Influence of sulphur and foliar application of molybdenum on growth and yield of summer cowpea (*Vigna unguiculata L.*)

ABSTRACT

A field experiment was conducted during *Zaid* 2022 at Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology And Sciences, Prayagraj (U.P). To determine the "Influence of sulphur and foliar application of molybdenum on growth and yield of summer cowpea (*Vigna unguiculata* L.)." The results showed that treatment 9 [Sulphur (30kg/ha) + Molybdenum (15ppm)] recorded significantly higher plant height (59.5 cm), higher number of branches/plant (6.60), higher number of nodules/plant (33.80), higher plant dry weight (16.26 g). Whereas, maximum number of pods/plant (14.87), maximum number of seeds/pod (10.67), higher test weight (133.34 g), higher seed yield (1.03 t/ha), higher haulm yield (1.70 t/ha), was recorded in treatment 9 [sulphur (30kg/ha) + Molybdenum (15ppm)]. Similarly, maximum gross returns (73,697.44 INR/ha), higher netreturns (49,050.92 INR/ha) and highest benefit cost ratio (1.99) was also recorded in treatment 9 [sulphur (30kg/ha) + Molybdenum (15ppm)] as compared to other treatments.

Keywords: sulphur, molybdenum, growth, yield and economics

Introduction

"Cowpea (*Vigna unguiculata L.*) is commonly known as lobia, southern pea, black- eyed pea. It is an annual legume crop which belongs to the family Leguminosae and hence, it is cultivated widely in tropics and subtropics during the warm season. It is commercially grown throughout the India for its seed and green pods which are used as vegetable. The leading states in cowpea production in our country are UP, Bihar, Jharkhand, West Bengal, Odisha". **(Sudharani *et al.*, 2020).**

"It is an important source of nutrients and provides high quality, inexpensive protein diet based on cereal grains and starch foods. Cowpea is a good source of food, fodder and vegetables. In India pulses are grown nearly in 25.43 m ha with an annual production of 17.20 m t and a median productivity of 679 kg/ha. The per capita availability of pulses in India is 35.5 g/day as against the minimum requirement of 70 g/day". **(Yadav *et al.*, 2022). "**Cowpea grown across the world on an area 14.5 m ha of land planted each year and the total annual production is 6.2 m t. In India during 2020-21 cowpea is grown in 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 is about 2.38 m ha with an annual production of 2.56 and productivity of 1079 kg/ha major producer of cowpea in India". **(GOI, 2020).**

The Sulphur deficiency often results in delayed maturity and slower growth of the leaves. If the deficiency advances, the yellowed leaves will spread throughout the plant. In most cases, there is a deficiency in both sulphur and nitrogen. Detecting a sulphur deficiency in plants is more difficult because the deficiency must generally become severe before any symptoms appear the most classic sign of a sulphur deficiency in plants is the yellow coloration of the older leaves. The color of the leaves change beginning with the tip of the leaf, then proceeding all the way to the midrib. Older leaves often become discolored in the whorl. In some instances, interveinal striping is present.

"The effect of molybdenum deficiency was the activity of nitrate reductase decreased with the absence of molybdenum in plant, the reduction of nitrate was inhibited, and the nitrogen assimilation was decreased. It deals with the changes in metabolism and reproduction has affected by variable Mo supply on growing the plants to maturity in refined sand. The changes in the seed quality and metabolism in the seedling stage at variable Mo has been included". **(Gopal *et al.*, 2015). "**Molybdenum deficiency leads to nitrate accumulation in plants, as the enzyme activity to convert the nitrate to nitrite is restricted. Molybdenum deficiency is associated with acid soil conditions and is not generally a problem on adequate limed fields and its only the essential plant trace element that is less available at low pH”. **(Gungula *et al.*, 2006).**

