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Effect of Sulphur and Zinc application on Growth and Nutrient uptake by Gobhi Sarson (*Brassica napus* L.) under Central Plain Region of Punjab, India

Rohit Saral[1], Mayur Darvhankar[1], Rajesh Kumar[1], Anu Devi[2], Shalini Aryan[3]

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ABSTRACT

Background: Zinc (Zn) and Sulphur (S) play critical roles in enhancing plant growth, nutrient uptake and productivity. Despite their importance, there is limited understanding of their combined impact under field conditions in Punjab, India. This study aimed to evaluate the effects of varying levels of zinc and sulphur application on growth, chlorophyll content and nutrient uptake in plants to optimize their agricultural use.

Methods: A two-year field experiment (2022–2023 and 2023–2024) was conducted at the Agronomy Research Field, Lovely Professional University, Phagwara, Punjab, India. The experimental design included four zinc application treatmentsviz., Z_0-Control, Z_1-1 appl. (one spray @ 15 DAS), Z_2-2 appl. (two spray @ 15 + 45 DAS) and Z_3-3 appl. (three spray @ 15 + 45 + 75 DAS) and four sulphur application treatments viz., S_0-Control, S_1 (10 kg ha^{-1}), S_2 (20 kg ha^{-1}) and S_3 (30 kg ha^{-1}). The plant height (cm), fresh weight (g), dry weight(g), number of leaf/plant, chlorophyll content (mg/g), number of primary leaf and number of secondary leaf was recorded maximum under Z_3-3 appl. (three spray @ 15 + 45 + 75 DAS) and which was at par with Z_2-2 appl. (two spray @ 15 + 45 DAS) and similar trend were also found in N, P, K, S and Zn uptake by stover and seed.

Result: In sulphur levels highest plant height (cm), fresh weight (g), dry weight(g), number of leaf/plant, chlorophyll content (mg/g), number of primary leaf and number of secondary leaf, N, P, K, S and Zn uptake by stover and seed were found under S_3 (30 kg ha^{-1}). These findings highlight the synergistic effect of higher zinc and sulphur applications on plant growth and productivity.

Key words: DAS (days after sowing), Nutrient uptake, Plant height, Sulphur, Yield, Zinc.

INTRODUCTION

Oilseeds hold a distinguished position in Indian agriculture as a result of their critical contribution to the nation's sustainable economy. Edible vegetable oil is important for human nutrition. Edible oil, which has high energy content, is crucial for supplying humans with the calories they need. One of the most significant winter oil seed crops is Indian mustard. Due to a lack of accurate knowledge on its nutritional needs, mustard output is not effectively utilized. With a yield of 9.12 MT and an average productivity of 1586 kg/ha, Indian rapeseed and mustard grow on an area of around 7.2 million hectares (Anonymous, 2020).

For plants to thrive at their best, a N:S ratio of around 20:1 is necessary (Cram, 1990). When sulphur is insufficient, accumulation of non-protein substances such amides happens, increasing the N:S ratio. In addition, sulphate builds accumulated in plant tissues when the supply of S exceeds that needed for protein synthesis (Reneau *et al.*, 1986). The N:S ratio determines whether proteins are available or lacking in S. According to Spencer and Freney (1980), the N and S ratio is typically used as a diagnostic standard for S deficit. The N:S ratio can be found in tissues at a variety of various concentration levels, Schnug and Hanklaus (2000) noted, making its use as a diagnostic criteria less than ideal. Due to the ongoing loss of soil fertility, Zn deficiency in Indian soils is predicted to rise from 42 percent in 1970 to 63 percent by 2025 (Singh, 2011). According to Jena *et al.* (2008), the zinc deficit in alluvial soils varied from 7.0 to 76.0 percent, 2 to 12 percent in laterite and 42 percent in black soils. Black, mixed black and red and alluvial soils tend to be more zinc deficient than other soil types, according to Sahu and Mitra (1992). Zn deficit is due to Zn precipitating as hydroxide, carbonate and sulphide and to its adsorption on newly produced oxides of Fe with the highest surface area. Increased clay and silt concentration reduced the Zn-supplying ability of rice soils (Pal *et al., 2021*).Studies have shown that sulphur and zinc fertilization significantly improve soybean growth and yield attributes. Specifically, the application of both

[1]Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara-144 411, Punjab, India.
[2]MSM Institute of Ayurveda, Khanpur Kalan-131 305, Haryana, India.
[3]Mata Gujri College, Fatehgarh Sahib-140 406, Punjab, India.

