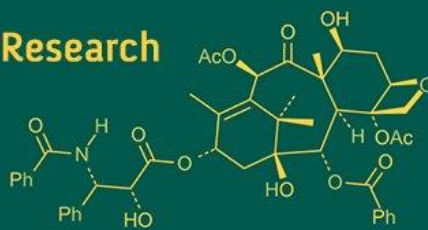


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Response of Molybdenum and Sulphur on Growth and Yield of Sunflower (*Helianthus annuus* L.)

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Abstract

The field experiment was conducted during *kharif* season of 2025 at the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.), India. To study the “Response of Molybdenum and Sulphur on growth and yield of Sunflower (*Helianthus annuus* L.)”. The treatment consists of three levels of Molybdenum (M₁ – 1.3 g/L, M₂ – 1.4 g/L and M₃ – 1.5 g/L) which was foliar spray and Sulphur three (S₁ – 20 kg/ha, S₂ – 40 kg/ha and S₃ – 60 kg/ha). The soil of experimental plot was sandy loamy in texture, nearly neutral in soil reaction (7.3), low in organic carbon (0.71%). Results obtained that application of Molybdenum 1.5 g/L + Sulphur 60 kg/ha (Treatment – 9), recorded with highest plant height (194.99 cm), highest plant dry weight (105.49 g), highest number of seeds/capitulum (379.93), highest test weight (57.59 g), highest seed yield (1.84 t/ha), highest stover yield (3.36 t/ha), highest oil content (49.22 %), harvest index (37.46 %).

Keywords: Sunflower, Molybdenum, Sulphur, growth yield, Foliar spray

Introduction

Sunflower (*Helianthus annuus* L.) is an important oilseed crop of India which is known as the “Champion” of the oil seed crops. In India, sunflowers can be sown during the *kharif* season from the second half of June to mid-July in light soils and until the second half of August in heavy soils.

During the *rabi* season, sunflowers can be sown from September to the end of November. Sunflower seeds can be sown successfully from January to June for flowering during the summer and rainy season. For the best chances of germination, sow seeds individually in 10 cm pots of peat-free, multi-purpose compost. There are two types of sunflowers seed produced, oilseed and confectionery. About 95% of world production is the oil seed type and only 5% the confectionery type.

Sunflower contains appreciable quantities of proteins, vitamins A, B, E & K. In India the sunflower is traditionally cultivated in Karnataka, Maharashtra and Andhra Pradesh. In recent years its cultivation has also been taken up in non-traditional states like Haryana, Punjab, UP, Gujarat, Tamil Nadu, Orissa, MP, and Rajasthan. Among the important sunflower growing states in the country, Karnataka is one where it occupies an area of 9.85 lakh hectares with annual production of 3.62 lakh tones and productivity of 336 kg per hectare. (Shrine *et al.* 2024) ^[21]

India is one of the world's leading producers of oilseeds (Lokesh and Dandoti 2017) ^[7], producing a wide variety of crops such as soybean, rapeseed-mustard, groundnut, sesame, sunflower, castor, etc. The oilseed sector contributed significantly to the agricultural economy of the country providing a source of income for millions of farmers and supporting various downstream sectors (Narayan 2016, Sharma 2018, Satishkumar *et al* 2022) ^[12, 19, 18]. The total oilseeds production in India has increased from 18 to 35.90 million tonnes in last three decades reflecting the doubling of production. This increment in production is due to rise in both acreage (19.50%) and productivity (61.73%) during the same time period.

Molybdenum (Mo) belongs among essential microelements. Total Mo content of soil varies from 0.01 to 17.0 mg/kg (Kabata-Pendias 2011) ^[5]. Most agricultural soils contain a relatively low amount of molybdenum by comparison, with an average of 2.0 mg/kg total

molybdenum and 0.2 mg/kg available molybdenum (Mengel and Kirkby 2001) ^[11]. The availability of molybdenum for plant growth is strongly dependent on the soil pH, concentration of adsorbing oxides (e.g. Fe oxides), extent of water drainage, and organic compounds found in the soil colloids. Molybdenum is essential for most organisms and occurs in more than 60 enzymes catalyzing diverse oxidation-reduction reactions in plant metabolism (Zimmer and Mendel 1999) ^[23]. Mo is a constituent of nitrogenase (NA) and nitrate reductase (NR), required for the assimilation of soil nitrates. Therefore, the function of Mo is closely related to plant nitrogen metabolism, and Mo deficiency is manifested as deficiency of plant N (Pollock *et al.* 2002) ^[14].

