances the root elongation, leaf expansion and photosynthesis efficiency per unit of chlorophyll and helps in cell division, cell elongation, translocation and respiration process. Similar results have been reported by Singh et al. [20]. Further, maximum number of pods/plant was observed with spacing (30cm×30cm) might be due to wide crop geometry is to better absorption of moisture and nutrients by the individual crop. Similar results have been reported by Bhavana et al. [21] in horse gram.

3.2.2 Number of seeds/pod

The data found that significant and higher number seeds/pod (10.87) was recorded in treatment 8 [Phosphorus (50kg/ha) + (30cm×30cm)]. However, treatment 7 [Phosphorus (50kg/ha) + (20cm×20cm)], and treatment 9 [Phosphorus (50kg/ha) + (40cm×40cm)] were statistically at par with the treatment 8 [Phosphorus (50kg/ha) + (30cm×30cm)]. The significant and maximum number of seeds/pod was with the application of phosphorus (50kg/ha) might be due to plant growth, photosynthesis, flowering, seed setting and nitrogen fixation which ultimately resulted in enhancement of yield attributes. Similar results

Table 1. Impact of phosphorus levels and spacing on growth parameters of cowpea

S No	Treatments	Plant height (cm)	Number of branches/ plant	Number of nodules/ Plant	Plant dry weight (g)	CGR (g/m2/day)	RGR (g/g/day)
1.	Phosphorus 30kg/ha + 20cm×20cm	58.1	5.53	7.00	13.10	1.06	0.0034
2.	Phosphorus 30kg/ha **+** 30cm×30cm	58.5	6.47	8.07	13.97	0.47	0.0030
3.	Phosphorus 30kg/ha + 40cm×40cm	58.4	6.40	7.50	13.63	0.27	0.0032
4.	Phosphorus 40kg/ha + 20cm×20cm	59.5	6.67	8.60	14.40	1.17	0.0034
5.	Phosphorus 40kg/ha + 30cm×30cm	59.7	7.07	8.80	15.53	0.99	0.0060
6.	Phosphorus 40kg/ha + 40cm×40cm	59.5	6.73	8.73	14.83	0.29	0.0031
7.	Phosphorus 50kg/ha + 20cm×20cm	60.0	7.13	9.13	15.87	1.95	0.0050
8.	Phosphorus 50kg/ha + 30cm×30cm	60.3	7.40	10.00	16.47	0.32	0.0017
9.	Phosphorus 50kg/ha + 40cm×40cm	60.1	7.27	9.27	16.20	0.15	0.0015
10.	Control (Phosphorus 40kg/ha + 45cm×15cm)	58.2	5.67	7.07	13.20	0.59	0.0032
	F-test	S	S	S	S	S	NS
	SEm(±)	0.38	0.22	0.27	0.14	0.27	0.0010
	CD at 5%	1.14	0.64	0.80	0.43	0.79	-

Table 2. Impact of phosphorus levels and spacing on yield attributes of cowpea

S No	Treatments	Number of pods/plant	Number of seeds/pod	Test weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
1.	Phosphorus 30kg/ha + 20cm×20cm	10.13	8.00	12.33	0.89	1.28	41.0
2.	Phosphorus 30kg/ha **+** 30cm×30cm	12.40	9.27	12.70	0.91	1.34	40.5
3.	Phosphorus 30kg/ha + 40cm×40cm	11.53	9.20	12.60	0.89	1.30	40.7
4.	Phosphorus 40kg/ha + 20cm×20cm	13.60	9.40	12.83	0.92	1.39	39.8
5.	Phosphorus 40kg/ha + 30cm×30cm	14.40	9.80	13.10	0.95	1.43	39.9
6.	Phosphorus 40kg/ha + 40cm×40cm	14.27	9.60	12.90	0.94	1.39	40.4
7.	Phosphorus 50kg/ha + 20cm×20cm	14.60	10.20	13.10	1.00	1.44	41.0
8.	Phosphorus 50kg/ha + 30cm×30cm	15.07	10.87	13.30	1.05	1.60	39.6
9.	Phosphorus 50kg/ha + 40cm×40cm	14.73	10.40	13.20	1.02	1.52	40.4
10.	Control (Phosphorus 40kg/ha + 45cm×15cm)	10.60	8.73	12.57	0.82	1.26	39.6
	F-test	S	S	NS	S	S	NS
	SEm(±)	0.18	0.30	0.22	0.02	0.06	0.94
	CD at 5%	0.53	0.88	--	0.05	0.17	--