Corresponding Author: Mayur Darvhankar, Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara-144 411, Punjab, India. Email: mayur.21878@lpu.co.in

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nutrients enhanced plant height, pod number, seed yield and stover yield(Imsong *et al.* 2023).In acidic Alfisols and Inceptisols, phosphorus levels up to 120 mg P kg^{-1} significantly enhanced rapeseed yield and phosphorus uptake, with single super phosphate performing better than Mussoorie rock phosphate (Maurya *et al.* 2023)

The productivity of oilseed is much lower than the global average (1.9 t ha^{-1}) and that of emerging nations (2.5 - 3.0 t ha^{-1}). Low productivity is mostly caused by improper or uneven fertiliser use, farming on marginal soils and rainfed conditions (Tripathi *et al.*, 2010). Therefore, there is a significant disparity between the demand for and production of mustard in our nation, or low productivity may be caused by oilseed crops continuously depleting the soil of its nutrients (Sudhakara and Hegde, 2011; Pant *et al.*, 2022). Organic manures, such as vermicompost and pressmud, improved the seed quality, including oil and protein content. Overall, the integration of foliar sulphur with organic and inorganic fertilizers improved both the yield and quality of canola, offering a sustainable approach for better production and soil health (Singh *et al.,* 2020). Therefore, improving sulphur and zinc utilization and managing soil-crop-sulphur-zinc fertilization are urgently needed to boost mustard crop yield. The goal of the current study was to determine the effects of zinc and sulphur application on growth and nutrient uptake by gobhi sarson.

MATERIALS AND METHODS

The study was carried out for a period of two years at the Research Farm, Lovely Professional University and Phagwara, Punjab, India (31°14'35.2" N latitude and 75°41'48.2" E longitude). The experiment location is in a semi-arid, subtropical climate zone. Summer temperatures ranged from 24 to 46.5°C and winter temperatures varied from 3.6 to 26°C. The majority of the yearly rainfall is anticipated during the monsoon season (July to September) and ranges from 500 to 800 mm on average. In the soil, the water is around 90–100 m below the surface. The soil composition of the region classified as Central alluvial plain or sandy loam, the soil surface, 0–15 cm, had a pH (7.65), EC (0.45 dS m^{-1}), medium SOC (0.57%) and also low status of available N, P_2O_5 and K_2O, S and Zn (185.7, 24.9, 198.5 kg ha^{-1}, 8.50 and 0.46 mg kg^{-1} respectively), for initial soil samples in October 2022.

The experiment was conducted with two factor zinc spray (through zinc oxide 39.5% Zn, 1.5 ml L^{-1}) and sulphur (through bentonite sulphur 90%) soil application comprised of Z_0-Control, Z_1-1 appl. (one spray @ 15 DAS), Z_2-2 appl. (two spray @ 15 + 45 DAS) and Z_3-3 appl. (three spray @ 15 + 45 + 75 DAS) and four sulphur application treatments viz., S_0-Control, S_1 (10 kg ha^{-1}), S_2 (20 kg ha^{-1}) and S_3 (30 kg ha^{-1}), were tested in factorial randomized block design replicated 3 times and recommended dose of fertilizer N, P_2O_5, K_2O (40:12:40) was applied and test variety was GSC-7. Growth parameters were recorded from five randomly tagged plants in net plot. The mean value of plant height was expressed in centimeter (cm), which was measured at 30, 60, 90 DAS and at the time of harvesting. Dry matter accumulation was recorded in gram per plant from three randomly selected plants at 30, 60 and 90 DAS. The samples were taken from second last rows and sun drying of samples was done prior to keeping in oven for achieving constant weight. Number of primary and secondary branches were counted from five tagged plants at 60 and 90 DAS and expressed as numbers of branches plant-1. Chlorophyll content was recorded with the help of chlorophyll meter (SPAD–502 Plus, Konica Minolta Optics, Inc., Japan) at 30, 60 and 90 DAS and expressed as SPAD unit. The seed and stover samples were digested in HNO_3 and $HClO_4$ mixture and sulphur and zinc were determined by turbidimetricmethod (Chesnin and Yien 1951) and atomic absorption spectrophotometer, respectively. Phosphorus in the acid extract was determined by vanadomolybdate yellow colour method (Jackson 1973) and K by flame photometer (Jackson 1973). The nitrogen was determined by Kjeldahl method (Jackson 1973).

