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Effect of phosphorous and molybdenum on growth and yield of chickpea *(Cicer arietinum* L.) under rainfed condition in Chitrakoot area

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Abstract
A field experiment was conducted at the Rajaula Agriculture Farm, Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot, to study the effect of phosphorus (P) and molybdenum (Mo) on the growth and yield of chickpea (*Cicer arietinum* L.) under rainfed conditions. The experiment involved four levels of phosphorus (0, 30, 40, 50 kg P_2O_5 ha^{-1}) and three levels of molybdenum (0, 1, 2 ppm), resulting in 12 treatment combinations. The soil was moderately fertile with a pH of 7.31, organic carbon of 0.32%, and available phosphorus and molybdenum levels of 18.32 kg ha^{-1} and 3.8 ppm, respectively. The results indicated that the combined application of phosphorus and molybdenum significantly enhanced plant height, branch number, and yield parameters. The maximum plant height (58.9 cm), number of branches (13.9), number of pods per plant (55.9), and number of seeds per plant (53.7) were observed in the M_2P_3 treatment (2 ppm Mo + 50 kg P_2O_5 ha^{-1}), compared to the control (M_0P_0), which recorded minimum values of 42.3 cm, 11.4 branches, 38.2 pods, and 32.8 seeds per plant. Seed yield also improved, with the highest yield (17.8 q ha^{-1}) recorded in the M_2P_3 treatment, significantly higher than the control (12.3 q ha^{-1}). These findings suggest that the combined application of phosphorus and molybdenum enhances chickpea growth and yield under rainfed conditions in this region.

Keywords: Chickpea, molybdenum, phosphorus, yield, growth

Introduction
India is the largest producer and consumer of pulses in the world. Among the pulses, chickpea is the most important grown inevery part of India. It is largest produced food legume in South Asia. Chickpea (*Cicer arietinum* L.) is a major legume crop cultivated for its edible seeds legume of the genus *Cicer*, Tribe *Cicereae*, family *Fabaceae* (*leguminaceae*), and subfamily *Papilionaceae*. It provide protein rich diet to the vegetarian of the Indian and complement the stable cereals in the diets with proteins, essential amino acids, vitamins and minerals (Pingoliya *et al.* 2013) [16].

Chickpea solely contributes nearly 50% of the Indian pulse production. States like Maharashtra (25.97% contribution to national production), Madhya Pradesh (18.59%), Rajasthan (20.65%), Gujarat (10.10%) and Uttar Pradesh (5.64%) are major chickpea producing states of India. In Madhya Pradesh chickpea occupies 21.08 lakh ha area, with a production of 30.95 lakh tonnes registering the productivity of 14.68 q/ha (DES 2023, MOAF&W, GoI).

They contain 22- 24% protein, which is almost twice the protein in wheat & thrice that of rice (Shukla *et al.* 2013) [22] and carbohydrate (61.51%), fat (4.5%) and relatively free from anti nutritional factors. Chickpea is rich in protein content (20.47 g/100 g), carbohydrate (62.95 g/100 g), fibre (12.2 g/100 g), phosphorous (252 mg/l00 g), high amount of minerals such as calcium (57 mg/100 g), magnesium (79 mg/100 g), iron (4.31 mg/l00 g) and zinc (15 mg/100 g), low in fat content and most of it is polyunsaturated (Wallace *et al.* 2016) [29]. It is originated in south eastern turkey (Redden *et al.* 2007) [18]. Chickpea as a legume crop plays a significant role in improving soil fertility by fixing the atmospheric nitrogen (Balai *et al.* 2017) [3]. Phosphorus (P) is an essential nutrient of numerous vital plant structural compounds. Phosphorus is one of the essential nutrients for legume growth and BNF (Mhango *et al.,* 2008). Phosphorus deficiency can limit nodule number, leaf area, and biomass and grain development in legumes.

Symbiotic nitrogen fixation has a high P demand because the process consumes large amounts of energy (Schulze *et al.*, 2006) [21] and energy generating metabolism strongly depends upon the availability of P (Plaxton, 2004) [17]. P fertilization stimulates root growth, photosynthesis and increases hydraulic conductibility of roots. Phosphorus is used in numerous molecular and biochemical plant processes, particularly in energy acquisition, storage and utilization (Fageria and Baligar, 2017) [6].

Legumes are heavy feeder of phosphorus and less responsive to nitrogen because of their capacity to meet their own nitrogen requirement through symbiotic fixation (Kumar *et al.* 2016) [11]. Phosphorus is connected with some particular plant growth factors that are root development, vigorous stem, enhanced flower formation and seed production, earlier and more uniform crop maturity, increase nitrogen fixing capacity of legumes, improvement in crop quality and resistance to plant diseases (Rehan *et al.* 2018) [19].

