The effect of Phosphorus and Molybdenum on growth and yield of cowpea (*Vigna unguiculata* L.)

ABSTRACT

A field experiment was conducted during *Zaid* season (March to June; Summer season crop) of 2022 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology And Sciences, Prayagraj, Uttar Pradesh, India to determine the "The effect of phosphorus and molybdenum on the growth and yield of summer Cowpea (*Vigna unguiculata* L.)"**.** The results showed that the treatment 9 [Phosphorus (50kg/ha) + Molybdenum (2 kg/ha)] recorded significantly higher plant height (73.43 cm), higher number of nodules per plant (17.66), higher plant dry weight (23.07 g/plant), higher crop growth rate(18.87g/m^2/day) maximum number of pods per plant (15.10), maximum number of seeds per pod (14.67), higher seed index (16.03 g), higher seed yield (1550.27 kg/ha) and higher stover yield (1615.50 kg/ha) and higher harvest index(49.05%) was recorded in treatment 8 [Phosphorus (50kg/ha) + Molybdenum (1.5kg/ha)]. Similarly, maximum gross return (94954.8 INR/ha), higher net return (65670.3 INR/ha) and highest Benefit Cost ratio (2.24) was also recorded in treatment 9 [Phosphorus (50kg/ha) + Molybdenum (2kg/ha)] as compared to other treatments.

***Key words*:** Phosphorus, Molybdenum, Growth, Yield, Economics, Cowpea, Pulse.

Introduction

"Cowpea (*Vigna unguiculata* L.) is commonly grown in sub-tropical regions that are moderately humid and warm and more drought resilient. However, the plant is not tolerant to frost and waterlogging. Seeds of cowpea are nutritious and cheap sources of quality protein, vitamins, iron and phosphorus and are an excellent substitute for eggs, meat and other protein-rich foods, thus they are a significant part of the human diet. It also plays an important role in providing soil nitrogen to cereal crops (such as maize, millet and sorghum) when grown in rotation, especially in areas where poor soil fertility is a problem. It does not require a high rate of nitrogen fertilization; its roots have nodules in which soil bacteria called rhizobia (Rhizobium spp.) inhabit and help to fix nitrogen from the air into the soil in the form of nitrates" **(Sheahan, 2012)**. "The protein in cowpea seeds is rich in amino acids like lysine, phenyl amine, leucine and tryptophan compared to cereal grains" **(Gad and Kandil, 2013)**. "The protein content present in cowpea is about 25-30% in mature seeds, 4-5% in immature pods and 3-5% in green leaves" **(Bressani and Elias, 1980)**. The ripe seed on average contains 22% protein, 1.4% fat, 59.1% carbohydrate, and 3.7% ash. The energy value is 340 kcal/ 100 g.

In India, pulses are grown nearly in 25.43 million hectare (m ha) with an annual production of 17.28 million metric tons (mt) and productivity of 679 kg/ha. The per capita availability of pulses in India is 35.5g/day as against the minimum requirement of 70g/day/capita as advocated by the Indian Council of Medical Research. Cowpea is grown across the world on an area of 14.5 m ha of land planted each year and the total annual production is 6.2m t. In India during 2020-21 cowpea grew 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 are 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 the Ministry of Agriculture and Farmers Welfare **(GOI, 2020-21)**.

"Phosphorus is critical to cowpea yield because it is reported to stimulate growth, initiate nodule formation as well as influence the efficiency of rhizobium-legume symbiosis" **(Haruna and Aliyu, 2011)**. "It is required in large amount in young cells such as shoot and root tips to increase metabolism and promote rapid cell division. It also assists flower initiation, seed and fruit development" **(Ndakidemi and Dakora, 2007). "**Phosphorus plays a key role in many plant processes such as energy metabolism, nitrogen fixation, synthesis of nucleic acids and membranes, photosynthesis, respiration and enzyme regulation". **(Karikari *et al*., 2015)**.