Table 3. Impact of phosphorus levels and spacing on economics of cowpea

S No	Treatments	Total cost of cultivation (INR/ha)	Gross returns (INR/ha)	Net returns (INR/ha)	B:C ratio
1	Phosphorus 30kg/ha + 20cm×20cm	30468.40	74490.00	44022.40	1.44
2	Phosphorus 30kg/ha + 30cm×30cm	29968.40	76570.00	46602.40	1.55
3	Phosphorus 30kg/ha + 40cm×40cm	29468.40	74750.00	45282.40	1.53
4	Phosphorus 40kg/ha + 20cm×20cm	31093.40	78390.00	47297.40	1.52
5	Phosphorus 40kg/ha + 30cm×30cm	30593.40	81120.00	50527.40	1.65
6	Phosphorus 40kg/ha + 40cm×40cm	30093.40	79170.00	49077.40	1.63
7	Phosphorus 50kg/ha + 20cm×20cm	31718.40	83720.00	52002.40	1.63
8	Phosphorus 50kg/ha + 30cm×30cm	31218.40	89050.00	57832.40	1.85
9	Phosphorus 50kg/ha + 40cm×40cm	30718.40	86060.00	55342.40	1.80
10	Control (Phosphorus 40kg/ha + 45cm×15cm)	30593.40	69680.00	39087.40	1.27

Data was not subjected to statistical analysis

have been reported by Sahu et al. [22] in green gram. Further, increase in number of seeds/pod was observed with spacing (30cm×30cm) might be due to more space per plant ultimately enhanced availability of nutrients, moisture and light consequently better development of yield attributes. Similar results have been reported by Kumar et al. [23] in black gram.

3.2.3 Test weight (g)

The data recorded that no significant difference among all the treatments. However, highest test weight (13.30 g) was observed in treatment 8 [Phosphorus (50kg/ha) + (30cm×30cm)].

3.2.4 Seed yield (t/ha)

The significant and higher seed yield (1.05 t/ha) was recorded in treatment 8 [Phosphorus (50kg/ha) + (30cm×30cm)]. However, treatment 7 [Phosphorus (50kg/ha) + (20cm×20cm) and treatment 9 [Phosphorus (50kg/ha) + (40cm×40cm)] were statistically at par with the treatment 8 [Phosphorus (50kg/ha) + (30cm×30cm)]. The highest seed yield with the application of phosphorus (50kg/ha) might be due to root proliferation leads to nitrogen fixation for better crop production. Similar results have been reported by Abraham et al. [24] in black gram. Further, increase in seed yield was observed with spacing (30cm×30cm) might be due to optimum spacing helped plant to receive sufficient amount of heat, water and nutrients from soil. Similar results have been reported by Pandey et al. [25] in black gram.

3.2.5 Stover yield (t/ha)

Results revealed that treatment 8 [Phosphorus (50kg/ha) + (30cm×30cm)] recorded significantly higher stover yield (1.60 t/ha). However, treatment 7 [Phosphorus (50kg/ha) + (20cm×20cm)] and the treatment 9 [Phosphorus (50kg/ha) + (40cm×40cm)] were statistically at par with the treatment 8 [Phosphorus (50kg/ha) + (30cm×30cm)]. Maximum stover yield might be due the application of phosphorus (50kg/ha) increased plant height, branching, and dry matter accumulation at harvest as a consequence of a better assimilates production by the plants. Similar results were found by Sahu et al. [22] in green gram. Further, increase in stover yield was observed with spacing (30cm×30cm) might be due to optimum row spacing have effectively utilized the growth resources, particularly solar radiation. Similar results have been reported by Devi et al. [9] in lentil.

3.3 Harvest Index (%)

The data showed that no significant difference among all the treatments. However, maximum harvest index (41.0%) was recorded in treatment 7 [Phosphorus (50kg/ha) + (20cm×20cm)].

3.4 Economics

The result revealed that maximum gross return (89,050.00 INR/ha), higher net returns (57,832.40 INR/ha), and highest benefit cost ratio (1.85) was recorded in treatment 8 [Phosphorus (50kg/ha) + (30cm×30cm)] as compared to other treatments [Table 3]. Higher gross returns, net returns, benefit cost ratio was recorded with application of phopshorus (50kg/ha) might be due to higher growth and yield attributes resulting in more seed and stover yield with recommended dose of phosphorus. Similar results have been reported by Bhat et al. [26] in field pea [27].

4. CONCLUSION

Based on the above findings it can be concluded that application of Phosphorus 50kg/ha with the spacing 30cm×30cm has performed better in growth parameters and yield attributes of cowpea and also proven profitable. Since the findings are based on one season, further trails are needed to confirm the results.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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