“Sulphur is fourth major nutrient next to N, P and K and an essential element for plant growth particularly for legumes crops which play an important role in plant metabolism system, S containing amino acids (cystine, cysteine and methionine) and promotes nodulation in legumes. It helps in chlorophyll formation and encourages vegetative plant growth”. **(Yadav *et al.*, 2022). “**It required for the synthesis of chlorophyll and promote nodule formation sulphur absence in soil are gradually increasing with reduction of sulphur proportion in atmosphere and the descending usage of ammonium sulphate containing sulphur, but the accending usages of urea from nitrogenous fertilizers without sulphur. It also increases the protein content of legume vegetables”. **(Abdar *et al.*, 2022).**

“Molybdenum is required to the *Rhizobium* bacteria for proper function of nitrogenase enzyme which involved in nitrogen fixation. Again, molybdenum is the cofactor for the enzyme nitrate reductase which involved in nitrogen assimilation”. **(Chatterjee *et al.*, 2015). “**Nitrogen fixing bacteria need Molybdenum for the function of the enzyme nitrogenase that helps in nitrogen fixation. In nitrogen assimilation the enzyme nitrate reductase is required. Molybdenum acts as cofactor in this process. The application of molybdenum in the soil will encourage the formation of nodules by fixing atmospheric nitrogen. Molybdenum is a necessary element, it is a component of the nitrogenase enzyme, and every bacterium that fixes nitrogen requires it. The role of molybdenum in legumes are nodulation, nitrate reduction, nitrogen fixation and general metabolism. In legume crops, molybdenum has a beneficial effect of production, quality and the formation of nodules. Molybdenum will increase crop growth and yield characteristics by increasing the bioavailability of other key elements”. **(Koganti *et al.*, 2022).** Keeping in view the above facts, the present experiment was undertaken to find out “Influence of sulphur and foliar application of molybdenum on growth and yield of summer cowpea (*Vigna unguiculata* L.)’’.

MATERIALS AND METHODS:

The experiment was conducted during the *Zaid* season 2022 at the Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.). The soil of the field constituting a partof central gangetic alluvium is neutral and deep. The soil of the experimental field was sandy loamy 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). The treatment consists of three different levels of sulphur *viz*, 10kg/ha, 20kg/ha, 30kg/ha with combination of different levels of molybdenum *viz*, 5ppm, 10ppm, 15ppm. The experiment was laid out in RBD with 10 treatments each replicated thrice. The treatment combinations are T1 – Sulphur (10kg/ha) + Molybdenum (5ppm), T2 – Sulphur (10kg/ha) + Molybdenum (10ppm) , T3 – Sulphur (10kg/ha) + Molybdenum (15ppm), T4 – Sulphur (20kg/ha) + Molybdenum (5ppm), T5 – Sulphur (20kg/ha) + Molybdenum (10ppm), T6 - Sulphur (20kg/ha) + Molybdenum (15ppm), T7 – Sulphur (30kg/ha) + Molybdenum (5ppm), T8 – Sulphur (30kg/ha) + Molybdenum (10ppm), T9 – Sulphur (30kg/ha) + Molybdenum (15ppm), T10 – Control N:P:K (20:40:20kg/ha). The data recorded on different aspects of crop *viz*., growth parameters and yield attributes were subjected to statistical analysis by variance method (Gomez and Gomez, 1984).

RESULT AND DISCUSSION

Growth parameters

Plant height (cm)

The data revealed that significant and higher plant height (59.5 cm) was observed in treatment 9 [Sulphur (30kg/ha) + Molybdenum (15ppm)]. However, treatment 8 [Sulphur (30kg/ha) + molybdenum (10ppm)] and the treatment 6 [Sulphur (20kg/ha) molybdenum (15ppm)] and the treatment 5 [Sulphur (20kg/ha) molybdenum (10ppm)] and the treatment 3 [Sulphur (10kg/ha) molybdenum (15ppm)] were statistically at par with the treatment 9 [Sulphur (30kg/ha) molybdenum (15ppm)] (Table 1). The significant and higher plant height was with application of Sulphur (30kg/ha) as play important role in several physiological and biochemical processes which are of vital importance for growth and development of plant. Similar findings also reported by **Yadav *et al*. (2022).** Further, higher plant height was found that molybdenum (15 ppm) increases availability of nitrogen which helps in process of nitrogen assimilation. Similar findings also reported by **(Chatterjee and Bandyopadhyay, 2015).**

