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Effect of Molybdenum Nutrition on Different Growth and Root Parameters of Garden Pea (*Pisum sativum* L.)

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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

The present investigation was conducted at the Department of Agronomy Farm, R.S.M. (P.G.) College, Dhampur, Bijnor, Uttar Pradesh, India, during the *rabi* season from November 2024 to April 2025 to study the effect of molybdenum nutrition on the growth and root parameters of garden pea (*Pisum sativum* L.). The experiment was laid out in a Randomized Block Design (RBD) with four replications and comprised six treatments, namely T_1: Control, T_2: RDF (20 - 60 - 40 kg N-P_2O_5-K_2O ha^{-1}), T_3: RDF + Soil application of Mo @ 0.5 kg ha^{-1}, T_4: RDF + Soil application of Mo @ 1.0 kg ha^{-1}, T_5: RDF + Foliar application of Mo @ 1.5 g lit^{-1}, and T_6: RDF + Foliar application of Mo @ 3.0 g lit^{-1}. The results showed that RDF + foliar application of Mo @ 1.5 g lit^{-1}

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(T_5) recorded the maximum plant height, number of leaves per plant, root fresh weight, and root dry weight at both 20 and 40 DAS. This treatment consistently outperformed the control and other molybdenum levels, indicating the beneficial role of foliar-applied molybdenum in enhancing vegetative growth and root development of garden pea. It may therefore be concluded that foliar application of molybdenum @ 1.5 g lit^{-1} along with RDF is the most effective strategy for improving early crop performance in garden pea.

Keywords: Garden pea; root fresh weight; root dry weight; molybdenum.

1. INTRODUCTION

Pulses are rich sources of protein and contributed significantly to correcting malnutrition, particularly in developing countries such as Bangladesh (Singh *et al.,* 2015). Among pulses, pea (*Pisum sativum* L.) holds a unique position, serving both as a pulse crop (field pea) and as a vegetable (garden pea) (Aakash et al., 2023). Garden pea is an important cool-season leguminous vegetable grown widely in regions with cool climates (10 – 18°C), where temperature extremes often limit cultivation.

The genus *Pisum* comprises five species—*P. fulvum, P. abyssinicum, P. sativum, P. humile,* and *P. elatius*—mostly found in the Mediterranean region and West Asia, but only *P. sativum* is cultivated. It is a short-lived, herbaceous annual (2n = 14) that climbs with tendrils. Garden pea, also called table pea, produces bold, wrinkled seeds, generally in green, yellowish, or bluish shades. It is consumed as a fresh, cooked, or processed vegetable (canned, dehydrated, and frozen) and is valued for its high nutritional content. Each 100 g edible portion of green pea provides moisture (78 g), protein (6.3 g), carbohydrates (14.4 g), energy (84 kcal), calcium (26 mg), phosphorus (116 mg), iron (1.9 mg), and vitamin A (640 IU) Thamburaj and Singh (2013) It is particularly rich in protein, lysine, carbohydrates, vitamins (A, C), minerals, dietary fiber, and antioxidants (Nawab et al., 2008). Apart from its nutritional value, pea contributes to soil fertility through biological nitrogen fixation, leaving behind 50–60 kg N ha^{-1} as residual nitrogen for succeeding crops (Negi *et al*., 2006).

Globally, garden pea ranks third among pulse crops after dry bean and chickpea with area 2.66 million ha, production 21.48 million tonnes with productivity 8074.5 kg ha^{-1} FAOSTAT, (2023) Within India, it stands as the third most grown rabi (winter) pulse after chickpea and lentil. India is the second-largest producer of garden pea globally, after China, cultivating it over 0.56 million hectares and production around 5.84 million tonnes, with an average productivity of 10.30 t ha^{-1} (DA&FW, 2021). Vegetable, garden, or green pea is primarily grown during the Rabi season across several states: Karnataka, Madhya Pradesh, Rajasthan, West Bengal, Punjab, Assam, Haryana, Uttar Pradesh, Uttarakhand, Himachal Pradesh, Bihar, and Odisha. Among these, Uttar Pradesh holds the top position, contributing 0.23 million hectares in area and 2.66 million tonnes in production. Meanwhile, states like Jharkhand (21.76 kg ha^{-1}) and Karnataka (17.34 kg ha^{-1}) continue to register comparatively higher productivity levels (DA&FW, 2021).

