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Response of sulphur and micronutrients foliar application on yield and yield attributes of mustard (*Brassica juncea* L.) under semi-arid conditions

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Abstract

An experiment was conducted during rabi seasons of 2022-23 and 2023-24 at Crop Research Farm of SHUATS, Prayagraj, Uttar Pradesh with the objective to evaluate the effect of sulphur and micronutrients foliar application on yield and yield attributes of mustard under semi-arid conditions of Prayagraj. The Crop Research Farm is situated at 25.57°N latitude, 87.19°E longitude at an altitude of 98 m above mean sea level. The soil is sandy loam in texture, low in organic carbon, potassium and medium in available nitrogen, phosphorus. The experiment consists of 16 treatments with three replications in Randomized Block Design. Foliar application of micronutrients and sulphur in various concentrations was given at 45 and 65 DAS with the objective to evaluate impact of these nutrients on yield and yield attributes of hybrid mustard (Pioneer hybrid 45S46). Yield and yield attributes taken were Seed yield (t/ha), No. of siliqua/plant, No. of seeds/siliqua, Test weight (g), Stover yield (t/ha) and Harvest index (%). The effects of foliar spray of micronutrients and sulphur were found significant on yield attributes. The highest number of siliqua/plant (190.10, 191.50 and 190.80, respectively) were recorded in treatment T₁₁ (RDF + Sulphur @ 1.0%) which was 56.46, 92.85 and 72.83% higher than lowest in control during both the years and pooled analysis. Similarly significantly more number of seeds/siliquae (15.30, 15.70 and 15.50, respectively) were noted in treatment T₁₁ (RDF + Sulphur @ 1.0%), which was 44.34, 46.73 and 45.54% higher than lowest in control during both the years and pooled analysis. Test weight varied significantly where the highest test weight (5.80, 5.88 and 5.84 g, respectively) was recorded in treatment T₁₁ (RDF + Sulphur @ 1.0%) which was 41.46, 40.48 and 40.96% higher than lowest in control during both the years and pooled analysis. Significant differences in seed yield were observed where spray of sulphur and micronutrients resulted more seed yield and stover yield than RDF. The highest seed yield (1.80, 1.85 and 1.83 t ha⁻¹, respectively) was recorded in treatment T₁₁ (RDF + Sulphur @ 1.0%) which was significantly higher than RDF by 33.3, 32.1 and 32.2%, respectively during both the years and pooled data. Stover yield was the highest (6.87, 6.90 and 6.89 t ha⁻¹ respectively) in treatment T₁₁ (RDF + Sulphur @ 1.0%) which was 13.2, 11.3 and 12.2% higher than RDF during both the years and pooled data, respectively. Highest harvest index (24.6, 25.0 and 24.8% respectively) was noted in treatment T₁₁ (RDF + Sulphur @ 1.0%) during both the years and pooled analysis. Thus, it could be concluded that 1.0% sulphur with RDF as foliar application at growth stage proved better amongst all treatments as all the yield and attributes were significantly higher resulting into higher profitability to the farmers.

Keywords: Sulphur, micronutrients, foliar application, yield, yield attributes, mustard

Introduction

Mustard cultivation is done in tropical as well as temperate regions between October-November, and February-March (Rana *et al.*, 2020) ^[13]. There are three main species (*Brassica juncea*, *Brassica campestris*, and *Brassica napus* L.) grown in the Indian subcontinent. In India, about 27.5 million ha area is occupied by oilseeds which represent 14% of the total cropped area with the production of 24.72 million tonnes accounting for 5 per cent of gross national product and 10% value of all agricultural commodities (Pandey *et al.*, 2024) ^[12]. Indian mustard is predominantly cultivated in the states of Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh, and Gujarat. Rajasthan ranks first in area and production of Indian mustard with 2.50 million ha area and 3.71 million tonnes production (Rana *et al.*, 2020) ^[13]. In Punjab mustard is grown on