"Molybdenum (Mo) also playing important role in the structural integrity of the cell wall and cell membrane and synthesis of protein and nitrogen fixation, as well. Molybdenum is a component (Moco) of the nitrate reductase enzyme and in the legume, it plays an additional role in symbiotic nitrogen fixation. The nitrogen-fixing enzyme, nitrogenase consists of molybdenum iron protein and without adequate an quantities of this element, nitrogen fixation cannot occur. Thus, the application of Mo increased the yield but also improved the quality" **(Movalia *et al*., 2020).** Molybdenum also has a function as a co-factor, i.e., structural and catalytic function, in several enzymes which have been discovered in higher plants. Although molybdenum does not take part in nitrogen metabolism directly, some researchers showed that it still plays an important stimulation role in the process of nitrogen metabolism. Keeping in view these reported facts, the present investigation was undertaken to find out "Effect of phosphorus and molybdenum on the growth and yield of summer Cowpea (*Vigna unguiculata* L.)"

MATERIALS AND METHODS:

The experiment was conducted during *zaid* season (March to June; the summer season crop in India) of 2022 at Crop Research Farm, Department of Agronomy, SHUATS, 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 loam 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) and zinc (2.32 mg/kg). The treatment consisted of three levels of phosphorus *viz.*, 30, 40, 50 kg/ha and three levels of molybdenum *viz.*, 1, 1.5, 2 kg/ha. The experiment was laid out in RBD with 10 treatments each replicated three times. The treatment combinations are T1 - phosphorus (30kg/ha) + molybdenum (1 kg/ha) , T2 - phosphorus (30kg/ha) + molybdenum (1.5 kg/ha) , T3 - phosphorus (30kg/ha) + molybdenum (2 kg/ha) , T4 - phosphorus (40kg/ha) + molybdenum (1 kg/ha), T5 - phosphorus (40kg/ha) + molybdenum (1.5 kg/ha) , T6 - phosphorus (40kg/ha) + molybdenum (2 kg/ha) , T7 - phosphorus (50kg/ha) + molybdenum (1 kg/ha), T8 - phosphorus (50kg/ha) + molybdenum (1.5 kg/ha), T9 - phosphorus (50kg/ha) + molybdenum (2 kg/ha), T10 – Control (25:50:25NPK kg/ha). The growth parameters and yield, production was recorded at harvest from randomly selected plants in each plot. The data was computed and analyzed by following statistical method of Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth parameters

Plant height (cm)

At 60 days after sowing (DAS), higher plant height (73.43 cm) was recorded in treatment 9 [Phosphorus (50kg/ha) +Molybdenum (2 kg/ha)] which was significantly superior over all other treatments. However, treatment 6 [Phosphorus (40kg/ha) + Molybdenum (2 kg/ha)] is statistically at par with treatment 9 [Phosphorus (50kg/ha) + Molybdenum (2kg /ha)] (Table 1). The significant and highest plant height observed with the application of phosphorus (50 kg/ha) might be due the role of phosphorus in cell division **(Namakka *et al.*, 2017).** Further, the increase in plant height was due to the fact that molybdenum (2kg/ha) increases availability of nitrogen which helps in the process of nitrogen assimilation. Similar findings also reported by **Chatterjee and Bandyopadhyay (2015).**

Number of Nodules/plant

At 60 days after sowing (DAS), a higher number of Nodules /Plant (7.89) was recorded in treatment 9 [Phosphorus (50kg/ha) + Molybdenum (2 kg/ha)], which was significantly superior over all other treatments (Table 1). However, treatment 6 [Phosphorus (40kg/ha) + Molybdenum (2 kg/ha)] is statistically at par with treatment 9 [Phosphorus (50kg /ha) + Molybdenum (2kg /ha)]. The application of phosphorus showed significant and higher number of nodules/plant which might be due to it plays role in energy metabolism, nitrogen fixation, synthesis of nucleic acid and membranes, photosynthesis, respiration and enzyme regulation **(Nkaa *et al.*,2014).** Further, Mo (20 kg/ha) application significantly increased the number of nodules/plant due to its vital role in synthesis and activity of molybdo enzymes such as nitrogen assimilation enzyme – nitrate reductase and the nitrogen fixing enzyme - nitrogenase, key regulatory component for initiation of nodulation **(Franco and Munns, 1981).**

Plant Dry Weight (g)

At 60 days after sowing (DAS), a higher plant dry weight (23.07 g) was recorded in treatment 9 [Phosphorus (50kg/ha) + Molybdenum (2 kg/ha)], which was significantly superior over all other treatments. However treatment 6 [Phosphorus (40kg/ha) + Molybdenum (2 kg/ha)] is statistically at par with treatment 9 [Phosphorus (50kg /ha) + Molybdenum (2kg /ha)] (Table 1). Maximum plant dry weight was increased significantly with application of molybdenum (2kg/ha) this might be due to higher availability of nutrients, synthesis of more carbohydrates and their translocation to different plant parts resulted in increased vegetative growth including the reproductive structures which in turn increase dry weight of the plant. Similar results have been reported by **Harireddy *et al* (2021).**

