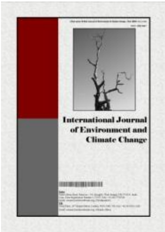

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Effect of Various Sources and Levels of Sulphur on Growth, Dry Matter Production and Nutrient Uptake of Indian Mustard (*Brassica juncea L.*)

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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 conducted to assess the response of Indian mustard to various sources and levels of sulphur during *rabi* season of 2021 at College Farm, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad. The experiment was carried out with three sources of sulphur (ammonium sulphate, gypsum and bentonite sulphur) and three levels of sulphur (20, 40 and 60 kg S ha-1) with one additional treatment (control *i.e.,* 0 kg S ha-1) in factorial concept and replicated thrice. Significant crop response was observed for plant height, leaf area index and dry matter production with application of ammonium sulphate among all the three sources. Among the levels of sulphur, the higher values of plant height, leaf area index and dry matter recorded on application of 60 kg S ha-1, which showed parity with 40 kg S ha-1. The similar trend was also noticed for seed yield and nutrient uptake (N and S).

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Keywords: Sources; levels; plant height; LAI; dry matter and nutrient uptake.

1. INTRODUCTION

Mustard (*Brassica juncea* L.) holds nearly a third (33.3%) of the total oilseeds production in India [1]. Mustard is the second important oilseeds crop grown during *rabi* both rainfed as well as under irrigated conditions. Mustard, a member of Cruciferae family is well known as rai, raya, laha in different parts of the country. Sulphur is the key element for oil, protein (Fe-S protein, called ferrodoxine), vitamins (Biotine, Thiamine) and flavoured compounds synthesis in plant [2]. Sulphur provides better nutritional and market quality to oilseed crops. The sulphur deficiency escalation in Indian soils is the result of agricultural intensification with high yielding varieties and simultaneous adoption of multiple cropping systems with high analysis sulphur free fertilizers [3]. In S- scarcity soil, the effectiveness of applied NPK fertilizers might be truly influenced and crop yield may not be feasible [4]. External application of sulphur fertilizer will provide a positive response in yield improvement. Among oilseeds, Indian mustard noticeably respond to sulphur fertilization. The growth, yield and quality of seed is majorly decided by sulphur. Presumably for these reasons, mustard crop needs supplementary quantity of sulphur for absolute growth, development and yield. In mustard, seed and stover yield is markedly governed by sulphur levels [5]. Therefore the present investigation was carried out to study the effect of sources and levels of sulphur on performance of mustard.

2. MATERIALS AND METHODS

The experiment was conducted to study the “Response of mustard [Brassica juncea (L.) Czern. and Cosson] crop to sources and levels of sulphur nutrition” during winter (rabi) season of 2020-21 at the College Farm, College of Agriculture, Professor Jayashankar Telangana State Agriculture University, Rajendranagar, Hyderabad. The farm is geographically located at 17°19′.?.″ N latitude, 78°23′.?.″ E longitude and at an altitude of 542.6 m above mean sea level.

The weekly mean maximum temperature during the crop growth period (04.11.2020 to 16.02.2021) ranged from 26.4℃ to 31.7°C with an average of 29.3°C, while the weekly mean minimum temperature ranged from 11.1℃ to 18.6°C with an average of 14.5°C. The total rainfall received during the crop growth period was 2.8 mm.

The soil was found to be sandy loam in nature with slightly alkaline (pH 8.28), high in organic carbon content (0.78%), low in available nitrogen (199.54 kg ha-1), high in available phosphorus (33.60 kg ha-1), high in available potassium (410.45 kg ha-1) and low in available sulphur content (9.74 ppm).

The present study was conducted with factorial randomized block design with ten treatments and three replications. Each replication was splitted into ten equal parts and treatments were imposed in it. Basically, the sources and levels of sulphur fertilizer were used for experimental purpose. All the treatments were allocated randomly to the plots to avoid same treatments in nearby plots. The treatment combinations and symbols used were: T1 (S1L1): Ammonium sulphate @ 20 kg ha-1, T2 (S1L2): Ammonium sulphate @ 40 kg ha-1, T3 (S1L3): Ammonium sulphate @ 60 kg ha-1, T4 (S2L1): Gypsum @ 20 kg ha-1, T5 (S2L2): Gypsum @ 40 kg ha-1, T6 (S2L3): Gypsum @ 60 kg ha-1, T7 (S3L1): Bentonite sulphur @ 20 kg ha-1, T8 (S3L2): Bentonite sulphur @ 40 kg ha-1, T9 (S3L3): Bentonite sulphur @ 60 kg ha-1 and T10 (S0L0): Control.