In plant physiology, molybdenum is biologically inactive on its own. It only becomes catalytically active when it binds to a specific organic molecule to form the Molybdenum Cofactor (Moco). According to foundational plant nutrition literature by Horst Marschner (2002) and extensive biochemical reviews by researchers such as Ralf R. Mendel (2002), this cofactor is required for the activity of a select few, but absolutely critical, plant enzymes Nitrate Reductase. This is the most crucial enzyme for non-leguminous crops like sunflowers. It catalyses the reduction of nitrate—the primary form of nitrogen absorbed from the soil into nitrite. This nitrite is then converted into ammonium and eventually synthesized into amino acids and proteins. Without Mo, this process halts, leading to nitrogen starvation even if the soil is rich in nitrogen.

Sulphur is crucial for the production of protein, lipids, and vitamins. It contains amino acids and is essential for the creation of proteins. Due to the application of N and P as well as the sources and quantities of S, dry matter production was significantly higher; nevertheless, greater dry matter production was seen with the application of gypsum. High crop yields, which result in a higher rate of sulphate removal by crops, and decreased use of Sulphur - containing fertilizers are the main causes of Sulphur deficit. Keeping the above aspects in view, the present investigation “entitled response of Sulphur and foliar application of Nano Urea on growth and yield of sunflower (*Helianthus annuus L.*)”. They established the early mechanisms showing that Sulphur provides the disulphide (-S-S-) bonds necessary for protein linkage and chemically aids the conversion of carbohydrates into oils in seeds (Chopra and Kanwar 1966; Allaway & Thompson 1966) ^[2, 1].

Sulphur shortage is observed mainly due to high crop yield and consequently higher rate of Sulphur removal by crops, and lesser use of Sulphur comprising fertilizers (Messick, 2003) ^[9]. Sulphur is an essential plant nutrient for crop production. For oil crop producers, Sulphur fertilizer is especially significant because oil crop requires more Sulphur than cereal grains. Sulphur is best known for its role in the formation of amino acids methionine (21% S) and cysteine (27% S); synthesis of proteins and chlorophyll oil content of the seeds and nutritious quality of forages (Jamal *et al.* 2005) ^[4]

Materials and Method

This experiment was carried out during *kharif* 2025 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj, (U.P), to check the effect of molybdenum and sulphur on growth and yield of Sunflower. The experimental field soil was sandy loam with less availability of nitrogen.

The experiment was laid out in randomised block design consisting of ten treatment viz T₁ Molybdenum 1.3 g/L + Sulphur 20 kg/ha, T₂ Molybdenum 1.3 g/L + Sulphur 40 kg/ha, T₃ Molybdenum 1.3 g/L + Sulphur 60 kg/ha, T₄ Molybdenum 1.4 g/L + Sulphur 20 kg/ha, T₅ Molybdenum 1.4 g/L + Sulphur 40 kg/ha, T₆ Molybdenum 1.4 g/L + Sulphur 60 kg/ha, T₇ Molybdenum 1.5 g/L + Sulphur 20 kg/ha, T₈ Molybdenum 1.5 g/L + Sulphur 40 kg/ha, T₉ Molybdenum 1.5 g/L + Sulphur 60 kg/ha, T₁₀ N-P-K (80-60-40Kg/ha). Which were replicated thrice. 2.5 kg/ha seed of Sunflower variety *FB-Bhaskar F1 hybrid* the spacing adopted was plant to plant 20 cm and row to 60 cm according to the treatment details and the seeds were drilled at 3-4 cm depth in the net plot area 3m x 3m on 16th August 2025. Sulphur was applied to all of the plots as per the treatments through soil application and Molybdenum (Sodium Molybdate) was diluted with water to given through foliar application.

The observation on growth parameters i.e. Plant height (cm), Plant dry weight (g), Crop growth rate (g/m²/day) and relative growth rate (g/g/day) were recorder whereas yield attributing parameters i.e. Number seeds/capitulum, Test Weight(g), Seed yield (t/ha), Stover yield (t/ha), Oil Content (%) and Harvest Index (%) from the net plot area these observation were recorded. The seed and stover yield were taken for the net plot of 1m² and using this formula (economic yield /Biological yield) x 100 then calculate for 1 ha harvest index is calculated. The recorded data were analysed statically by ANOVA technique.