32 thousand hectares with a production of 41.8 thousand tones and productivity of 1306 kg per hectare (Sulaiman *et al.*, 2021, Sinha *et al.*, 2022) ^[23, 22]. Sulphur affects important activities either directly or indirectly and is essential to many plant metabolic pathways. The synthesis of amino acids, proteins, lipids and even a component of vitamin-A depends on sulphur, which is the fourth major nutrient for plants after nitrogen, phosphorus and potassium. Moreover, sulphur aids in the synthesis of glycosylates (mustard oils), glucosides, enzyme activation, and sulphydryl (SH-) connections, which give oilseeds their pungency (Singh *et al.* 2022) ^[21]. Mustard has the highest Sulphur demand, with an ideal amount of 20 to 60 kg /ha depending on soil sulphur status and yield potential. Indian mustard responded strongly to sulphur fertilization in oilseeds. Sulphur is essential for the quality and development of seed (Yadav *et al.*, 2022) ^[26]. Foliar application of micronutrients is a valuable strategy for improving the productivity and nutritional quality of mustard crops in India. Micronutrient foliar sprays are crucial for enhancing the yield and nutritional quality of mustard. These sprays, particularly of zinc and iron, have been shown to significantly improve growth, seed yield, and the concentration of micronutrients within the plant. Furthermore, micronutrients play a vital role in the translocation of photosynthates, increasing seed setting, and ultimately boosting productivity. By addressing soil deficiencies and optimizing nutrient uptake, farmers can achieve higher yields and better quality harvests. Present study also reports the effect of sulphur and application of various doses of micronutrients at 45 and 65 DAS on yield and yield attributes of hybrid mustard in semi-arid conditions.

Materials and Methods

A field experiment was conducted during rabi season, 2022-23 and 2023-24 at Crop Research Farm, Samhigginbottom University of Agriculture, Technology and Science, Prayagraj, Uttar Pradesh. The characteristic of soil was sandy loam in texture, low in organic carbon, potassium and medium in available nitrogen, phosphorus. Hybrid variety (Pioneer 45S46) was sown with spacing of 45 cm × 20 cm. The experiment was laid down in Randomized Block Design with 16 treatments, (RDF 80:40:40 (kg N:P₂O₅:K₂O/ha, T1: RDF + ZnSO₄.7H₂O @ 0.25%, T2: RDF + ZnSO₄.7H₂O @ 0.5% T3: RDF + molybdenum @ 0.05%, T4: RDF + molybdenum @ 0.1%, T5: RDF + Boron @ 0.05%, T6: RDF + Boron @ 0.1%, T7: RDF + FeSO₄.5 H₂O @ 0.2%, T8: RDF + FeSO₄.5 H₂O @ 0.4%, T9: RDF + 2% Sulphur @ 0.5%, T10: RDF + 2% Sulphur @ 1.0%, T11: RDF + MnSO₄ @ 0.2%, T12: RDF + MnSO₄ @ 0.4%, T13: RDF + CuSO₄.5 H₂O @ 0.2%, T14: RDF + CuSO₄.5 H₂O @ 0.4%, T15: Control, T16) replicated thrice. The data was analyzed using ANOVA for interpretation.

Results and Discussion

Results obtained are presented in tables-1 and-2.

1. Number of siliqua/plant

The data of number of siliqua/plant were recorded at harvest. It revealed that there was significant effect among different treatments on Number of siliqua/plant during both the years and pooled data. Foliar spray of sulphur @ 1% had significantly higher number of siliqua/plant than control and RDF in both the years which was 56.46% and 92.85% higher than control during 2022 and 2023, respectively (Table-1). Application of sulphur @ 1% had significantly effect on number of siliqua per plant which was better than manganese @ 0.2% and 0.4% in 1st year where as in 2nd year, RDF + Sulphur @ 1.0% had significantly superior

results over manganese @ 0.2% and 0.4% and FeSO₄ @ 0.2% and 0.4% (Table-1).

The advantageous effect of sulphur was most likely brought about by the interactions between sulphur and their roles in the synthesis of IAA, the metabolism of auxin and chlorophyll synthesis (Shoja *et al.*, 2018) ^[17]. The lowest number of siliqua per plant were noted 121.50, 99.30 and 110.40 respectively) in control during both the years and pooled analysis. These findings concur with those of Binha *et al.* (2017), Singh *et al.* (2018) ^[20]. Yadav and Debberma (2024) ^[25] noted similar values i.e. 184.43 siliqua /plant in treatment -8 (sulphur 30 kg+zinc 20 kg/ha. However, treatment-9(Sulphur30kg/ha+Manganese 20 kg/ha was found statistically at par with treatment-8. Deewan *et al* (2024) ^[4] also reported 182.7-242.8siliquae/plant. Significant and maximum number of siliqua/plant was obtained with application of sulphur 30kg/ha might be due to more branches with number of siliquae/plant by higher dose of sulphur available throughout the crop growth period which promoted the growth of crop and reproductive parts. Similar findings were also reported by Singh *et al* (2021) ^[19].