Crop growth rate (g/m^2/day)

At 45-60 days after sowing (DAS), higher crop growth rate (11.78 g /m^2/day) was recorded in treatment 9 [Phosphorus (50kg/ha) + Molybdenum (2 kg/ha)], which was significantly superior over all other treatments. However, treatment 1 [Phosphorus (30kg/ha) + Molybdenum (1 kg/ha)], treatment 2 [Phosphorus (30kg/ha) + Molybdenum (1.5 kg/ha)], treatment 3 [Phosphorus (30kg/ha) + Molybdenum (2 kg/ha)], treatment 4 [Phosphorus (40kg/ha) + Molybdenum (1 kg/ha)], treatment 5 [Phosphorus (40kg/ha) + Molybdenum (1.5 kg/ha)], treatment 6 [Phosphorus (40kg/ha) + Molybdenum (2 kg/ha)] were statistically at par with treatment 9 [Phosphorus (50kg /ha) + Molybdenum (2kg /ha)] (Table 1). The maximum crop growth rate was observed by the application of molybdenum (2 kg/ha) this might be due to a better accumulation of dry matter throughout the plant vegetative and reproductive phase, which enhances the physiological and metabolic activity and growth by assimilating the available nutrients at higher rate, facilitating more photosynthesis. A similar trend was reported by **Harshini *et al* (2022)**.

Yield parameters (Table 2)

Number of pods/plants

Treatment with application of treatment 9 [Phosphorus (50kg/ha) + Molybdenum (2 kg/ha)] was recorded higher number of pods/plant (15.10) which was significantly superior over all other treatments. However, treatment 6 [Phosphorus (40kg/ha) + Molybdenum (2 kg/ha)] is statistically at par with treatment 9 [Phosphorus (50kg/ha) + Molybdenum (2 kg/ha)] (Table 2). The higher number of pods/plant with application of phosphorus (50 kg/ha) might be due to it favourably influenced the plant vigour, morphology and metabolic processes. **(Chatterjee and Bandyopadhyay. 2015).** Further higher number of pods/plant was observed with application of molybdenum (2kg/ha) might have been possible due to increased availability of nitrogen leads to biological nitrogen fixation that induces plant growth to produce huge biomass and number of pods/plant. Similar results were reported by **Mahesh *et al.*, (2021)** in black gram.

Number of seeds/pods

Treatment with application of treatment 9 [Phosphorus (50kg/ha) + Molybdenum (2 kg/ha)] was recorded higher number of seeds/pods (14.67) which was significantly superior over all other treatments. However, treatment 6 [Phosphorus (40kg/ha) + Molybdenum (2 kg/ha)] is statistically at par with treatment 9 [Phosphorus (50kg/ha) + Molybdenum (2 kg/ha)]. The higher number of seeds/pod with the application of phosphorus (50kg/ha) might be due to its role in translocation of assimilates to the pods being a constituent of protoplasm. Similar results were reported by **Shilpa *et al.*, (2011)** in table 2.

Seed index

Treatment with application of treatment 9 [Phosphorus (50kg/ha) + Molybdenum (2 kg/ha)] was recorded higher number of test weight (16.03 g) which was significantly superior over all other treatments. However, treatment 6 [Phosphorus (40kg/ha) + Molybdenum (2 kg/ha)] is statistically at par with treatment 9 [Phosphorus (50kg/ha) + Molybdenum (2 kg/ha)]. Significant and higher seed index was with application of phosphorous (50kg/ha) might be due to increase photosynthetic activity of leaves, translocation of photosynthates from source to sink. Similar result was observed by **Singh *et al.*, (2018)** in green gram. Further increase in seed index with the application of molybdenum (2kg/ha) might be due to the increase in phosphorus contents of the seed (phospholipids and phosphorus - protein) and also its involvement in many physiological processes in plants. Similar results was reported by **Tahir *et al.*, (2014)** in black gram in table 2.