Result and Discussion

Growth parameters

Plant Height

At 80 DAS, the significant maximum plant height (194.99 cm) was observed in (treatment 9) Molybdenum 1.5 g/l + S 60 kg/ha significant increase in height compared to the control (132.92 cm). Whereas Molybdenum 1.5 g/l + Sulphur 40 kg/ha (183.97cm) +Molybdenum 1.5 g/l + Sulphur 20 kg/ha (177.96cm) Molybdenum 1.4 g/l + Sulphur 60 kg/ha (174.62cm) Molybdenum 1.5 g/l + Sulphur 40 kg/ha (183.97cm) Correspondingly found to be statically at par with (treatment 9) Molybdenum 1.5 g/L + Sulphur 60 kg/ha.

"Increased plant height with K and Mo foliar application may be due to rapid cell elongation in the apical region of the plant. Similar findings were reported by researchers who indicated that exogenous application of S and Mo increased plant height." Pattanayak *et al.* (2016) ^[13]

Plant dry weight

At 80 DAS, the significant maximum Plant dry matter accumulation (105.49g) was observed in (treatment 9) Molybdenum 1.5 g/l + Sulphur 60 kg/ha compared to the control (54.43g). Whereas Molybdenum 1.5 g/l + Sulphur 40 kg/ha (93.2g) Molybdenum 1.5 g/l + Sulphur 20 kg/ha (87.84g) Molybdenum 1.4 g/l + Sulphur 60 kg/ha (79.74g). Correspondingly found to be statically at par with (treatment 9) Molybdenum 1.5 g/l + Sulphur 60 kg/ha. Researching optimal sulphur application under semi-arid conditions.

Sheoran and colleagues found a highly significant positive correlation between sulphur uptake and oil content. They demonstrated that proper sulphur dosage increased seed yield by over 10%, expanded the flower head diameter, and

improved overall dry matter accumulation (Sheoran *et al.* 2016) [20].

Yield parameters

Number of Seeds/Capitulum

At harvest the significant maximum Numbers of Seeds/Capitulum (379.93) was observed in (treatment 9) Molybdenum 1.5 g/l + Sulphur 60 kg/ha compared to the

control (235.79). Whereas Molybdenum 1.5 g/l + Sulphur 40 kg/ha (364.41) + Molybdenum 1.5 g/l + Sulphur 20 kg/ha (338.30) Molybdenum 1.4 g/l + Sulphur 60 kg/ha (321.04). Correspondingly found to be statically at par with (treatment 9) Molybdenum 1.5 g/l + Sulphur 60 kg/ha. These observations corroborate the findings of Stiner *et al.* (2015)

Table 1: Effect of Molybdenum and Sulphur on growth of Sunflower

	Treatments	Plant height (cm)	Plant dry weight (g/plant)
T ₁	Molybdenum 1.3 g/L + Sulphur 20 kg/ha	147.04	57.21
T ₂	Molybdenum 1.3 g/L + Sulphur 40 kg/ha	154.90	59.38
T ₃	Molybdenum 1.3 g/L + Sulphur 60 kg/ha	166.32	65.29
T ₄	Molybdenum 1.4 g/L + Sulphur 20 kg/ha	167.85	71.40
T ₅	Molybdenum 1.4 g/L + Sulphur 40 kg/ha	170.77	75.77
T ₆	Molybdenum 1.4 g/L + Sulphur 60 kg/ha	174.62	79.74
T ₇	Molybdenum 1.5 g/L + Sulphur 20 kg/ha	177.96	87.84
T ₈	Molybdenum 1.5 g/L + Sulphur 40 kg/ha	183.97	93.21
T ₉	Molybdenum 1.5 g/L + Sulphur 60 kg/ha	194.99	105.95
T ₁₀	N-P-K 80-60-40 kg/ha (control)	137.92	54.43
	F - Test	S	S
	S.Em (±)	4.86	2.24
	CD (p = 0.05)	14.43	6.65

