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Role of Sulphur and Molybdenum in Improving Nutritional Quality and Profitability of Cowpea (*Vigna unguiculata* 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

A field experiment was carried out in the summer of 2020 at the College Farm of N. M. College of Agriculture, Navsari Agricultural University, located in Navsari, Gujarat. The objective was to assess the role of sulphur and molybdenum in improving nutritional quality and profitability of cowpea (*Vigna unguiculata* L.) The soil at the experimental site was clayey in texture and slightly alkaline in reaction. The study included nine different treatment combinations. T_1 - RDF, T_2 - 25 kg S/ha, T_3 - 50 kg S/ha, T_4 -500 ppm foliar Mo, T_5 -0.5 g Mo/kg seed, T_6 - 25 kg S + 500 ppm Mo, T_7 - 25 kg S + 0.5 g Mo/kg seed, T_8 - 50 kg S + 500 ppm Mo and T_9 -50 kg S + 0.5 g Mo/kg seed. All treatments

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were uniformly supplied with the recommended dose of fertilizers (RDF) at 20-40-00 kg NPK/ha. Sulphur was incorporated into the soil at the time of sowing, whereas molybdenum was applied as a foliar spray at 30 days after sowing (DAS) using 250 L of water per hectare. The experiment followed a randomized block design (RBD) with three replications. Among the treatments, T_6 (25 kg S + 500 ppm Mo) recorded a significant improvement in quality parameters, as well as in the nitrogen, phosphorus and potassium content and uptake by both seed and haulm. Post-harvest soil analysis revealed that the availability of nitrogen, sulphur and molybdenum was influenced by the different sulphur and molybdenum treatments. However, soil phosphorus and potassium levels after harvest were not significantly affected by any of the treatments.

Keywords: Cowpea; economics; fertilization; content and uptake; molybdenum; sulphur.

1. INTRODUCTION

Cowpea, sometimes called *lobia* (*Vigna unguiculata* L.), is a multipurpose legume that is used for grain, vegetables, fodder and to increase soil fertility. Due to its ability to withstand drought and its minimal input requirements, cowpea is primarily cultivated in arid and semi-arid regions and plays a vital role as a crop during the kharif and summer seasons in India (Reddy et al., 2023; Banerjee et al., 2021). Similar to other pulse crops, cowpea enhances soil fertility through biological nitrogen fixation and the incorporation of organic matter, facilitated by *Rhizobium leguminosarum* (Xavier *et al*., 2023). Despite its agronomic advantages, India continues to experience a shortfall in pulse production. According to the Ministry of Agriculture, total pulse output was estimated at 234 lakh tonnes in 2023–2024, down from 261 lakh tonnes in 2022–2023. To bridge the gap between supply and demand, India has been importing an average of 25 lakh tonnes of pulses annually, with forecasts indicating over 4.5 million tonnes of tur, urad and masoor imports in 2024. In response, the government has extended the duty-free import policy for these pulses until 2025 to help stabilize domestic availability and control prices (Anon., 2023).

Cowpea, known for its high nutritional value and extensive cultivation in tropical and subtropical regions, plays a significant role in ensuring food and nutritional security. It also contributes to improved soil fertility through atmospheric nitrogen fixation (Silva et al., 2025). Despite its potential, cowpea productivity in India remains sub optimal, primarily due to imbalanced fertilization and widespread deficiencies of key secondary and micronutrients particularly sulphur (S) and molybdenum (Mo). Sulphur is an essential secondary nutrient involved in protein synthesis, chlorophyll production and various enzymatic activities. Molybdenum, on the other hand, functions as a crucial cofactor for enzymes like nitrogenase and nitrate reductase, thereby influencing nodulation and nitrogen fixation processes. Proper and balanced application of these nutrients can significantly boost legume yield and overall productivity (Dhaliwal *et al.*, 2022).

In this context, the present study was undertaken to evaluate the effects of sulphur and molybdenum, applied individually and in combination through soil application, seed treatment and foliar spray on the yield, nutrient content, uptake and economics of cowpea under the agro-climatic conditions of south Gujarat.