2. Number of seed/silique

The number of seed/silique was recorded at harvest. It revealed that there was significant effect among different treatments on number of seed/silique between both the years and pooled data. The effects of foliar spray of micronutrients and sulphur were found significant and significantly higher number of seed/silique were recorded in treatment T₁₁ (RDF + Sulphur @ 1.0%) in both the years and pooled analysis (15.30, 15.70 and 15.50, respectively). During first year of the study T₁₁ was statistically at par with T₃, T₆, T₇, T₁₀, T₁₄ and T₁₅. In 2nd year, T₁₁ was found statistically at par with T₃, T₆, T₇ and T₁₀ (Table-1). In contrast to this study Yadav and Debberma (2024) ^[25] found less number of seed per silique (9.50) following basal application of sulphur and Zinc. Deewan *et al* (2024) ^[4] noted 11.95-14.54 seeds /silique which are at par with our findings. Perusal of data unveiled that, sulphur, zinc and boron application significantly influenced the number of seeds/silique in the study. Increased seed number per silique as result of zinc and boron fertilization, boron helps in translocation of sugars from the roots to the shoots (Rehem *et al.*, 1998) ^[16] and promotion of anthers pollen producing capacity (Singh *et al.*, 2017) ^[18].

3. Test weight (g)

Test weight (1000-seed weight) was recorded at harvest. The data revealed that there was significant effect among different treatments on test weight (g) between both the years and pooled data. The significantly highest test weight (5.80, 5.90 and 5.85 g, respectively) was noted in treatment (RDF + Sulphur @ 1.0%) in both the years and pooled analysis. During 2022, this treatment was found statistically at par with T₃, T₆, T₇, T₈, T₉, T₁₀, T₁₄ and T₁₅. Similar results were recorded in 2023, except for foliar application of FeSO₄@ 0.2% and 0.4% which was not statistically at par with 2022 (Table-1). Yadav and Debberma (2024) ^[25] revealed 4.54 gm following use of 30 kg sulphur +20 kg Zinc/ ha. Deewan *et al* (2024) ^[4] revealed 4.14-4.45 gm test weight in their study.

Compared to control, increase in test weight under RDF + Sulphur @ 1.0%, was 44.34, 46.73 and 45.54%, respectively during both the years and pooled analysis. The superior test weight of mustard might be due to inclusion of macro and micronutrients which improved accumulation of assimilate in seeds and thus resulted in heavier seed (Shoja *et al.*, 2018) ^[17]. Similar results were reported by Kabdal *et al.* (2018) ^[6], Paliwal *et al.* (2016) and Kour *et al.* (2017) ^[7].

Table 1: Effect of foliar spray of micronutrients and sulphur on yield attributes of mustard:

Sr. No.	Treatments	Post- Harvest								
		Number of siliqua/plant			Number of seeds/siliqueae			Test weight (g)		
		2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
1	RDF (80:40:40)	175.10	175.80	175.45	13.10	14.00	13.55	5.15	5.26	5.20
2	RDF + ZnSO ₄ @ 0.25%	177.20	184.20	180.70	14.00	14.10	14.05	5.30	5.38	5.34
3	RDF + ZnSO ₄ @ 0.5%	188.80	188.20	188.50	14.50	14.90	14.70	5.75	5.78	5.76
4	RDF + Molybdenum @ 0.05%	182.90	178.90	180.90	13.50	13.30	13.40	5.38	5.45	5.41
5	RDF + Molybdenum @ 0.10%	188.60	181.90	185.25	13.80	13.50	13.65	5.30	5.50	5.40
6	RDF + Boron @ 0.05%	188.60	190.00	189.30	14.70	15.00	14.85	5.53	5.83	5.68
7	RDF + Boron @ 0.1%	187.40	190.20	188.80	15.00	15.00	15.00	5.78	5.85	5.81
8	RDF + FeSO ₄ @ 0.2%	178.00	178.90	178.45	13.30	13.80	13.55	5.73	5.39	5.56
9	RDF + FeSO ₄ @ 0.4%	179.00	179.50	179.25	14.00	14.00	14.00	5.84	5.43	5.63
10	RDF + Sulphur @ 0.5%	189.70	190.90	190.30	14.60	15.30	14.95	5.73	5.78	5.76
11	RDF + Sulphur @ 1.0%	190.10	191.50	190.80	15.30	15.70	15.50	5.80	5.88	5.84
12	RDF + MnSO ₄ @ 0.2%	176.90	178.10	177.50	13.30	13.90	13.60	5.13	5.46	5.29
13	RDF + MnSO ₄ @ 0.4%	177.00	180.20	178.60	13.50	14.00	13.75	5.32	5.49	5.41
14	RDF + CuSO ₄ @ 0.2%	178.10	189.30	189.05	14.70	14.70	14.70	5.44	5.79	5.61
15	RDF + CuSO ₄ @ 0.4%	188.80	189.70	183.90	14.80	14.70	14.75	5.80	5.82	5.81
16	Control	121.50	99.30	110.40	10.60	10.70	10.65	4.10	4.19	4.15
	F-test	S	S	S	S	S	S	S	S	S
	SEm (±)	4.50	3.40	2.80	0.4	0.3	0.3	0.14	0.09	0.09
	CD (p=0.05)	13.00	9.90	8.10	1.2	0.9	0.8	0.41	0.25	0.27