Molybdenum is required to synthesize the nitrate reductase enzyme of nitrogenase. It plays an important role in legumes for the fixation of atmospheric nitrogen in the symbiotic relationship with rhizobium (Roy *et al.,* 2006) [20]. The availability of molybdenum in the soil increases with increasing pH from neutral. Although, molybdenum availability is less in acidic conditions. Mahlar (2005) reported that a rate of 1 pound (0.45 kg) per acre of molybdenum should apply to the soil at a pH less than 5.7 and seed treatment with 3.5 g of sodium molybdate having beneficial in chickpea. Ahlawat *et al.* (2007) reported that chickpea growing under molybdenum deficient soil leads to a reduced number of flowers, failure to flower opening, reduced the size of the seeds, and affects the maturity of fruits. Therefore, the present investigation was to evaluate boron and molybdenum's effect on the growth and yield of chickpea crops.

Method and materials

Experimental Sites

The experiment was carried out at Rajaula Agriculture farm, Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya Chitrakoot, Satna (M.P.) which lies in the semi- arid and sub-tropical region of Madhya Pradesh between 25.148°North latitude and 80.855° East longitude. The altitude of town is about 190-210 meter above mean sea level.

Soil Characteristics

Before starting the experiment, a composite soil sample was taken from the experimental plots with the help of a soil auger up to 0-30 cm depth to determine the initial physico- chemical properties of the soil.

Table 1: Chemical properties of the Experimental Soil

S. No.	Parameters	Results	Method Employed
1	pH (1:2.5 soil water suspension ratio)	7.31	Glass electrode, pH meter
2	Organic Carbon (%)	0.32	Wet Oxidation Method (Walkley and Black's method 1934) [28]
3	Total Nitrogen ($kgha^{-1}$)	97.5	Kjeldahl Method (Subbiah and Asija, 1956) [24]
4	Available Phosphorus ($kg\ P_2O_5ha^{-1}$)	18.32	Colorimetric method (Olsen *et al.* 1954) [13]
5	Available Potash ($kg\ K_2Oha^{-1}$)	296.53	Flame photometric method (Toth and Price, 1949)
6.	Available Molybdenum (ppm)	3.8	Dithiol Method (Grigg, 1953) [7]

Experimental details

The experiment was conducted with 4 levels of Phosphorous (0, 30, 40, 50 kg ha^{-1}) plant growth and 3 levels of Molybdenum (0, 1, 2 ppm ha^{-1}) of 12 treatment combination as indicated below.

Table 2: Detail of the treatment combinations

Symbol	Treatment Combinations	Details of Treatment
T_1	M_0P_0	Control
T_2	M_0P_1	Mo @ 0 ppm + P_2O_5 @ 30 kg ha^{-1}
T_3	M_0P_2	Mo @ 0 ppm + P_2O_5 @ 40 kg ha^{-1}
T_4	M_0P_3	Mo @ 0 ppm + P_2O_5 @50 kg ha^{-1}
T_5	M_1P_0	Mo @ 1 ppm + P_2O_5 @ 0 kg ha^{-1}
T_6	M_1P_1	Mo @ 1 ppm + P_2O_5 @ 30 kg ha^{-1}
T_7	M_1P_2	Mo @ 1 ppm + P_2O_5 @ 40 kg ha^{-1}
T_8	M_1P_3	Mo @ 1 ppm + P_2O_5 @ 50 kg ha^{-1}
T_9	M_2P_0	Mo @ 2 ppm + P_2O_5 @ 0 kg ha^{-1}
T_{10}	M_2P_1	Mo @ 2 ppm + P_2O_5 @ 30 kg ha^{-1}
T_{11}	M_2P_2	Mo @ 2 ppm + P_2O_5 @ 40 kg ha^{-1}
T_{12}	M_2P_3	Mo @ 2 ppm + P_2O_5 @ 50 kg ha^{-1}

Crop Husbandry

The field was prepared by ploughing with a tractor drawn disc plough by cross harrowing and planking. After through mixing organic manures or chemical fertilizer and leveling of soil surface of each experimental plot. After the layout of experimental plot, the fertilizers were weighed and applied in the plots and thoroughly mixed with soil. As per the experimental recommended doses of Nitrogen and Potassium were applied to all the plots. Phosphorous and molybdenum were applied as per treatment in the plots. The seed sowing was done on 23th Nov. 2021. The pre-sowing irrigation was given to entire experimental field. Apart for pre sowing irrigation, two irrigation were given at pre-flowering and pod formation stages.

Statistical analysis

The growth parameters and yields were recorded and analyzed as per Gomez and Gomez (1984) the tested at 5% level of significance to interpret the significant differences.