2. MATERIALS AND METHODS

A field experiment was conducted during the summer season of 2020 at the College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari, to study the influence of sulphur and molybdenum fertilization on cowpea (*Vigna unguiculata* L.). The experimental soil was clayey in texture with a slightly alkaline reaction. The study comprised nine treatment combinations: T_1 – RDF, T_2 – 25 kg S/ha, T_3 – 50 kg S/ha, T_4 – 500 ppm foliar Mo, T_5 – 0.5 g Mo/kg seed, T_6 – 25 kg S + 500 ppm Mo, T_7 – 25 kg S + 0.5 g Mo/kg seed, T_8 – 50 kg S + 500 ppm Mo, and T_9 – 50 kg S + 0.5 g Mo/kg seed. All treatments received a common dose of 20:40:00 NPK kg/ha. Sulphur was applied at sowing, while foliar application of molybdenum (500 ppm) was carried out at 30 DAS using 250 L/ha of water.

The experiment was conducted using a randomized block design (RBD) with three replications. Land preparation involved ploughing, harrowing and planking to achieve a fine tilth suitable for sowing. Cowpea variety GC-4 was planted on 18th February 2020 at a seed rate of 25 kg/ha, with a sowing depth of 3–4 cm and spacing of 45 × 10 cm. To ensure uniform germination, irrigation was applied immediately after sowing. The required amounts of farmyard manure (FYM) and bio-compost were calculated based on the gross plot area. Urea, single superphosphate, gypsum and ammonium molybdate were weighed according to the treatment specifications, thoroughly mixed with the organic amendments and manually applied in pre-opened furrows. Weed control was carried out using standard herbicide practices, and plant protection measures were implemented as needed. The crop was harvested on 10 May 2020.

The nitrogen content in cowpea seeds was estimated using the micro-Kjeldahl method, as described by Jackson (1973). Chemical analyses for nitrogen, phosphorus and potassium content in both seed and haulm, as well as their uptake and the post-harvest available N, P and K status of the soil, were conducted using standard procedures. Nitrogen was determined using the modified Kjeldahl method, phosphorus by the wet digestion (diacid) method followed by the vanado-molybdo phosphoric acid yellow colorimetric technique and potassium through the flame photometric method (Jackson, 1973). Available sulphur in the soil was analyzed by extracting the sample with 1% NaCl and estimating it using the turbidimetric method (Williams and Steinbergs, 1959). Available molybdenum was extracted using acid ammonium oxalate and estimated by the colorimetric method (Chapman and Pratt, 1961). Experimental data were subjected to statistical analysis as per the procedures outlined by Panse and Sukhatme (1985). Analysis of variance (ANOVA) was used to assess the significance of treatment effects on cowpea performance. Protein content (%), protein yield (kg/ha), and nutrient uptake by seed and haulm were calculated using the following formulas:

$$\text{Protein content (\%)} = \text{Nitrogen content (\%)} \times 6.25$$

$$\text{Protein yield (kg/ha)} = \frac{\text{Protein content in grain (\%)} \times \text{Grain yield (kg/ha)}}{100}$$

$$\text{Uptake (kg/ha)} = \frac{\text{Content (\%)} \times \text{Yield(kg/ha)}}{100}$$

3. RESULTS AND DISCUSSION

Quality parameters: Seed yield (928 kg/ha) and haulm yield (2280 kg/ha) were also significantly increased with T_6 (25 kg S + 500 ppm Mo), but were statistically comparable to yields under T_2, T_4, T_7, T_8 and T_9. Based on the data provided in Table 1, the magnitude of the protein content of cowpea seed indicated that different treatments of sulphur and molybdenum fertilization improve protein content significantly. However, treatment T_6 (25 kg S + 500 ppm Mo) contributed to higher protein content (24.01 %) and statistically at par with treatment T_2, T_4, T_5, T_7, T_8 and T_9. Significantly higher protein yield of cowpea (223.24 kg/ha) was recorded under treatment of T_6 and was at par with the treatments of T_7, T_8 and T_9.