Nutrient management also affects crop yield because they are crucial for completing the life cycle of the plant and without these, plants are unable to survive and show growth abnormalities, deficiency symptoms and do not reproduce normally (Bhayal et al., 2022). Micronutrients plays an important role in crop growth (Sharma et al., 2023a). Micronutrients are very important to the compost program's goal of increasing sustainable agricultural yields (Sharma et al., 2023b). Integrated approach leads to improvements in soil productivity, sustainability, reclamation, as well as the growth, development, setting, and quality of crops and seeds (Solanki et al., 2023). Foliar application of nutrients improves the plant's capacity to synthesize, store and transport nutrients (Bhayal et al., 2022). Molybdenum (Mo), though required in minute quantities, is a vital micronutrient for plant growth (Krishna et al., 2024). It is an essential component of the enzymes nitrate reductase and nitrogenase, which regulate nitrate assimilation and symbiotic nitrogen fixation, respectively (Mendel & Hänsch, 2002; Kaiser *et al.,* 2005) Deficiency of Mo leads to poor nodulation, reduced nitrogenase activity, nitrate accumulation, impaired protein synthesis, and ultimately stunted growth and lower yields (Meharg, 2012). Legumes such as pea are especially sensitive to Mo deficiency due to their dependence on biological nitrogen fixation. Indian soils are often deficient in micronutrients because of intensive cultivation. More than half of Indian soils show deficiencies in one or more micronutrients, including Mo (Shukla *et al.,* 2014).

Several studies worldwide have confirmed the positive role of Mo in improving garden pea growth and yield. For example, Rabbi *et al.* (2011) reported that the combined application of 20 kg N ha^{-1} and 0.8 kg Mo ha^{-1} in Manipur produced the tallest plants, maximum branches, longest pods, highest number of seeds per pod, and maximum green pod yield (8.06 t ha^{-1}). Similarly, Alam *et al.* (2020) found that 0.6 kg Mo ha^{-1} significantly increased plant height and pod yield, while Mo in combination with zinc produced synergistic effects. "A field study conducted on alkaline calcareous soils reported that seed-treatment and soil application of molybdenum, particularly when combined with rhizobium inoculation, significantly increased effective nodulation, N_2-fixation, nutrient uptake and pod yield of pea; seed treatment was identified as the most effective application method (Hidayatullah *et al*., 2016). Comparable findings in cowpea further confirm the importance of Mo for nodulation, dry matter accumulation, and seed yield (Kumar et al., 2024).

Despite these findings, research on molybdenum nutrition in garden pea under Indian soil conditions remains limited. Since soil properties vary across regions, responses to Mo may differ in acidic, neutral, and alkaline soils. Interactions of Mo with macronutrients (N, P, K) also warrant detailed investigation to develop region-specific nutrient management practices. Such research is particularly relevant for India, where Mo supplementation could enhance yield attributes, nutrient use efficiency, and soil fertility. Therefore, the present study was undertaken with the objective to test the “effect of molybdenum nutrition on growth and root parameters of garden pea”.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at the farm of Department of Agronomy, R.S.M. (P.G.) College, Dhampur, Bijnor, Uttar Pradesh, India during *rabi* season, spanning from November 2024 to April 2025. The farm stands at an elevation of 286 meters above mean sea level (MSL) and is situated at coordinates 29.021°N latitude and 78.508°E longitude. Bijnor is situated in North – Western Plains Agro – climatic Zone in the Uttar Pradesh This region enjoys tropical semi – arid type climate with an average annual rainfall of 964 mm, most of which is received during mid – June to middle of September.

2.2 Planting Material and Treatment Details

The variety Azad Pea – 02 (C10) was used in this study.

2.3 Experimental Design

The experiment was laid out in a Randomized Block Design (RBD) with four replications, comprising 6 treatment and a total of 24 plots. The size of each unit plot was 6.8 × 3.9 m^2. Distance between two treatments and two replication 1 m × 1.5 m. Each gross plot measured 6.8 m × 3.9 m, while the net plot size was maintained at 5.8 m × 2.7 m.

2.4 Fertilizer Application

Urea, single super phosphate (SSP), and muriate of potash (MOP) were utilized to provide nutrients to the field at the rate of 20 kg nitrogen (N), 60 kg phosphorous pentoxide (P_2O_5), and 40 kg potassium oxide (K_2O) $hectare^{-1}$. Entire dose of Urea, SSP and MOP were applied as basal at the time of sowing. In addition to above fertilizer, Molybdenum **(**Mo) also used as basal (0.5 & 1 kg ha^{-1}) and foliar spray (1.5 and 3 g lit^{-1}) as per schedule treatment.