4. Seed yield (t ha⁻¹)

Seed yield (t/ha) revealed that there were significant differences amongst treatments during both the years. The effects of foliar spray of micronutrients and sulphur were found significant with highest seed yield in treatment RDF + Sulphur @ 1.0% during both the years of experimentation (1.80t/ha and 1.85t/ha in 2022 and 2023, respectively). This treatment had at par seed yield with rest of the treatments except control (0.93 t/ha) and RDF (1.35tha⁻¹) in 1st year and in 2nd year (0.60 t ha⁻¹in control and 1.40 t ha⁻¹ in RDF). Pooled data of both the years of experimentation revealed that all nutrient treatments except RDF (1.58 t ha⁻¹) and control (0.76 t ha⁻¹) were statistically at par with RDF + Sulphur @ 1.0% (1.83 t ha⁻¹) (Table-2).

The highest seed yield was obtained in mustard crop fertilized with RDF +Sulphur @ 1.0%), which was 93.97% and 209.21% higher than control during 2022 and 2023, respectively. Significantly higher yield was recorded by Yadav and Debberma (2024) [25], they found 1820.76 kg/ha which is at par with our findings, as sulphur increases cellular activity, photosynthetic efficiency, meristematic activity, tissue differentiation from somatic to reproductive and the development of floral primordial, it is expected that sulphur will also stimulate the reproductive period and ultimately, increase mustard seed yield (Tetarwal *et al.*, 2013). Deewan *et al* (2024) [4] recorded seed yield of 13.24-15.59 q/ha which was lower than our study which might have been due to varietal difference or time of sowing. Response of micronutrient application with sulphur highlights the crucial role of micronutrients (molybdenum, boron, iron, copper, manganese and zinc) in determining seed yield. Immanuel (2019), Ravi kumar *et al.* (2021), Kabdal *et al.* (2018) [6], Mekki *et al.* (2015) [10] and Jaiswal *et al.* (2015) [5] also reported similar kind of experimental findings.

5. Stover yield (t ha⁻¹)

The stover yield recorded at harvest was found significantly affected by treatments in both the years. Significantly higher stover yield was observed for treatment RDF + Sulphur @ 1.0%

in 2022 and 2023 (6.87 t ha⁻¹ and 6.90 t ha⁻¹, respectively) which was at par with all treatments of nutrients with an exception of treatments with molybdenum application (T₄: RDF + molybdenum @ 0.05% and T₅: RDF + molybdenum @ 0.01%) during first year (Table-2).

Stover yield in RDF was statistically lower than sulphur @ 1.0% during both the years. The lowest stover yield was found in control during both the years and pooled analysis (4.10, 4.27 and 4.19t/ha, respectively). Similar findings were inferred by Dadhich *et al.* (2021) [3], Ray *et al.* (2015) and Al-Amery *et al.* (2021) [1]. Yadav and Debberma (2024) [25] found lower stover yield of 3468.20 kg/ha.

6. Harvest index (%)

Perusal of data obtained in harvest index revealed that there was non-significant effect among different treatments during both the years and in pooled data. In the first year treatment (T₅) had maximum harvest index (21.3%) while in second year T₄, T₇ and T₁₀ recorded the highest value (20.3%).