Number of branches/plants

The data revealed that treatment 9 [Sulphur (30kg/ha) + Molybdenum (15ppm)] recorded significant and maximum number of branches/plant (6.60) which was superior to all the treatments and the treatment 8 [Sulphur (30kg/ha) + molybdenum (10ppm)] and the treatment 6 [Sulphur (20kg/ha) molybdenum (15ppm)] and the treatment 5 [Sulphur (20kg/ha) molybdenum (10ppm)] and the treatment 3 [Sulphur (10kg/ha) molybdenum (15ppm)] were statistically at par with the treatment 9 [Sulphur (30kg/ha) molybdenum (15ppm)] (Table 1). Application of Sulphur (30kg/ha) showed that maximum number of branches/plant that stimulates of cell division, photosynthetic process as well as formation of chlorophyll and also promotes the root nodules in legumes, which cause the more sulphur available during vegetative growth period and development of plant occurs. Similar findings also reported by **ArunRaj *et al.* (2018).** Further maximum number of branches/plant was found with application of molybdenum (15ppm) may be due to its effect on structural component of nitrogenase, the enzyme activity involved in nitrogen fixation by root nodule bacteria of leguminous crop. These results were in conformity with those of **Chhatrapati *et al.* (2017)** in black gram.

Number of nodules/plants

Results revealed that treatment 9 [Sulphur (30kg/ha) + Molybdenum (15ppm)] recorded significantly maximum number of nodules/plant (33.80). However, treatment 8 [Sulphur (30kg/ha) + molybdenum (10ppm)] and the treatment 6 [Sulphur (20kg/ha) molybdenum (15ppm)] and the treatment 5 [Sulphur (20kg/ha) molybdenum (10ppm)] and the treatment 3 [Sulphur (10kg/ha) molybdenum (15ppm)] were statistically at par with the treatment 9 [Sulphur (30kg/ha) molybdenum (15ppm)] (Table 1). The significant and maximum number of nodules/plant was with application of Sulphur (30kg/ha) may be due to better root development with increasing levels of these nutrients and for its beneficial effect which may have decreased soil pH and improved physical condition of the soil. **Niraj *et al.* (2014).** Further higher number of nodules increased with the application of molybdenum (15 ppm) may be due to molybdenum enhanced the plants root development, facilitating the formation of nodules improving them and contributing to an increase in their numbers and weights and enhancement nitrogen fixation, resulted maximum number of nodules/plant. **(Gad and Kandil 2013).**

Plant dry weight (g)

Data found that significant and higher plant dry weight (16.26 g) was obtained in the treatment 9 [Sulphur (30kg/ha) + Molybdenum (15ppm)]. However, treatment 8 [Sulphur (30kg/ha) + molybdenum (10ppm)] were statistically at par with the treatment 9 [Sulphur (30kg/ha) molybdenum (15ppm)] (Table 1). The significant and higher plant dry weight was with the application of Sulphur (30kg/ha) improves overall nutritional environment in rhizosphere by improving not only the availability of sulphur but also lowering the pH, which is the principle reason for availability and mobility of nutrients. Similar findings were reported by

Ramawtar *et al.* (2013). Further plant dry weight increased with application of molybdenum (15 ppm) was due to improvement in soil environment of encouraged proliferation of plant roots, synthesis of more carbohydrates and their translocation of different plant parts resulted increased vegetative growth including the reproductive structures. Similar findings were reported by **Harireddy *et al.* (2021).**

Crop Growth Rate (g/m^2/day)

The data revealed that during 45-60 DAS no significant difference among all the treatments. However, highest Crop Growth Rate (3.02g/m$^{2/}$day) was observed in treatment treatment 9 [Sulphur (30kg/ha) + Molybdenum (15ppm)] (Table 1).