RESULTS AND DISCUSSION

Growth parameter

The application of zinc and sulphur significantly affect plant height (Table 1). The maximum plant height were recorded (178.31 cm) under Z_3-3 appl. (three spray @ 15 + 45 + 75 DAS) at harvest and at par with Z_2-2 appl. (two spray @ 15 + 45 DAS) (167.54 cm) and minimum under (137.80 cm) Z_0-control treatment. The highest plant height under sulphur treatments were found under (174.62 cm) S_3-30 kg ha^{-1} followed by 170.75 cm, 154.88 cm and 136.62 cm S_2-20 kg ha^{-1}, S_1-10 kg ha^{-1} and S_0-control, respectively. Fresh weight (g) and dry weight (g) significantly affected by the application of zinc and sulphur (Table 2, 3). The highest fresh weight and dry weight 635.62 and 670.83 g were maximum found under Z3-3 appl. (three spray @ 15 + 45 + 75 DAS) and S_3-30 kg ha^{-1}, respectively at 120 DAS and dry weight (g) 55.58 and 56.76 g were also found highest in Z3-3 appl. (three spray @ 15 + 45 + 75 DAS) and S_3-30 kg ha^{-1}, respectively at harvest as compare to other treatments.

Data presented in Table 4 and 5 revealed that application of zinc and sulphur on number of leaf per plant, number of primary branches and secondary branches were found significant. Treatment Z_3-3 appl. (three spray @ 15 + 45 + 75 DAS) recorded highest (36.84) number of leaf per plant at 120 DAS followed by 35.90, 33.31 and 30.78 Z_2-2 appl. (two spray @ 15 + 45 DAS) (167.54 cm), Z_1-1 appl. (one spray @ 15 DAS) and Z_0-control, respectively at 120 DAS. In sulphur treatments maximum number of leaf per plant (37.55) in S_3-30 kg ha^{-1} followed by 35.61, 33.24 and 30.43 S_2-20 kg ha^{-1}, S_1-10 kg ha^{-1} and S_0-control, respectively at 120 DAS. Highest primary and secondary branches 5.06 and 16.15 were found under Z_3-3 appl. (three spray @ 15 + 45 + 75 DAS) which was remain at par with 4.95 and 15.93 Z_2-2 appl. (two spray @ 15 + 45 DAS) and minimum under 4.16 and 13.58 Z_0-control treatment, respectively. Whereas S_3-30 kg ha^{-1} was recorded maximum 5.26 and 16.40 primary and secondary branches per plant, respectively than rest of treatments.

Application of zinc and sulphur significantly affected the chlorophyll content in gobhi sarson (Table 5). Application of Z_3-3 appl. (three spray @ 15 + 45 + 75 DAS) recorded maximum chlorophyll content 2.55 (mg/g) and found at par with Z_2-2 appl. (two spray @ 15 + 45 DAS) 2.52 (mg/g). Whereas in sulphur treatments highest chlorophyll content 2.62 (mg/g) recorded under S_3-30 kg ha^{-1} followed by 2.52, 2.24 and 2.24 (mg/g) S_2-20 kg ha^{-1}, S_1-10 kg ha^{-1} and S_0-control, respectively.