Increase in stover yield can be ascribed due to overall improvement in plant organs associated with faster and uniform vegetative growth of the crop under the effect of sulphur over control. Biological yield of the crop is sum of seed and stover yield representing vegetative and reproductive growth. The marked increase in both of these with increasing rates of sulphur fertilization ultimately led to realization of higher biomass of mustard crop. Highest nutrient uptake and better use of radiant energy led to higher vegetative and reproductive growth thus, enhancing biological yield in presence of sulphur. Significant relationship between nutrient uptake by stover and stover yield as well as total uptake and biological yield also support the above findings (Table-2). Results of present study corroborate with the findings of Tandon (1991) [24], Moussa and Barsoum (1995) [11] however, Yadav and Debberma (2024) [25] reported higher harvest index of 35.51 following use of sulphur @30 kg/ha+Manganese@20 kg/ha.

Table 2: Effect of foliar spray of micro nutrient and sulphur on yield of mustard.

Sr. No.	Treatments	Post- Harvest								
		Seed yield (t ha ⁻¹)			Stover yield (t ha ⁻¹)			Harvest index (%)		
		2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
1	RDF (80:40:40)	1.35	1.40	1.38	6.07	6.20	6.14	17.7	19.0	18.4
2	RDF + ZnSO ₄ @ 0.25%	1.70	1.70	1.70	6.47	6.75	6.61	20.1	19.5	19.8
3	RDF + ZnSO ₄ @ 0.5%	1.79	1.81	1.80	6.67	6.80	6.74	20.3	19.8	20.0
4	RDF + Molybdenum @ 0.05%	1.71	1.64	1.67	6.30	6.40	6.35	20.6	20.3	20.5
5	RDF + Molybdenum @ 0.10%	1.79	1.66	1.72	6.31	6.47	6.39	21.3	18.9	20.1
6	RDF + Boron @ 0.05%	1.69	1.83	1.76	6.67	6.83	6.75	19.1	20.1	19.6
7	RDF + Boron @ 0.1%	1.72	1.84	1.78	6.77	6.87	6.82	19.2	20.3	19.8
8	RDF + FeSO ₄ @ 0.2%	1.69	1.62	1.65	6.47	6.50	6.49	20.0	19.1	19.6
9	RDF + FeSO ₄ @ 0.4%	1.70	1.64	1.67	6.77	6.63	6.70	20.0	19.1	19.5
10	RDF + Sulphur @ 0.5%	1.76	1.84	1.80	6.77	6.87	6.82	19.6	20.3	20.0
11	RDF + Sulphur @ 1.0%	1.80	1.85	1.82	6.87	6.90	6.89	20.0	20.2	20.1
12	RDF + MnSO ₄ @ 0.2%	1.71	1.67	1.69	6.47	6.60	6.54	20.2	19.6	19.9
13	RDF + MnSO ₄ @ 0.4%	1.76	1.67	1.72	6.49	6.63	6.56	20.7	19.3	20.0
14	RDF + CuSO ₄ @ 0.2%	1.65	1.81	1.73	6.40	6.83	6.62	18.8	20.0	19.4
15	RDF + CuSO ₄ @ 0.4%	1.67	1.82	1.74	6.70	6.83	6.77	18.9	19.9	19.4
16	Control	0.93	0.60	0.76	4.10	4.27	4.19	16.4	11.2	13.8
	F-test	S	S	S	S	S	S	NS	NS	NS
	S.Em (±)	0.08	0.12	0.96	0.167	0.189	0.139	1.14	1.68	1.03
	CD (p=0.05)	0.23	0.36	0.28	0.483	0.549	0.404	-	-	-

Conclusion

The effect of sulphur and micronutrients foliar application on yield and yield attributes of mustard under semi-arid conditions of Prayagraj has resulted into significantly higher yield attributes. Number of siliqua/plant, number of seeds/siliquae, test weight (1000-grain weight), seed yield and harvest index were significantly higher in treatment T₁₁ (RDF + Sulphur @ 1.0%) compared to other treatment combinations tested. Thus, it could be concluded that 1.0% sulphur with RDF as foliar application at crucial stages of plant growth(45 and 65DAS) proved better amongst all treatments resulting into higher profitability to the farmers.

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