Relative Growth Rate (g/g/day)

The data revealed that during 45-60 DAS no significant difference among all the treatments. However, highest Relative Growth Rate (0.0062g/g/day) was observed in treatment 5 [Sulphur (20kg/ha) + Molybdenum (10ppm)] (Table 1).

Yield attributes

Number of pods/plant

The data showed that treatment 9 [Sulphur (30kg/ha) + Molybdenum (15ppm)] recorded significantly higher number of pods/plant (14.87). However, treatment 8 [Sulphur (30kg/ha) + Molybdenum (10 ppm)] and treatment 6 [Sulphur (20kg/ha) + Molybdenum (15 ppm)] were statistically at par with the treatment 9 [Sulphur (30kg/ha) + Molybdenum (15 ppm)] (Table 2). The significant and increase in number of pods/plant with the application of Sulphur(30kg/ha) may be due to it influences the vegetative growth which was later converted into reproductive phase and resulted more pods/plant. Similar findings were reported by **Singh *et al.* (1999).** Further maximum number of pods/plant was observed with application of molybdenum (15 ppm) have enabled the plant to fix nitrogen from the atmosphere in nodules which improved the plant growth and its development, and was probably responsible for increased yield attributes. Similar findings were reported by **Kumar *et al.* (2018)** in black gram.

Number of seeds/pod

The data recorded that significant and higher number of seeds/pod (10.67) was recorded in treatment 9 [Sulphur (30kg/ha) + Molybdenum (15ppm)]. However, treatment 8 [Sulphur (30kg/ha) + Molybdenum (10 ppm)] and the treatment 6 [Sulphur (20kg/ha) + Molybdenum (15 ppm)] were statistically at par with the treatment 9 [Sulphur (30kg/ha) + Molybdenum (15 ppm)] (Table 2). The significant and higher number of seeds/pod was with the application of Sulphur (30kg/ha) may have enhances the plant growth that increases fruit bearing branches, seed setting and seed development an increase the seeds/pod. Similar findings were reported by **Malik *et al.* (2003).** Further maximum number of seeds/pods was observed with the application of molybdenum (15 ppm) may be due to its unique role in enhancing nitrogen fixation thereby increasing its availability to the plants for efficient growth and development of plants in terms of photosynthetic area which enhanced the photosynthesis and synthesis of other metabolites for plant use. Similar findings were reported by **Singh *et al.* (2017).**

Test weight (g)

The data recorded that no significant difference among all the treatments. However, highest test weight (133.34 g) was observed in treatment 9 [Sulphur (30kg/ha) + Molybdenum (15 ppm)] (Table 2).

Seed yield (t/ha)

Significant higher seed yield (1.03 t/ha) was obtained in treatment 9 [Sulphur (30kg/ha) + Molybdenum (15ppm)]. However, treatment 8 [Sulphur (30kg/ha) + Molybdenum (10 ppm)] were statistically at par with the treatment 9 [Sulphur (30kg/ha) + Molybdenum (15 ppm)] (Table 1). The significant and higher seed yield was observed with application of Sulphur (30kg/ha) may have increased rate of photosynthesis due to an increment in protein synthesis and maintenance of high chlorophyll content, resulted higher seed yield by **Karche *et al.* (2012).** Further maximum seed yield was observed with the application of molybdenum (15 ppm) may be due to cumulative effect of vegetative growth and yield attributes were increased by the better supply of nutrients as seed yield was increased. Similar findings were reported by **Singh *et al.* (2008)** in black gram.