The probable reason may be that adequate supply of all the nutrients, particularly sulphur which resulted in greater accumulation of carbohydrates, amino acids and their translocation to the productive organs, which, in-turn improved in all the growth and yield attributing characters (Singh and Meena, 2004; Pant *et al.*, 2022). Additionally, increased protein synthesis, glucose metabolism and photosynthate translocation with S administration are to blame (Thompson *et al.*, 1986). Alloway (2008) states that while B assisted in the development of reproductive structures and the translocation of photosynthates toward sinks, Zn fertilization increased the activity of several enzymes involved in photosynthesis, CO_2 assimilation, starch formation and protein synthesis (Shireen*et al.*, 2018).According to Singh *et al.* (2010), there was a discernible increase in 1000-seed weight, seed production and stover output of up to 30 kg S ha^{-1}.

Nutrient uptake

The nitrogen uptake was ranges from 53.03 to 80.83 kg/ha in seed and 27.27 to 39.64 kg/ha in stover (Table 6) highest nitrogen uptake in seed was recorded under 80.83 kg/ha Z_3-3 appl. (three spray @ 15 + 45 + 75 DAS) over 53.03 kg/ha under Z_0-control treatment. Whereas in sulphur treatments highest nitrogen uptake 41.11 kg/ha recorded under S_3-30 kg ha^{-1} followed by 37.49, 32.63 and 27.43 kg/ha S_2-20 kg ha^{-1}, S_1-10 kg ha^{-1} and S_0-control, respectively. Interactive effect of sulphur and zinc was found significant

Table 1: Effect of zinc and sulphur application on plant height at different stages of Gobhi sarson (pooled data).

Treatments	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
Zinc application					
Z_0-Control	10.56	43.10	113.41	129.05	137.80
Z_1-1 appl.	11.67	45.34	125.53	140.42	153.20
Z_2-2 appl.	12.47	47.55	135.65	151.21	167.54
Z_3-3 appl.	12.89	49.65	143.97	161.04	178.31
SEm±	0.17	0.54	1.79	2.13	2.49
CD (P=0.05)	0.49	1.53	5.06	6.03	7.05
Sulphur levels					
S_0-Control	10.46	43.54	117.17	131.64	136.62
S_1-10 kg/ha	11.57	45.82	127.61	142.46	154.88
S_2-20 kg/ha	12.41	48.06	136.07	151.93	170.75
S_3-30 kg/ha	13.16	48.23	137.72	155.69	174.62
SEm±	0.17	0.54	1.79	2.13	2.49
CD (P=0.05)	0.49	1.53	5.06	6.03	7.05

Table 2: Effect of zinc and sulphur application on fresh weight at different stages of Gobhi sarson (pooled data).

Treatments	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
Zinc application					
Z_0-Control	3.79	86.42	296.95	442.88	326.44
Z_1-1 appl.	4.19	102.52	338.94	528.93	375.65
Z_2-2 appl.	4.45	116.29	377.44	613.51	408.46
Z_3-3 appl.	4.55	120.38	382.37	635.62	417.69
SEm±	0.05	1.72	5.30	9.00	5.49
CD (P=0.05)	0.14	4.86	15.00	25.46	15.54
Sulphur levels					
S_0-Control	3.74	86.37	292.54	429.69	323.18
S_1-10 kg/ha	4.18	100.63	336.68	517.04	369.19
S_2-20 kg/ha	4.42	113.65	370.58	603.40	403.16
S_3-30 kg/ha	4.65	124.97	395.92	670.83	432.72
SEm±	0.05	1.72	5.30	9.00	5.49
CD (P=0.05)	0.14	4.86	15.00	25.46	15.54

Table 3: Effect of zinc and sulphur application on dry weight at different stages of Gobhi sarson (pooled data).

Treatments	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
Zinc application					
Z_0-Control	0.60	11.86	32.55	42.91	46.59
Z_1-1 appl.	0.69	13.69	34.80	47.78	51.26
Z_2-2 appl.	0.75	14.55	36.89	51.39	54.32
Z_3-3 appl.	0.77	14.69	37.19	52.24	55.58
SEm$\pm$	0.01	0.18	0.58	0.67	0.73
CD (P=0.05)	0.03	0.52	1.65	1.90	2.07
Sulphur levels					
S_0-Control	0.60	11.94	31.73	42.29	46.67
S_1-10 kg/ha	0.68	13.26	34.23	47.38	50.57
S_2-20 kg/ha	0.74	14.39	36.54	50.76	53.76
S_3-30 kg/ha	0.79	15.21	38.94	53.91	56.76
SEm$\pm$	0.01	0.18	0.58	0.67	0.73
CD (P=0.05)	0.03	0.52	1.65	1.90	2.07

Table 4: Effect of zinc and sulphur application on number of leaf per plant at different stages of Gobhi sarson (pooled data).