Sulphur plays an important role in the synthesis of amino acids, proteins, vitamins, and coenzymes. Recent studies indicate that lack of sulphur to meet plant requirements may reduce not only yields but also the quality of grain legumes (reduction of cysteine and methionine) by changing the gene expression of storage proteins in developing seeds. Molybdenum is also important for sulphur metabolism, so it can have a positive impact on the biological value of protein (Głowacka *et al.* (2019).

3.1 N, P and K Content in Cowpea Seed and Haulm

Nitrogen content in cowpea (%): Data revealed that the highest nitrogen content in seed (4.46%) was recorded under treatment T_6, which was statistically at par with T_7, while the lowest (2.35%) was observed under T_1. Similarly, nitrogen content in haulm was significantly higher with T_6 (0.70%), closely followed by T_7 and T_8, whereas the minimum (0.57%) was noted under T_1.

P_2O_5 content in cowpea (%): Data presented that P_2O_5 content in seed was found significantly higher under the treatment T_6 (2.10%) but remained at par with treatments T_7, T_8, T_9 and T_2. While in case of haulm, significantly higher P_2O_5 content in haulm was recorded with treatment T_6 (0.26%) but remained at par with T_4, T_5, T_7, T_8 and T_9. While the lowest P_2O_5 content in seed (1.47%) and haulm (0.19%) registered under T_1 (RDF).

K_2O content in cowpea (%): K_2O content in seed was found significantly higher under the treatment T_6 (1.35%) but remained at par with treatments T_7, T_8, T_9 and T_4. While there was no significant different found in case of K_2O content in haulm.

This increase might be due to the fact that sulphur and molybdenum being essential plant nutrients promote nodulation, better root formation being an essential plant nutrient which in turn activated higher absorption of nitrogen, phosphorus and potash from soil. The data present in Table 1 revealed that significantly higher content of N, P_2O_5, K_2O were observed under T_6 (25 kg S + 500 ppm Mo) while lower content found in T_1 (RDF). Similar findings were also reported by Venkatesh *et al.* (2006) and Reddy *et al*. (2023).

3.2 N, P and K Uptake in Cowpea Seed and Haulm

Nitrogen uptake by cowpea (kg/ha): Significantly the highest nitrogen uptake by seed was recorded with treatment T_6 (41.19 kg/ha) but remained at par with treatments T_7 (37.94 kg/ha). In the case of haulm, significantly higher nitrogen uptake by haulm was recorded with treatment T_6 (16 kg/ha), which remained at par with T_7 and T_8. The lowest nitrogen uptake by haulm registered under T_1 (10.46 kg/ha).

P_2O_5 uptake by cowpea (kg/ha): P_2O_5 uptake by seed (19.47 kg/ha) and haulm (5.94 kg/ha) was significantly higher under treatment T_6 but remained statistically at par with treatments T_7, T_8, and T_9.

K_2O uptake by cowpea (kg/ha): K_2O uptake by seed was significantly affected by different levels of sulphur and molybdenum fertilization. Significantly the highest K_2O uptake by seed (12.52 kg/ha) and haulm (20.12 kg/ha) was recorded with T_6 treatment and remained at par with treatments T_7, T_8 and T_9.

It might be due to the fact that sulphur and molybdenum play vital role in growth and yield of cowpea and also increase N, P_2O_5 and K_2O content in cowpea. Hence, it is obvious fact that application of sulphur and molybdenum improved overall uptake of N, P_2O_5 and K_2O by seed and haulm. Similar findings were also reported by Venkatesh *et al.* (2006) and Reddy *et al.* (2023).

3.3 Soil Property Status

The mean data pertaining to available N, P_2O_5 and K_2O status after harvest of cowpea are presented in Table 3.

Available N in soil after harvest (kg/ha): Available N in soil was significantly highest recorded with treatment T_7 (266.82 kg/ha). While significantly lower soil N was recorded in treatment T_1 (RDF).

Available P_2O_5 in soil after harvest (kg/ha): Non-significant effect of different treatments of sulphur and molybdenum fertilization treatments on available phosphorus of soil after harvest of cowpea. Data indicated that P_2O_5 content in soil after harvest was found non-significant. The highest P_2O_5 content in soil after harvest was recorded in treatment T_3 (44.61 kg/ha) while lowest registered in treatment T_1 (41.04 kg/ha).