2.5 Statistical Analysis

The observed parameters were subjected to analysis of variance (ANOVA) using Statistical Tool for Agricultural Research (STAR) software (version STAR 2.0.1, IRRI, Los Baños, Philippines), while the significance of differences between treatment mean values was determined using the Least significant difference (LSD) test at 5% level.

Table 1. Details of treatments with their symbols

S No.	Treatment	Symbol
1.	Control	T_1
2.	RDF (20 – 60 – 40 kg N - P_2O_5 - K_2O ha^{-1})	T_2
3.	RDF + Soil application of Mo @ 0.5 kg ha^{-1}	T_3
4.	RDF + Soil application of Mo @ 1.0 kg ha^{-1}	T_4
5.	RDF + Foliar application of Mo @ 1.5 g lit^{-1}	T_5
6.	RDF + Foliar application of Mo @ 3.0 g lit^{-1}	T_6

Note: RDF = Recommended dose of fertilizer, Mo = Molybdenum

3. RESULTS AND DISCUSSION

3.1 Effect on Growth Parameters

3.1.1 Plant height (cm)

At 20 DAS, the tallest plant (6.89 cm) noted in treatment RDF + Foliar application of Mo @ 1.5 g lit^{-1} (T_5) which was at par with RDF (20-40-60 Kg N - P_2O_5 - K_2O ha^{-1}) (T_2), (T_3), RDF + Soil application of Mo @ 1.0 kg ha^{-1} (T_4) and RDF + Foliar application of Mo @ 3.0 g lit^{-1} (T6) but found significantly superior over the rest of the treatments. At 40 DAS, the highest plant height (14.57 cm) noted in treatment RDF + Foliar application of Mo @ 1.5 g lit^{-1} (T_5) which was at par with RDF (20-40-60 Kg N - P_2O_5 - K_2O ha^{-1}) (T_2), RDF + Soil application of Mo @0.5 kg ha^{-1} (T_3), (T_4) and RDF + Foliar application of Mo @ 3.0 g lit^{-1} (T_6) but found significantly superior over the rest of the treatments (Table 2). Rani *et al.* (2023) observed significantly higher plant height in field pea (56.25 cm) with Mo @ 0.5 kg ha^{-1}, which they attributed to improved photosynthetic efficiency and nodulation, supporting the mechanism of increased height in T_5.

3.1.2 Number of leaves $plant^{-1}$

At 20 DAS, the highest number of leaves (7.35 $plant^{-1}$) noted in RDF + Foliar application of Mo @ 1.5 g lit^{-1} (T_5) which was at par with rest of the treatments except control (T_1). The lowest number of leaves was found in control (T_1) (Table 2). The data showed that at 40 DAS, the highest number of leaves (26.1 $plant^{-1}$) noted in RDF + Foliar application of Mo @ 1.5 g lit^{-1} (T_5) which was significantly superior to the rest treatment. Heena *et al.* (2023) found that foliar application of micronutrients enhanced leaf number in garden pea, reporting 41.23 leaves $plant^{-1}$ at 60 DAS.