Treatments	30 DAS	60 DAS	90 DAS	120 DAS
Zinc application				
Z_0-Control	4.11	17.63	25.94	30.78
Z_1-1 appl.	4.67	19.18	27.84	33.31
Z_2-2 appl.	5.10	20.11	29.51	35.90
Z_3-3 appl.	5.52	20.44	29.71	36.84
SEm$\pm$	0.09	0.23	0.38	0.46
CD (P=0.05)	0.24	0.66	1.08	1.30
Sulphur levels				
S_0-Control	4.17	17.75	25.78	30.43
S_1-10 kg/ha	4.72	18.88	27.51	33.24
S_2-20 kg/ha	5.24	19.89	29.11	35.61
S_3-30 kg/ha	5.28	20.86	30.62	37.55
SEm$\pm$	0.09	0.23	0.38	0.46
CD (P=0.05)	0.24	0.66	1.08	1.30

Table 5: Effect zinc and sulphur application on on chlorophyll content at 60 DAS, number of primary branches and secondary branches per plant of Gobhi sarson (pooled data).

Treatments	Chlorophyll content (mg/g)	Number of primary branches per plant	Number of secondary branches per plant
Zinc application			
Z_0-Control	2.29	4.16	13.58
Z_1-1 appl.	2.41	4.59	14.94
Z_2-2 appl.	2.52	4.95	15.93
Z_3-3 appl.	2.55	5.06	16.15
SEm$\pm$	0.02	0.06	0.20
CD (P=0.05)	0.07	0.17	0.56
Sulphur levels			
S_0-Control	2.24	4.08	13.58
S_1-10 kg/ha	2.39	4.51	14.89
S_2-20 kg/ha	2.52	4.92	15.74
S_3-30 kg/ha	2.62	5.26	16.40
SEm$\pm$	0.02	0.06	0.20
CD (P=0.05)	0.07	0.17	0.56

(Table 7) maximum nitrogen uptake was found in seed 95.55 kg/ha under Z_3-3 appl. + S_3 (three spray @ 15 + 45 + 75 DAS + 30 kg ha^{-1}) and at par with 90.46 kg/ha Z_2-2 appl. + S_3 (two spray @ 15 + 45 DAS + 30 kg ha^{-1}).

Data presented in Table 8 and 10 showed that the uptake of phosphorus and potassium significantly increased with increasing the application of zinc and sulphur. The interactive effect of zinc and sulphur was found significant on uptake of phosphorus and potassium (Table 9 and 11). Highest phosphorus and potassium uptake were found in 17.06 and 19.87 kg/ha under Z_3-3 appl. + S_3 (three spray @ 15 + 45 + 75 DAS + 30 kg ha^{-1}) and at par with 16.24 and

Table 6: Effect zinc and sulphur application on N content and their uptake by seed and stover of Gobhi sarson (pooled data).

Treatments	N content (%)		N uptake (kg/ha)	
	Seed	Stover	Seed	Stover
Zinc application				
Z_0-Control	2.939	0.597	53.03	27.27
Z_1-1 appl.	3.139	0.636	66.27	33.30
Z_2-2 appl.	3.265	0.667	77.38	38.44
Z_3-3 appl.	3.317	0.671	80.83	39.64
SEm±	0.022	0.004	0.91	0.42
CD (P=0.05)	0.063	0.011	2.58	1.20
Sulphur levels				
S_0-Control	2.940	0.597	56.12	27.43
S_1-10 kg/ha	3.139	0.636	66.25	32.63
S_2-20 kg/ha	3.268	0.664	75.47	37.49
S_3-30 kg/ha	3.313	0.674	79.66	41.11
SEm±	0.022	0.004	0.91	0.42
CD (P=0.05)	0.063	0.011	2.58	1.20

Table 7: Interactive effect of zinc and sulphur applicationon N uptake in seed of Gobhi sarson (pooled data).