The recommended fertilizer dose of 80:40:40 kg of N, P2O5 and K2O ha-1 was applied to all the treatments. Half of nitrogen, Phosphorus and Potassium were applied as basal, whereas rest of the nitrogen applied at 20 and 40 DAS. Nitrogen was applied in the form of urea (46% N), Phosphorus as di-ammonium phosphate (46% P2O5) and potash as muriate of potash (60% K2O), respectively. The sources of sulphur were ammonium sulphate (24% S), gypsum (18.6% S) and bentonite sulphur (90%). All the sources of sulphur were applied basal.

3. RESULTS AND DISCUSSION

3.1 Plant Height (cm)

The scrutinised data (Table 1) revealed that, application of ammonium sulphate recorded the maximum plant height of 172.7 cm at harvest over gypsum (156.7 cm) and bentonite S (161.8 cm). It was found significantly superior than gypsum and bentonite S but the later two sources were on par with each other. The lowest plant height was recorded with control (147.8 cm).

At harvest, among levels of sulphur the plant height increased with each successive addition of sulphur and highest being recorded at 60 kg S ha-1 (169.6 cm) which was on par with 40 kg S ha-1 (166.2 cm), whereas plant height of 155.3 cm was obtained at 20 kg S ha-1. The lowest height (147.8 cm) was noticed at control *i.e.,* 0 kg S ha-1. However, the variation in plant height due to 20 and 40 kg S ha-1 were noteworthy.

This increased plant height might be due to the enhanced cell division, cell elongation, expansion and chlorophyll synthesis caused by sulphur nutrition. Sulphur also plays a crucial role in the meristematic tissue activity and shoot development, which help in increment of plant height. The increase in plant height could also be attributed due to improved root development as sulphur helps in increased uptake of other nutrients and more vegetative growth leading to taller plants. These findings are in accordance with those reported by Alam et al. [6] and Begum et al. [7].

3.2 Leaf Area Index

Among the sources of sulphur examined, the highest leaf area index at 60DAS was recorded with the ammonium sulphate (3.58) which was significantly superior than gypsum (3.35) and bentonite S (3.39), whereas later two sources showed statistically parity. Control recorded least LAI of 3.05.

Among the levels of sulphur examined, the highest leaf area index (3.62) was recorded with the 60 kg S ha-1, which was on par with 40 kg s ha-1 (3.51) followed by 20 kg S ha-1 (3.19) and the lowest LAI being recorded at control (3.05) at 60 DAS.

Leaf formation depends on tissue differentiation and expansion. Sulphur is a constituent of three essential amino acids *viz.,* cystine, cysteine and methionine, which helped in the growth of plant. It resembles N in its capacity to enhance cell division, cell elongation and tissue differentiation. Thus, S fertilization has improved the number of leaves plant-1, which ultimately increased the LAI. These findings are in close proximity of Piri and Sharma [8], Dongarkar et al. [9] and Verma et al. [10].

3.3 Dry matter Production (kg ha-1)

The mean differences of dry matter accumulation at harvest due to sources were found significant and ammonium sulphate significantly recorded highest (6561.3 kg ha-1) compared to gypsum

Table 1. Plant height (cm), leaf area index, dry matter accumulation and seed yield (kg ha-1) of mustard crop at various growth stages as influenced by sources and levels of sulphur

Treatments **Sources of sulphur**	Plant height (cm) at harvest	LAI at 60 DAS	Dry matter accumulation (kg ha-1) at harvest	Seed yield (kg ha-1)
S1 (Ammonium sulphate)	172.7	3.58	6561.3	1507
S2 (Gypsum)	156.7	3.35	5619.0	1323
S3 (Bentonite S)	161.8	3.39	5731.9	1379
SEm (±)	3.6	0.06	121.8	33
CD (P=0.05)	10.7	0.18	362.0	98
Levels of sulphur				
L1 (20 Kg ha-1)	155.3	3.19	5634.3	1229
L2 (40 Kg ha-1)	166.2	3.51	6048.0	1459
L3 (60 Kg ha-1)	169.6	3.62	6229.9	1521
SEm (±)	3.6	0.06	121.8	33
CD (P=0.05)	10.7	0.18	362.0	98
Interaction				
SEm (±)	6.2	0.11	211.0	57
CD (P=0.05)	NS	NS	NS	NS
Control *vs*. other treatments				
Control	147.8	3.05	4790.0	1005
SEm (±)	6.5	0.11	222.5	60
CD (P=0.05)	13.8	0.24	467.4	126