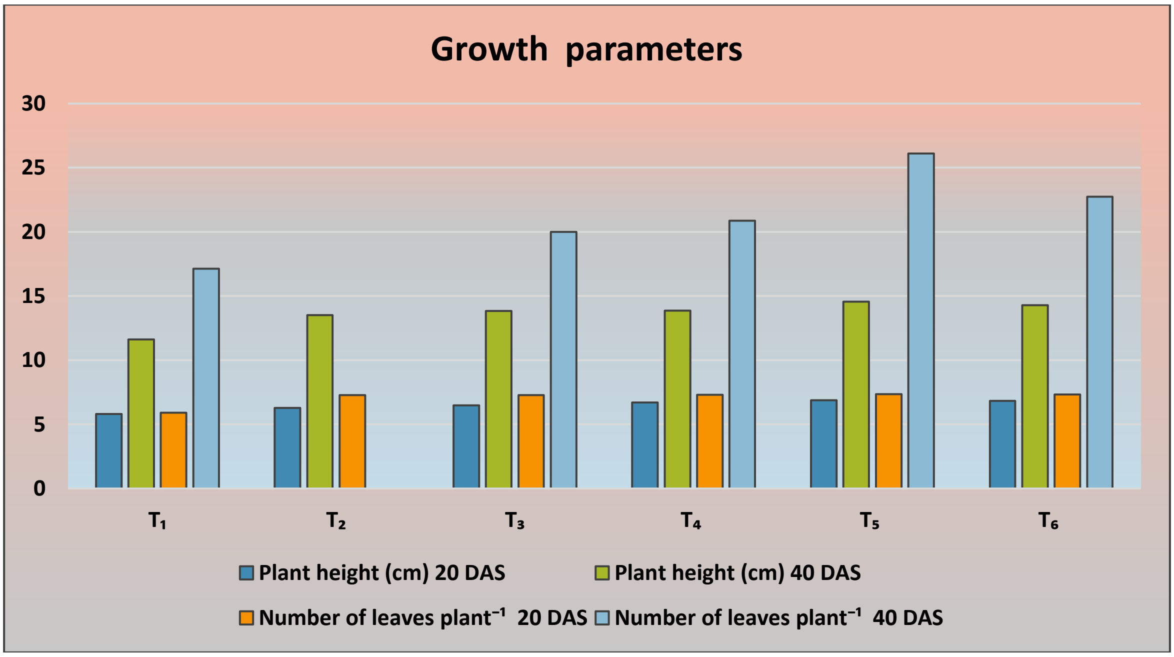

Fig. 1. Effect of molybdenum on growth parameters

Table 2. Effect of molybdenum on growth parameters

Treatment		Plant height (cm)		Number of leaves plant^{-1}	
		20 DAS	40 DAS	20 DAS	40 DAS
T_1	Control	5.82b	11.62b	5.91b	17.12d
T_2	RDF (20-40-60 Kg N -P_2O_5 - K_2O ha^{-1})	6.29b	13.51a	7.27a	18.5cd
T_3	RDF + Soil application of Mo @0.5 kg ha^{-1}	6.48b	13.84a	7.29a	20bc
T_4	RDF + Soil application of Mo @ 1.0 kg ha^{-1}	6.71a	13.86a	7.31a	20.87bc
T_5	RDF + Foliar application of Mo @ 1.5 g lit^{-1}	6.89a	14.57a	7.35a	26.1a
T_6	RDF + Foliar application of Mo @ 3.0 g lit^{-1}	6.84a	14.29a	7.33a	22.73b
	SEm±	0.24	0.60	0.32	0.89
	CD (0.05)	0.71	1.81	0.96	2.68

3.2 Effect on Root Parameters

3.2.1 Root fresh weight (g) plant^{-1}

At 20 DAS, maximum root fresh weight (1.42 g plant^{-1}) noted in treatment RDF + Foliar application of Mo @ 1.5 g lit^{-1} (T_5) which was at par RDF + Soil application of Mo @ 1.0 kg ha^{-1} (T_4) and RDF + Foliar application of Mo @ 3.0 g lit^{-1} (T6) but recorded significantly superior over (T_1), RDF (20-40-60 Kg N - P_2O_5 - K_2O ha^{-1}) (T_2) and RDF + Soil application of Mo @0.5 kg ha $^{-1}$(T_3) (Table 3). At 40 DAS, the highest root fresh weight (0.68 g plant^{-1}) noted in treatment RDF + Foliar application of Mo @ 1.5 g lit^{-1} (T_5) which was at par RDF + Foliar application of Mo @ 3.0 g lit^{-1} (T6) but proved superior to all other treatments. The results are in agreement with Jamali *et al.* (2023) who reported significantly higher root length and nodules per plant in soybean under Mo application, explaining that molybdenum improved nitrogenase activity and root system development.

3.2.2 Root dry weight (g) plant^{-1}

At 20 DAS, maximum root dry weight (0.30 g plant^{-1}) noted in treatment RDF + Foliar application of Mo @ 1.5 g lit^{-1} (T_5) which was significantly superior over (T_1), RDF (20-40-60 Kg N - P_2O_5 - K_2O ha^{-1}) (T_2), RDF + Soil application of Mo @0.5 kg ha $^{-1}$(T_3), RDF + Soil application of Mo @ 1.0 kg ha^{-1} (T_4) and RDF + Foliar application of Mo @ 3.0 g lit^{-1} (T_6). At 40 DAS, more root dry weight (0.51 g plant^{-1}) noted in treatment RDF + Foliar application of Mo @ 1.5 g lit^{-1} (T_5) which was significantly superior to left over treatments (Table 3). These results are in line with Nehra *et al.* (2024) who reported significantly higher root growth and nodulation in cowpea with foliar Mo application, attributing the improvement to enhanced nitrogen utilization and metabolic efficiency.