Seed yield (kg/ha)

Treatment with application of treatment 9 [Phosphorus (50kg/ha) + Molybdenum (2 kg/ha)] was recorded higher seed yield (1550.27 kg/ha) which was significantly superior over all other treatments. However, treatment 6 [Phosphorus (40kg/ha) + Molybdenum (2 kg/ha)] is statistically at par with treatment 9 [Phosphorus (50kg/ha) + Molybdenum (2 kg/ha)].The application of Phosphorus (50 kg/ha) significantly increases seed yield might be dueto its role in enhancing photosynthesis apparatus. (**Namakka *et al.*, 2017).** Further, increase in seed yield with application of molybdenum (2kg/ha) might be due to improved rhizobium activity, nitrogen fixation, vegetative growth and yield components. Similar results were recorded by **Chatterjee and Bandyopadhyay (2015)** in table 2.

Stover yield (kg/ha)

Treatment with application of treatment 9 [Phosphorus (50kg/ha) + Molybdenum (2 kg/ha)] was recorded higher stover yield (1615.50 kg/ha) which was significantly superior over all other treatments. However, treatment 6 [Phosphorus (40kg/ha) + Molybdenum (2 kg/ha)] is statistically at par with treatment 9 [Phosphorus (50kg/ha) + Molybdenum (2 kg/ha)].The significant and higher stover yield increased with the application of phosphorus (50kg/ha) might be due to it enhanced the survival and multiplication of microorganisms, improved nitrogen fixation, transport of sugars and better uptake, assimilation of available nutrients by the plants during the entire growth period. Similar results were recorded by **Anand *et al.*, (2022)** in black gram (*Vigna mungo*). Further, higher stover yield was recorded with application of molybdenum (2kg/ha) might due to it increased quantities of micronutrients in cowpea grain and stover, which may have been caused by plant leaves utilizing available micronutrients immediately. Zn, Fe, and Mo concentrations in cowpea grain and stover were raised. Similar findings were recorded by **Dhaliwal *et al.*, (2022)** in table 2.

Harvest index (%)

Treatment with application of treatment 8 [Phosphorus (50kg/ha) + Molybdenum (1.5 kg/ha)] was recorded higher harvest index (49.05 %) which was significantly superior over all other treatments. However, treatment 3 [Phosphorus (30kg/ha) + Molybdenum (2 kg/ha)], treatment 4 [Phosphorus (40kg/ha) + Molybdenum (1kg/ha)], treatment 5 [Phosphorus (40kg/ha) + Molybdenum (1.5 kg/ha)], treatment 6 [Phosphorus (40kg/ha) + Molybdenum (2 kg/ha)], treatment 7 [Phosphorus (50kg/ha) + Molybdenum (1kg/ha)], treatment 9 [Phosphorus (50kg/ha) + Molybdenum (2 kg/ha)] were statistically at par with treatment 8 [Phosphorus (50kg/ha) + Molybdenum (1.5 kg/ha)].The significant and higher harvest index was observed with application of phosphorus(50 kg/ha) might be due to development of extensive root system to extract more water and nutrient from soil **(Pramanik and Singh 2003).** Further higher harvest index was with application of molybdenum (2kg/ha) might be due to improved cell activities, enhanced cell multiplication, enlargement and luxuriant growth. Similar result was reported by **Kokani *et al.*,(2015)** in black gram in table 2.

Economics (Table 3)

The result showed that maximum gross return (94954.8 INR/ha), higher net return 65670.3 INR/ha) and higher benefit cost ratio (2.24) was recorded in treatment 9 [Phosphorus (50kg/ha) + Molybdenum (2 kg/ha)] as compared to other treatments.

Higher net returns, gross returns and B:C ratio was recorded with the application of phosphorus(50kg/ha) might be due to greater increase in grain and straw yield resulted higher benefit cost ratio. These results are in conformity with those observed by **Khanna *et al.*, (2019).**

Table 1: Effect of Phosphorus and Molybdenum on growth attributes of cowpea.