Available K_2O in soil after harvest (kg/ha): The data indicated that non-significantly the highest available K_2O of soil after harvest of the crop was recorded from treatment T_8 (344.29 kg/ha) while lowest registered in treatment T_7 (335.09 kg/ha).

Similar result also reported by Reddy *et al*. (2023) and Saiyad et al. (2017). This might be due to molybdenum unique role in enhancing nitrogen fixation. Application of S and Mo fertilization treatments in available P_2O_5 and K_2O in the soil after harvest of crop were found non significant.

Available Sulphur in soil after harvest (ppm): Data indicated that available sulphur in soil was significantly affected by different levels of sulphur and molybdenum fertilization. Significantly the highest available sulphur was recorded with T_8 (10.54 ppm) and remained at par with treatments T_9, T_7, T_2 and T_3.

Available molybdenum in soil after harvest (ppm): Available molybdenum in soil was significantly affected by different levels of sulphur and molybdenum fertilization. Significantly the highest available molybdenum was recorded with T_5 (0.047 ppm) and remained at par with treatments T_4, T_6 and T_7.

The increased S and Mo content might be due to increased concentration of sulphur and molybdenum in soil solution with application of increasing levels of sulphur and molybdenum Kumar and Umesha (2023), Nehra *et al*. (2024) and Markam *et al*. (2025).

Economics: The data on economics pertaining to gross return, net return and benefit cost ratio (BCR) under different sulphur and molybdenum fertilization treatments The data revealed that maximum gross return of Rs. 55521.33/ha was realized with T_6 (25 kg S + 500 ppm Mo),

Table 1. NPK content in seed and haulm of Cowpea as influenced by different levels of sulphur and molybdenum treatments

Treatments	Seed yield (kg/ha)	Haulm yield (kg/ha)	Quality parameters		N content (%)		P content (%)		K content (%)	
			Protein content (%)	Protein yield (kg/ha)	Seed	Haulm	Seed	Haulm	Seed	Haulm
T_1 : RDF	785	1843	18.29	143.22	2.35	0.57	1.47	0.19	1.11	0.74
T_2 : 25 kg S/ha	861	2020	21.53	185.39	2.92	0.59	1.86	0.23	1.24	0.84
T_3 : 50 kg S/ha	821	1916	21.10	173.14	2.42	0.58	1.57	0.20	1.18	0.76
T_4 : 500 ppm foliar Mo	852	2019	21.39	182.26	3.13	0.61	1.75	0.22	1.22	0.83
T_5 : 0.5 g Mo/kg seeds	832	1966	21.19	175.78	3.04	0.59	1.61	0.22	1.20	0.80
T_6 : 25 kg S + 500 ppm Mo	928	2280	24.01	223.24	4.46	0.70	2.10	0.26	1.35	0.88
T_7 : 25 kg S + 0.5 g Mo/kg seeds	916	2230	23.73	217.44	4.14	0.65	2.01	0.25	1.32	0.87
T_8 : 50 kg S + 500 ppm Mo	902	2206	22.71	204.75	3.56	0.63	1.95	0.24	1.28	0.86
T_9 : 50 kg S + 0.5g Mo/kg seeds	900	2174	13.39	202.80	3.29	0.62	1.91	0.24	1.26	0.85
S.Em. ±	30.03	88.43	0.93	9.82	0.17	0.024	0.11	0.014	0.045	0.041
C.D at 5 %	90.05	265.12	2.81	29.47	0.52	0.07	0.33	0.04	0.14	NS
C.V. %	6.00	7.38	7.45	8.97	9.15	6.71	10.44	10.89	6.33	8.56

Table 2. NPK uptake by seed and haulm of Cowpea as influenced by different levels of sulphur and molybdenum treatments