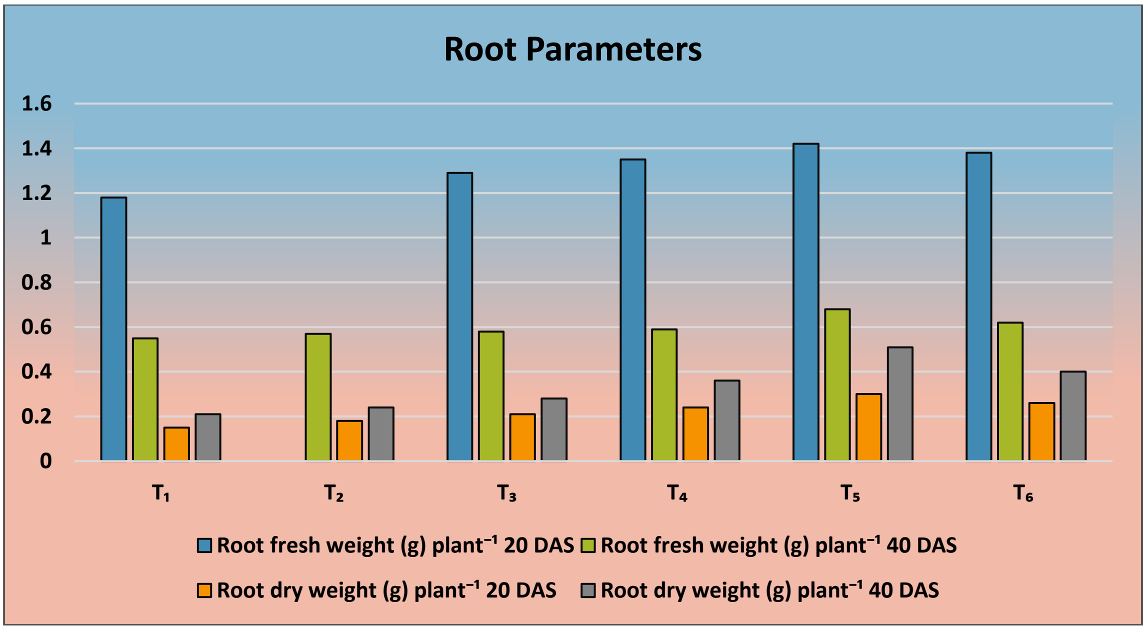

Fig. 2. Effect of molybdenum on root parameters

Table 3. Effect of molybdenum on root parameters

Treatment		Root fresh weight (g) plant^{-1}		Root dry weight (g) plant^{-1}	
		20 DAS	40 DAS	20 DAS	40 DAS
T_1	Control	1.18c	0.55c	0.15e	0.21d
T_2	RDF (20-40-60 Kg N -P_2O_5 - K_2O ha^{-1})	1.25bc	0.57bc	0.18d	0.24cd
T_3	RDF + Soil application of Mo @0.5 kg ha^{-1}	1.29abc	0.58bc	0.21c	0.28c
T_4	RDF + Soil application of Mo @ 1.0 kg ha^{-1}	1.35ab	0.59bc	0.24b	0.36b
T_5	RDF + Foliar application of Mo @ 1.5 g lit^{-1}	1.42a	0.68a	0.30a	0.51a
T_6	RDF + Foliar application of Mo @ 3.0 g lit^{-1}	1.38ab	0.62ab	0.26b	0.40b
	SEm±	0.05	0.02	0.01	0.02
	CD (0.05)	0.14	0.07	0.03	0.05

4. CONCLUSION

The experimental findings revealed that RDF (20-40-60 Kg N -P_2O_5 - K_2O ha^{-1}) + foliar application of Mo @ 1.5 g lit^{-1} (T_5) consistently recorded the highest values for growth parameters including plant height, number of leaves, root fresh weight, and root dry weight at both 20 DAS and 40 DAS.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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