S. No	Treatments	Plant height (cm)	Number of nodules/Plant	Plant dry weight(g)	CGR (g/m^2/day)
1.	Phosphorus 30kg/ha + Molybdenum 1kg/ha	64.54	14.11	18.02	15.94
2.	Phosphorus 30kg/ha + Molybdenum 1.5kg/ha	67.02	14.78	18.63	15.57
3.	Phosphorus 30kg/ha + Molybdenum 2kg/ha	70.89	15.56	20.40	17.79
4.	Phosphorus 40kg/ha + Molybdenum 1kg/ha	69.31	15.33	19.20	16.79
5.	Phosphorus 40kg/ha + Molybdenum 1.5kg/ha	71.86	16.45	20.45	17.03
6.	Phosphorus 40kg/ha + Molybdenum 2kg/ha	73.17	17.44	22.24	18.41
7.	Phosphorus 50kg/ha + Molybdenum 1kg/ha	70.95	16.11	20.25	16.53
8.	Phosphorus 50kg/ha + Molybdenum 1.5kg/ha	72.15	16.89	20.79	17.44
9.	Phosphorus 50kg/ha + Molybdenum 2kg/ha	73.43	17.66	23.07	18.87
10.	Control (25:50:25NPK kg/ha)	61.85	13.33	16.20	14.13
	F-test	S	S	S	S
	Sem±	0.40	0.24	0.28	0.48
	CD at 5%	1.19	0.72	0.85	1.45

Table 2: Effect of phosphorus and molybdenum on yield attributes and yield of cowpea.

S.No Treatment Combination	Number of Pods/plant	Number of Seeds/pod	Seed index (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
1. Phosphorus 30kg/ha + Molybdenum 1 kg/ha	11.17	11.43	11.50	883.13	1090.77	44.77
2. Phosphorus 30kg/ha + Molybdenum 1.5kg/ha	11.57	11.97	12.41	954.67	1158.50	45.18
3. Phosphorus 30kg/ha + Molybdenum 2 kg/ha	13.20	12.70	13.86	1197.60	1273.33	48.45
4. Phosphorus 40kg/ha + Molybdenum 1 kg/ha	11.20	12.47	13.03	1070.33	1190.33	47.54
5. Phosphorus 40kg/ha + Molybdenum 1.5kg/ha	14.17	12.83	14.03	1313.67	1497.07	46.74
6. Phosphorus 40kg/ha + Molybdenum 2 kg/ha	14.47	13.73	15.00	1476.80	1572.57	48.00
7. Phosphorus 50kg/ha + Molybdenum 1 kg/ha	13.93	13.00	13.30	1268.43	1394.97	47.60
8. Phosphorus 50kg/ha + Molybdenum 1.5kg/ha	13.80	13.07	14.09	1430.90	1486.80	49.05
9. Phosphorus 50kg/ha + Molybdenum 2 kg/ha	15.10	14.67	16.03	1550.27	1615.50	48.96
10. Control (25:50:25NPK kg/ha)	10.27	11.67	10.66	756.63	964.73	43.94
F Test	S	S	S	S	S	S
SEm±	0.29	0.39	0.40	30.33	27.96	0.85
CD (P=0.05)	0.88	1.18	1.21	90.12	83.09	2.54

Table 3: Effect of phosphorus and molybdenum on economics of cowpea.

S.No Treatment Combination	Total cost of Cultivation(INR/ha)	Gross returns (INR/ha)	Net returns (INR/ha)	B: C ratio
1. Phosphorus 30kg/ha + Molybdenum 1 kg/ha	24564.5	54296.52	29732.02	1.21
2. Phosphorus 30kg/ha + Molybdenum 1.5 kg/ha	25668.5	58670.4	33001.9	1.28
3. Phosphorus 30kg/ha + Molybdenum 2 kg/ha	26784.5	73383.8	46599.3	1.73
4. Phosphorus 40kg/ha + Molybdenum 1 kg/ha	25814.5	65648.2	39833.7	1.54
5. Phosphorus 40kg/ha + Molybdenum 1.5 kg/ha	26918.5	80616.68	53698.18	1.99
6. Phosphorus 40kg/ha + Molybdenum 2 kg/ha	28034.5	90495.08	62460.58	2.22
7. Phosphorus 50kg/ha + Molybdenum 1 kg/ha	27064.5	77779.56	50715.06	1.87
8. Phosphorus 50kg/ha + Molybdenum 1.5 kg/ha	28168.5	87637.92	59469.42	2.11
9. Phosphorus 50kg/ha + Molybdenum 2 kg/ha	29284.5	94954.8	65670.3	2.24
10. Control (25:50:25 NPK kg/ha)	24844.5	46555.68	21711.18	0.87

CONCLUSION

Based on the above findings it can be concluded that application of Phosphorus 50kg/ha along with Molybdenum 2kg/ha has performed better in growth parameters and yield attributes of cowpea (*Ankur Gomati-VU 89*) and also proven profitable.

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