(5619.0 kg ha-1) and bentonite S (5731.9 kg ha-1). Dry matter accumulation of 4790.0 kg ha-1 was noticed in control plot. The percent increase in dry matter due to application of ammonium sulphate over control, gypsum and bentonite S were 36.9%, 16.7% and 14.4% respectively.

Significantly highest dry matter accumulation (6229.9 kg ha-1) was recorded at highest level of sulphur *i.e.,* 60 kg ha-1, which was on par with 40 kg S ha-1 (6048.0 kg ha-1). The dry matter production at 20 kg S ha-1 was low (5634.3 kg ha-1) and lowest being at control (4790.0 kg ha-1). The increment in dry matter accumulation was 30.0%, 10.5% and 3.0% due to incorporation of 60 kg S ha-1 over control, 20 kg S ha-1 and 40 kg S ha-1, at harvest.

Sulphur fertilization increased the available sulphur status of soils leading to higher S uptake, which promoted chlorophyll synthesis and dry matter production. Application of sulphur at higher levels were responsible for increased leaf area, which caused higher photosynthesis and assimilates. The metabolic activities were enhanced by S, which were responsible for overall growth characters and development of mustard. Better plant nutrition resulted in increased height and other growth parameters, which resulted in increased dry matter production. The increase in dry matter production might be resulted from the higher rate in protein synthesis and enhanced photosynthetic activity of the plant with increased chlorophyll synthesis due to fertilization with sulphur. The similar result was found by Rajput et al. [11], Tetarwal et al. [12] and Singh and Thenua [13].

3.4 Seed Yield (kg ha-1)

The seed yield was significantly responded by various sources and levels of sulphur. The highest seed yield was obtained due to application of ammonium sulphate (1507 kg ha-1) and was significantly superior to the other sulphur sources *i.e*., bentonite S (1376 kg ha-1) and gypsum (1323 kg ha-1) respectively. However, the lowest seed yield was observed from the control plot (1005 kg ha-1). The percent increase in seed yield due to application of ammonium sulphate over control, gypsum and bentonite S were 49.9%, 13.9% and 9.2% respectively.

Increasing sulphur levels resulted in an increase in mustard seed yield up to 60 kg S ha-1. Application of 60 kg S ha-1 resulted in a maximum seed yield of 1521 kg ha-1, which was on par to 40 kg S ha-1 (1459 kg ha-1) and demonstrated statistical superiority, over 20 kg S ha-1 (1229 kg ha-1). The most reduced seed yield (1005 kg ha-1) was recorded from control (0 kg S ha-1), which showed factual inadequacy over rest of the sulphur levels. The seed and stover yield increased 51.3%, 23.7% and 4.2% due to incorporation of 60 kg S ha-1 over control, 20 kg S ha-1 and 40 kg S ha-1 respectively.

This might be ascribed due to the increasing levels of S which resulted in higher deposition of carbohydrate, protein and their translocation to the productive organs, which in turn enhanced all the growth and yield attributing characters resulting more seed yield. Higher S levels were responsible for increased leaf area and chlorophyll content of leaves causing higher photosynthesis, assimilation and metabolic activities which were responsible for overall improvement in vigour and yield attributes, dry matter accumulation, it’s partitioning and finally seed yield of mustard. This is in conformity with Jyoti et al. [14], Singh and Kumar [15].

3.5 Nutrient Uptake

Sulphur uptake by seed and stover was significantly higher when sulphur was applied at 60 kg S ha-1 (6.89 kg ha-1 and 19.27 kg ha-1), which was statistically comparable to 40 kg S ha-1 (6.46 kg ha-1 and 17.60 kg ha-1) and was significantly superior to 20 kg S ha-1 (4.92 kg ha-1 and 12.93 kg ha-1) respectively. Significantly lowest S uptake was recorded in control treatment (3.52 kg ha-1 and 10.05 kg ha-1) by seed and stover respectively. The uptake of sulphur nutrition at various stages was in an increasing trend and found highest with ammonium sulphate among sources and at 60 kg S ha-1 application, which was on par with 40 kg S ha-1.