Treatments	Pooled			
	S_0	S_1	S_2	S_3
Z_0	45.22	50.73	56.61	59.57
Z_1	56.87	64.00	71.15	73.06
Z_2	60.25	72.02	86.78	90.46
Z_3	62.16	78.23	87.35	95.55
SEm±	1.82			
CD (P=0.05)	5.16			

Table 8: Effect of zinc and sulphur application on P content and their uptake by seed and stover of Gobhi sarson (pooled data).

Treatments	P content (%)		P uptake (kg/ha)	
	Seed	Stover	Seed	Stover
Zinc application				
Z_0-Control	0.513	0.167	9.26	7.66
Z_1-1 appl.	0.568	0.184	12.00	9.65
Z_2-2 appl.	0.585	0.198	13.87	11.45
Z_3-3 appl.	0.591	0.200	14.41	11.85
SEm±	0.004	0.001	0.16	0.13
CD (P=0.05)	0.012	0.004	0.45	0.38
Sulphur levels				
S_0-Control	0.514	0.167	9.82	7.68
S_1-10 kg/ha	0.568	0.185	11.99	9.49
S_2-20 kg/ha	0.583	0.198	13.48	11.20
S_3-30 kg/ha	0.592	0.200	14.25	12.24
SEm±	0.004	0.001	0.16	0.13
CD (P=0.05)	0.012	0.004	0.45	0.38

18.97 kg/ha Z_2-2 appl. + S_3 (two spray @ 15 + 45 DAS + 30 kg ha^{-1}), respectively in seed and lowest under 7.74 and 8.42 kg/ha in Z_0-Control + S_0-Control.

Zinc uptake in gobhi sarson seed was found significant (Table 12). Maximum zinc uptake in seed was recorded under 162.43 g/kg Z_3-3 appl. (three spray @ 15 + 45 + 75 DAS) over 99.83 g/kg under Z_0-control treatment. Whereas in sulphur treatments highest zinc uptake167.93 g/kg recorded under S_3-30 kg ha^{-1} followed by 152.59, 127.61 and 99.86 g/kg S_2-20 kg ha^{-1}, S_1-10 kg ha^{-1} and S_0-control, respectively. Interactive effect of sulphur and zinc was found significant (Table 13) maximum zinc uptake was found in seed 106.99 g/kg under Z_3-3 appl. + S_3 (three spray @ 15 + 45 + 75 DAS + 30 kg ha^{-1}) and at par with 101.76 g/kg Z_2-2 appl. + S_3 (two spray @ 15 + 45 DAS + 30 kg ha^{-1}).

Data presented in Table 14 showed that the uptake of sulphur significantly increased with increasing the application of zinc and sulphur. The interactive effect of zinc and sulphur was found significant on uptake of sulphur (Table 15). Highest zinc uptake were found in 26.30 g/kg under Z_3-3 appl. + S_3 (three spray @ 15 + 45 + 75 DAS + 30 kg ha^{-1}) and at par with 24.93 g/kg Z_2-2 appl. + S_3 (two spray @ 15 + 45 DAS + 30 kg ha^{-1}) in seed and lowest under 12.13 g/kg in Z_0-Control + S_0-Control.

The favourable influence of zinc on photosynthesis and metabolic processes augments the production of photosynthates and their translocation to different plants

Table 9: Interactive effect of zinc and sulphur application on P uptake in seed of Gobhi sarson (pooled data).

Treatments	Pooled			
	S_0	S_1	S_2	S_3
Z_0	7.74	8.98	9.89	10.42
Z_1	10.10	11.75	12.89	13.26
Z_2	10.58	13.08	15.56	16.24
Z_3	10.86	14.13	15.57	17.06
SEm±	0.32			
CD (P=0.05)	0.90			

Table 10: Effect of zinc and sulphur application on K content and their uptake by seed and stover of Gobhi sarson (pooled data).