Table 2: Effect of Molybdenum and Sulphur on yield of Sunflower

	Treatments	No. of seeds/capitulum	Test weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Oil Content (%)	Harvest index (%)
T ₁	Molybdenum 1.3 g/L + Sulphur 20 kg/ha	257.76	25.00	1.35	2.50	34.26	34.38
T ₂	Molybdenum 1.3 g/L + Sulphur 40 kg/ha	262.74	29.15	1.45	2.58	36.57	34.56
T ₃	Molybdenum 1.3 g/L + Sulphur 60 kg/ha	290.21	33.03	1.49	2.67	40.02	34.71
T ₄	Molybdenum 1.4 g/L + Sulphur 20 kg/ha	295.22	37.02	1.51	2.76	42.37	34.95
T ₅	Molybdenum 1.4 g/L + Sulphur 40 kg/ha	304.90	40.97	1.53	2.88	43.11	35.19
T ₆	Molybdenum 1.4 g/L + Sulphur 60 kg/ha	321.04	45.03	1.56	2.93	44.00	35.37
T ₇	Molybdenum 1.5 g/L + Sulphur 20 kg/ha	338.30	49.06	1.58	3.02	44.68	35.50
T ₈	Molybdenum 1.5 g/L + Sulphur 40 kg/ha	364.41	53.01	1.71	3.11	47.06	35.72
T ₉	Molybdenum 1.5 g/L + Sulphur 60 kg/ha	379.89	57.12	1.84	3.36	49.22	37.46
T ₁₀	N-P-K 80-60-40 kg/ha (control)	235.74	23.04	1.19	2.20	33.51	33.24
	F - Test	S	S	S	S	S	S
	S.Em (±)	8.97	3.64	0.52	0.3	1.21	1.24
	CD (p = 0.05)	26.64	3.28	3.28	8.94	3.60	3.69

Test weight (g)

The significant maximum Test weight (57.79g) was observed in (treatment 9) Molybdenum 1.5 g/l + Sulphur 60 kg/ha compared to the control (23.04g). Whereas Molybdenum 1.5 g/L + Sulphur 40 kg/ha (53.01g) + Molybdenum 1.5 g/l + Sulphur 20 kg/ha (49.16g) Molybdenum 1.4 g/l + Sulphur 60 kg/ha (45.32g). Correspondingly found to be statically at par with (treatment 9) Molybdenum 1.5 g/L + Sulphur 60 kg/ha. These observations corroborate the findings of Rahul *et al.* (2021).

Seed yield (t/ha)

It is observed among the various treatments, regarding seed yield (t/ha) in (treatment 9) Molybdenum 1.5 g/l + Sulphur 60 kg/ha was recorded significant highest yield (1.84 t/ha) and least was recorded in control (1.19 t/ha). These observations corroborate the findings of Choudhary *et al.* (2016) [6].

Stover yield (t/ha)

It is observed among the various treatments, regarding stover yield (t/ha) in (treatment 9) Molybdenum 1.5 g/l + Sulphur 60 kg/ha was recorded was significantly highest stover yield (3.36 t/ha) and least was recorded in control

(2.20 t/ha) these observations corroborate the findings of Hassan, B. (2015) [3]

Oil content (%)

The data revealed that significantly maximum oil content (37.73%) was observed in (treatment 9) Molybdenum 1.5 g/l + Sulphur 60 kg/ha. Highest oil content was obtained with the application of Sulphur (60kg/ha) might be due to the application of Sulphur being a constituent of acetyl Co-A, is converted into maloyl Co-A in fatty acid synthesis and for this conversion an enzyme, thiokinase is involved. These observations corroborate the findings of Rani *et al.* (2009) [17].

Harvest index (%)

The significant highest harvest index was recorded in (treatment 9) Molybdenum 1.5 g/l + Sulphur 60 kg/ha (37.46%) these observations corroborate the findings of Ramamoorthy *et al.* (2021) [16].

Conclusion

It is concluded that application of Molybdenum 1.5g/l combination with Sulphur 60 kg/ha proved to be the most

effective treatment for Sunflower. In the above study recorded significantly highest yield (1.84 t/ha) and B:C (2.43) in Sunflower among all tested groups. However, as these results are derived from a single-season study, further multi-locational or multi-seasonal trials are necessary to validate these findings before making a generalized recommendation to farmers."

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Conclusion

Authors have declared that no competing interests exist

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