These findings might be attributed due to deficiency of sulphur in soil, which enhanced higher uptake that resulted in higher dry matter accumulation and sulphur content at all growth stages. Seed sulphur content at harvest was maximum and high seed yield caused highest seed uptake at harvest, similarly the stover yield was also higher, which brought about higher sulphur uptake by stover. These findings are in consonance with Sahoo et al. [16], Ray et al. [17], Sarangathem et al. [18], Pandey et al. [19] and Kumar [20].

Table 2. Nitrogen and sulphur uptake (kg ha-1) by seed and stover of mustard crop at harvest as influenced by sources and levels of sulphur

Treatments	Sulphur uptake (kg ha-1)		Nitrogen uptake (kg ha-1)	
Sources of sulphur	**Seed**	**Stover**	**Seed**	**Stover**
S1 (Ammonium sulphate)	7.21	18.77	54.90	36.01
S2 (Gypsum)	5.36	14.95	41.71	28.51
S3 (Bentonite S)	5.70	16.08	45.91	31.02
SEm (±)	0.19	0.58	1.627	0.864
CD (P=0.05)	0.58	1.73	4.833	2.566
Levels of sulphur				
L1 (20 Kg ha-1)	4.92	12.93	37.93	26.82
L2 (40 Kg ha-1)	6.46	17.60	50.31	33.33
L3 (60 Kg ha-1)	6.89	19.27	54.28	35.40
SEm (±)	0.19	0.58	1.627	0.864
CD (P=0.05)	0.58	1.73	4.833	2.566
Interaction				
SEm (±)	0.34	1.01	2.817	1.496
CD (P=0.05)	NS	NS	NS	NS
Control *vs*. other treatments				
Control	3.52	10.05	23.56	20.49
SEm (±)	0.36	1.06	2.970	1.577
CD (P=0.05)	0.75	2.23	6.239	3.313

Nitrogen uptake by seed and stover was significantly higher through ammonium sulphate (54.90 kg ha-1 and 36.01 kg ha-1) and statistically at par nitrogen uptake were gained with the application of gypsum (41.71 kg ha-1 and 28.51 kg ha-1) and bentonite S (45.91 kg ha-1 and 31.02 kg ha-1) respectively. The seed and stover nitrogen uptake recorded least with Control (23.56 kg ha-1 and 20.49 kg ha-1). Maximum concentration of nitrogen uptake at harvest by seed and stover was recorded with sulphur @ 60 kg ha-1 (54.28 kg ha-1 and 35.40 kg ha-1), which was significantly superior among all the treatments, and was statistically at par with 40 kg S ha-1 (50.31 kg ha-1 and 33.33 kg ha-1). The lowest nitrogen uptake (23.56 kg ha-1 and 20.49 kg ha-1) at harvest was seen in Control (0 kg S ha-1) and was inferior to treatment containing 20 kg S ha-1 (37.93 kg ha-1 and 26.82 kg ha-1).

The increased uptake with ammonium sulphate might be due to more availability of sulphur, which caused more nitrogen metabolism, content and more dry matter accumulation at all growth stages. The seed uptake was more than stover because the nitrogen content in seed was around 6-7 times more stover content. The increased uptake with levels might be ascribed due to same reason. The parity between 40 and 60 kg S ha-1 might be due to similar dry matter, yield and content at each growth stages. This is in the accordance with the results reported by Baburao [21], Verma et al. [22] and Sarangathem et al. [18].

4. CONCLUSION

From the results it could be concluded that, the growth characters viz., plant height, leaf area index, dry matter accumulation were highly influenced due to adequate supply of sulphur externally, which was deficient in the soil. A dose of 60 kg S ha-1 was excess to obtain higher seed yield (1521 kg ha-1) of mustard as it was on par with 40 kg S ha-1 (1459 kg ha-1). Therefore 40 kg S ha-1 in the form of ammonium sulphate could be advocated for remunerative seed yield.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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