Haulm yield (t/ha)

Significant and higher haulm yield (1.70 t/ha) was recorded in treatment 9 [Sulphur (30kg/ha) + Molybdenum (15ppm)]. However, treatment 8 [Sulphur (30kg/ha) + Molybdenum (10 ppm)] were statistically at par with the treatment 9 [Sulphur (30kg/ha) + Molybdenum (15 ppm)] (Table 1). The significant and higher haulm yield was observed with the application of Sulphur(30kg/ha) may be due to the pronounced role of sulphur in stimulation of cell division, photosynthetic process as well as formation of chlorophyll. It also promotes the root nodules in legumes, which cause the more sulphur available during vegetative growth period and development of plant occurs. Similar findings were reported by **Kumawat *et al.* (2014).** Further maximum stover yield was observed with the application of molybdenum (15 ppm) may have resulted in higher production of photosynthates were utilized by the plant for development of sink under adequate supply of nutrients. Similar findings were reported by

Pargi *et al.* (2018).

Harvest Index (%)

The data revealed that treatment 8 [Sulphur (30kg/ha) + Molybdenum (10ppm)] recorded the higher harvest index (39.3%). However, treatment 9 [Sulphur (30kg/ha) + Molybdenum (15 ppm)] and the treatment 6 [Sulphur (20kg/ha) + Molybdenum (15 ppm)] were statistically at par with the treatment 8 [Sulphur (30kg/ha) + Molybdenum (10 ppm)] (Table 1). The significant and higher harvest index was obtained with the application of Sulphur (30kg/ha) due to cell activities, enhanced cell multiplication and enlargement and luxuriant growth and yield attributes of the crops probably due to more absorption and utilization of available nutrients leading to overall improvement of crop growth reflected to source-sink relationship, which in turn enhanced the yield attributes that ultimately more yield. Similar findings were reported by **Kokani *et al.* (2015).**

Economics

The result showed that maximum gross return (73,697.44 INR/ha), higher net returns (49,050.92 INR/ha), and highest benefit cost ratio (1.99) was recorded in treatment 9 [Sulphur (30kg/ha) + Molybdenum (15ppm)] as compared to other treatments (Table 3). Higher gross returns, netreturns, benefit cost ratio was recorded with application of Sulphur (30kg/ha) might be due to higher grain and haulm yield of cowpea. **Kumar (2006).**

Table 1. Influence of sulphur and foliar application of molybdenum on growth parameters of cowpea.

S No	Treatments	Plant height (cm)	Number of branches/ Plant	Number of nodules /plant	Plant dry weight (g)	CGR (g/m^2/day)	RGR (g/g/day)
1.	Sulphur 10kg/ha + Molybdenum 5ppm	57.4	4.87	30.80	13.00	1.33	0.0033
2.	Sulphur 10kg/ha + Molybdenum 10ppm	57.6	5.60	31.30	13.44	1.44	0.0034
3.	Sulphur 10kg/ha + Molybdenum 15ppm	58.7	5.93	32.53	14.62	1.53	0.0031
4.	Sulphur 20kg/ha + Molybdenum 5ppm	57.6	5.67	31.87	13.77	1.44	0.0032
5.	Sulphur 20kg/ha + Molybdenum 10ppm	58.9	6.27	32.60	15.32	3.02	0.0062
6.	Sulphur 20kg/ha + Molybdenum 15ppm	59.1	6.33	32.93	15.66	2.58	0.0050
7.	Sulphur 30kg/ha + Molybdenum 5ppm	58.6	5.87	32.40	14.20	1.62	0.0036
8.	Sulphur 30kg/ha + Molybdenum 10ppm	59.3	6.47	33.07	15.97	0.81	0.0015
9.	Sulphur 30kg/ha + Molybdenum 15ppm	59.5	6.60	33.80	16.26	0.78	0.0014
10.	Control N:P: K (20:40:20 Kg/ha)	57.3	4.73	30.73	12.88	1.33	0.0033
	F-test	S	S	S	S	NS	NS
	Sem±	0.38	0.22	0.26	0.14	0.46	0.0010
	CD at 5%	1.14	0.64	0.77	0.42	--	--

Table 2. Influence of sulphur and foliar application of molybdenum on yield attributes of cowpea.