Treatments	N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)	
	Seed	Haulm	Seed	Haulm	Seed	Haulm
T_1 : RDF	18.42	10.46	11.64	3.50	8.79	13.58
T_2 : 25 kg S/ha	25.17	11.90	16.02	4.64	10.67	16.98
T_3 : 50 kg S/ha	19.90	11.09	12.84	3.78	9.66	14.55
T_4 : 500 ppm foliar Mo	26.65	12.33	14.91	4.44	10.41	16.75
T_5 : 0.5 g Mo/kg seeds	25.33	11.66	13.43	4.31	10.02	15.77
T_6 : 25 kg S + 500 ppm Mo	41.19	16.00	19.47	5.94	12.57	20.12
T_7 : 25 kg S + 0.5 g Mo/kg seeds	37.94	14.40	18.43	5.57	12.05	19.39
T_8 : 50 kg S + 500 ppm Mo	32.09	13.91	17.61	5.36	11.54	19.00
T_9 : 50 kg S + 0.5g Mo/kg seeds	29.63	13.39	17.16	5.22	11.31	18.49
S.Em. ±	1.64	0.86	1.13	0.36	0.57	1.04
C.D at 5 %	4.92	2.58	3.39	1.09	1.72	3.14
C.V. %	9.98	11.64	12.47	13.21	9.22	10.56

Table 3. Available N, P, K, S and Mo in soil after harvest of cowpea as influenced by different levels of sulphur and molybdenum treatments

Treatments	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_20 (kg/ha)	Available S (ppm)	Available Mo (ppm)	Returns (₹/ha)		BCR
						Gross return	Net return	
T_1: RDF	201.53	41.04	339.94	7.01	0.034	46621	28952	2.64
T_2: 25 kg S/ha	216.47	41.76	342.21	8.85	0.036	51131	33234	2.86
T_3: 50 kg S/ha	227.43	44.61	338.57	10.19	0.037	48731	30606	2.69
T_4: 500 ppm foliar Mo	223.29	42.89	338.09	7.48	0.045	50658	32277	2.76
T_5: 0.5 g Mo/kg seeds	225.73	42.74	339.04	7.19	0.047	49465	31522	2.76
T_6: 25 kg S + 500 ppm Mo	233.81	42.95	338.17	8.55	0.043	55521	36912	2.98
T_7: 25 kg S + 0.5 g Mo/kg seeds	266.82	43.20	335.02	9.48	0.044	54755	36584	3.01
T_8: 50 kg S + 500 ppm Mo	228.31	42.48	344.29	10.54	0.040	53924	35087	2.86
T_9: 50 kg S + 0.5g Mo/kg seeds	232.18	41.91	338.81	9.99	0.041	53678	35279	2.92
S.Em. ±	8.20	1.85	18.02	0.65	0.0016			
C.D at 5 %	24.58	NS	NS	1.94	0.0047			
C.V. %	6.21	7.53	9.19	12.70	6.60			
Initial status	220.12	39.50	340.25	7.86	0.035			

followed by the treatments T_7, T_8, T_9 and T_2 and maximum net return of Rs. 36912/ha was realized with T_6 (25 kg S + 500 ppm Mo) followed by the treatment T_7 (25 kg S + 0.5 g Mo/kg seeds) by recording net return of Rs. 36584/ha. An appraisal of data showed that maximum BCR of 3.01 was obtained with the T_7 (25 kg S + 0.5 g Mo/kg seeds), followed by the treatment T_6 (25 kg S + 500 ppm Mo) by securing BCR of 2.98.

4. CONCLUSION

Until quite recently, reviews and studies confirm the positive effect of sulphur and molybdenum for a significant improve on the nutritional quality and yield of cowpea. These nutrients enhance protein content and support essential metabolic functions in the plant. The combined application of RDF with 25 kg S/ha + 500 ppm foliar Mo (T_6) significantly enhanced the N, P, and K content and uptake by seed and haulm. Post-harvest soil analysis indicated that available nitrogen, sulphur, and molybdenum status were positively influenced by sulphur and molybdenum fertilization. Hence, integrated nutrient management involving sulphur and molybdenum, particularly through seed treatment, can be recommended for improving cowpea productivity and soil fertility under south Gujarat conditions.

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 writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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