Results and Discussion

Growth parameters

Plant height increased with the combined use of phosphorous and molybdenum at any growth stages of chickpea. The minimum plant height (cm) were noted 13.6, 21.1 and 42.3 cm at 30, 60 and 90 DAS in $M_0 \times P_0$ interaction. The maximum plant height (cm) were noted 18.7, 24.6 AND 58.9 cm at 30, 60 and 90 DAS in $M_2 \times P_3$ interaction. Similar findings were reported by Tahir *et al.*, (2011) [25], Kumar *et al.* (2016) [11] and Yadav *et al.* (2022) [30]

The minimum no. of branches were noted 2.1, 4.0 and 11.4 at 30, 60 and 90 DAS in $M_0 \times P_0$ interaction. The maximum no. of branches were noted 2.6, 5.8 and 13.9 at 30, 60 and 90 DAS in $M_2 \times P_3$ interaction. Similar findings were reported by Tak *et al.*, (2012) [26], Azizi *et al.* (2017) [2] and Chandra *et al.* (2020) [4]

Table 3: Effect of different treatment combination on growth parameters of chickpea

Treatments	Plant height (cm)			
	30 DAS	30 DAS	60 DAS	90 DAS
T_1	13.6	2.1	4.0	11.4
T_2	14.2	2.1	4.1	11.6
T_3	15.6	2.2	4.5	12.2

T_4	16.1	2.3	4.6	12.5	22.8	49.7
T_5	14.8	2.1	4.3	11.8	21.9	45.3
T_6	16.6	2.3	4.7	12.8	23.0	50.2
T_7	17.5	2.4	5.1	13.3	23.6	51.7
T_8	18.3	2.5	5.5	13.7	24.2	56.2
T_9	15.1	2.2	4.4	12.0	22.2	46.8
T_{10}	17.1	2.3	4.9	13.1	23.3	52.6
T_{11}	17.9	2.4	5.3	13.5	23.9	55.5
T_{12}	18.7	2.6	5.8	13.9	24.6	58.9
S.E(m)±	**0.03**	**0.003**	**0.012**	**0.018**	**0.024**	**0.109**
C.D. at 5%	**NS**	**NS**	**0.037**	**0.054**	**0.073**	**0.328**

Yield attributes and yield

No. of pod per plant significantly increased with the combined use of phosphorous and molybdenum. The minimum no. of pod per plant were noted 38.2 at harvest stage in $M_0 \times P_0$interaction. The maximum no. of pod per plant were noted 55.9 at harvest stage in $M_2 \times P_3$interaction. No. of seed per plant significantly increased with the combined use of sulphur and molybdenum. The minimum no. of seed per plant were noted 32.8 at harvest stage in $M_0 \times P_0$interaction. The maximum no. of seed per plant were noted 53.7 at harvest stage in $M_2 \times P_3$interaction. Seed Index increased with the combined use of phosphorous and molybdenum but the increase were non-significant. The minimum seed index were noted 32.5 gm at harvest stage in $M_0 \times P_0$ interaction. The maximum seed index were noted 36.5 gm at harvest stage in $M_2 \times P_3$interaction. Similar findings were reported by Khan *et al.* (2021) [10], Pal *et al.*, (2021) [14] and Singh and Pradhan (2023) [23]

Seed yield significantly increased with the combined use of phosphorous and molybdenum. The minimum seed yield were noted 12.3 q ha^{-1}at harvest stage in $M_0 \times P_0$interaction. The maximum seed yield were noted 17.8 q ha^{-1} at harvest stage in $M_2 \times P_3$interaction.Similar findings were reported by Valenciano *et al.*, (2011) [27], Pegoraro *et al.*, (2018) [15] and Choudhary *et al.*, (2023) [5]

Table 4: Effect of different treatment combination on yield attributes and yield of chickpea

Treatments	Combinations	No. of pod plant^{-1}	No. of seed plant^{-1}	Seed index (g)	Seed yield (q ha^{-1})
T_1	M_0P_0	38.2	32.8	32.5	12.3
T_2	M_0P_1	40.3	35.4	32.8	12.9
T_3	M_0P_2	45.6	41.2	34.2	14.2
T_4	M_0P_3	46.7	42.9	34.8	14.7
T_5	M_1P_0	42.5	37.8	33.4	13.5
T_6	M_1P_1	47.8	44.7	35.1	15.2
T_7	M_1P_2	50.2	48.5	35.6	16.1
T_8	M_1P_3	53.7	51.4	36.2	17.1
T_9	M_2P_0	44.5	39.4	33.9	13.9
T_{10}	M_2P_1	48.3	46.3	35.3	15.7
T_{11}	M_2P_2	52.3	49.6	35.9	16.6
T_{12}	M_2P_3	55.9	53.7	36.5	17.8
S.E(m)±		0.111	0.136	0.029	0.036
C.D. at 5%		0.328	0.400	NS	0.105

Conclusion

The study concludes that the combined application of phosphorus and molybdenum significantly enhances the growth and yield of chickpea under rainfed conditions. Phosphorus levels up to 50 kg P_2O_5 ha^{-1} and molybdenum up to 2 ppm positively influenced plant height, number of branches, pods, and seeds per plant, leading to higher productivity. The treatment combination of 50 kg P2O5 ha^{-1} and 2 ppm molybdenum ($_{M2P3}$) proved to be the most effective, resulting in the highest seed yield of 17.8 q ha^{-1}. These results indicate that phosphorus and molybdenum play a critical role in maximizing chickpea productivity, especially under rainfed conditions where nutrient management is crucial. Therefore, the use of these nutrients at the optimal levels can be recommended to improve chickpea production in similar agro-climatic regions.

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