S No	Treatments	Number of pods/plant	Number of seeds/pod	Test Weight (g)	Seed yield (t/ha)	Haulm yield (t/ha)	Harvest index (%)
1.	Sulphur 10kg/ha + Molybdenum 5ppm	10.40	8.53	125.49	0.89	1.43	38.3
2.	Sulphur 10kg/ha + Molybdenum 10ppm	11.36	8.98	126.03	0.89	1.49	37.5
3.	Sulphur 10kg/ha + Molybdenum 15ppm	14.08	9.39	129.32	0.94	1.55	37.7
4.	Sulphur 20kg/ha + Molybdenum 5ppm	12.22	9.06	127.24	0.91	1.50	37.7
5.	Sulphur 20kg/ha + Molybdenum 10ppm	14.21	9.62	130.89	0.95	1.56	38.0
6.	Sulphur 20kg/ha + Molybdenum 15ppm	14.40	10.00	131.56	0.98	1.57	39.2
7.	Sulphur 30kg/ha + Molybdenum 5ppm	13.40	9.19	128.58	0.92	1.50	38.0
8.	Sulphur 30kg/ha + Molybdenum 10ppm	14.55	10.18	132.50	1.02	1.57	39.3
9.	Sulphur 30kg/ha + Molybdenum 15ppm	14.87	10.67	133.34	1.03	1.70	39.1
10.	Control N:P: K (20:40:20 Kg/ha)	9.93	7.79	123.40	0.89	1.43	38.3
	F-test	S	S	NS	S	S	S
	Sem±	0.18	0.30	0.69	0.004	0.01	0.17
	CD at 5%	0.53	0.88	-	0.01	0.03	0.50

Table 3: Influence of sulphur and foliar application of molybdenum on economics of cowpea.

S No	Treatments	Total cost of cultivation (INR/ha)	Gross Returns (INR/ha)	Net Returns (INR/ha)	B:C ratio
1	Sulphur 10kg/ha + Molybdenum 5ppm	22546.52	63740.22	41193.70	1.82
2	Sulphur 10kg/ha + Molybdenum 10ppm	22596.52	64325.14	41728.62	1.84
3	Sulphur 10kg/ha + Molybdenum 15ppm	22646.52	67639.40	44992.88	1.98
4	Sulphur 20kg/ha + Molybdenum 5ppm	23546.52	65261.72	41715.20	1.77
5	Sulphur 20kg/ha + Molybdenum 10ppm	23596.52	68603.48	45006.94	1.90
6	Sulphur 20kg/ha + Molybdenum 15ppm	23646.52	71889.20	45201.50	1.91
7	Sulphur 30kg/ha + Molybdenum 5ppm	24546.52	66302.90	41756.38	1.70
8	Sulphur 30kg/ha + Molybdenum 10ppm	24596.52	73157.08	48560.56	1.97
9	Sulphur 30kg/ha + Molybdenum 15ppm	24646.52	73697.44	49050.92	1.99
10	Control N:P: K (20:40:20 Kg/ha)	21496.52	63609.43	42112.91	1.95

*****Data was not subjected to statistical analysis.

CONCLUSION

Based on the above findings it can be concluded that application of Sulphur 30kg/ha and Molybdenum 15ppm as foliar spray has performed better in growth parameters and yield attributes of cowpea (Ankur Gomati) and also proven profitable. Overall, the study of sulfur and foliar application of molybdenum in cowpea production is an important area of research that has the potential to improve agricultural productivity and contribute to sustainable development in tropical regions. Further research is needed to optimize the application of these nutrients and to better understand their interactions with other environmental factors.

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