Treatments	K content (%)		K uptake (kg/ha)	
	Seed	Stover	Seed	Stover
Zinc application				
Z_0-Control	0.567	0.095	10.25	4.41
Z_1-1 appl.	0.615	0.144	13.01	7.69
Z_2-2 appl.	0.671	0.177	15.94	10.42
Z_3-3 appl.	0.676	0.185	16.51	11.18
SEm±	0.004	0.001	0.19	0.12
CD (P=0.05)	0.011	0.003	0.53	0.35
Sulphur levels				
S_0-Control	0.567	0.095	10.84	4.39
S_1-10 kg/ha	0.616	0.144	13.03	7.52
S_2-20 kg/ha	0.671	0.177	15.54	10.17
S_3-30 kg/ha	0.676	0.186	16.30	11.61
SEm±	0.004	0.001	0.19	0.12
CD (P=0.05)	0.011	0.003	0.53	0.35

Table 11: Interactive zinc and sulphur application on K uptake in seed of Gobhi sarson (pooled data).

Treatments	Pooled			
	S_0	S_1	S_2	S_3
Z_0	8.42	9.61	11.22	11.73
Z_1	10.76	12.32	14.33	14.62
Z_2	11.95	14.53	18.31	18.97
Z_3	12.23	15.65	18.28	19.87
SEm±	0.38			
CD (P=0.05)	1.07			

parts including seed, which ultimately increased the uptake of N,P,K, Zn and S in seed and stover (Shireen *et al.*, 2018; Dubey *et al.* 2013; Pant *et al.*, 2022) . Release of nutrients in available form and other physical properties might have influenced the availability of other nutrients leading to their absorption, thereby showing a higher uptake with application of sulphur. Increase in uptake of nutrients with sulphur application at varying levels has been reported by Jat and Mehra (2007).

Table 12: Effect of zinc and sulphur application on Zn content and their uptake by seed and stover of Gobhi sarson (pooled data).

Treatments	Zn content (mg/g)		Zn uptake (g/kg)	
	Seed	Stover	Seed	Stover
Zinc application				
Z_0-Control	30.77	21.79	55.58	99.83
Z_1-1 appl.	33.76	24.72	71.36	129.96
Z_2-2 appl.	36.19	26.89	85.98	155.77
Z_3-3 appl.	36.60	27.37	89.38	162.43
SEm$\pm$	0.22	0.18	1.14	2.04
CD (P=0.05)	0.61	0.52	3.23	5.76
Sulphur levels				
S_0-Control	30.87	21.68	59.01	99.86
S_1-10 kg/ha	33.79	24.78	71.49	127.61
S_2-20 kg/ha	36.21	26.92	83.86	152.59
S_3-30 kg/ha	36.47	27.39	87.94	167.93
SEm$\pm$	0.22	0.18	1.14	2.04
CD (P=0.05)	0.61	0.52	3.23	5.76

Table 13: Interactive effect zinc and sulphur application on Zn uptake in seed of Gobhi sarson (pooled data).

Treatments	Pooled			
	S_0	S_1	S_2	S_3
Z_0	45.81	52.71	60.53	63.27
Z_1	59.21	68.33	78.17	79.75
Z_2	64.64	79.25	98.27	101.76
Z_3	66.39	85.68	98.47	106.99
SEm$\pm$	2.29			
CD (P=0.05)	6.47			

Table 14: Effect of zinc and sulphur application on S content and their uptake by seed and stover of Gobhi sarson (pooled data).

Treatments	S content (%)		S uptake (kg/ha)	
	Seed	Stover	Seed	Stover
Zinc application				
Z_0-Control	0.794	0.397	14.33	18.20
Z_1-1 appl.	0.849	0.447	17.94	23.51
Z_2-2 appl.	0.894	0.484	21.20	28.03
Z_3-3 appl.	0.907	0.490	22.11	29.04
SEm$\pm$	0.006	0.003	0.27	0.34
CD (P=0.05)	0.017	0.009	0.76	0.98
Sulphur levels				
S_0-Control	0.794	0.395	15.16	18.19
S_1-10 kg/ha	0.847	0.447	17.88	22.98
S_2-20 kg/ha	0.896	0.485	20.70	27.45
S_3-30 kg/ha	0.908	0.493	21.84	30.17
SEm$\pm$	0.006	0.003	0.27	0.34
CD (P=0.05)	0.017	0.009	0.76	0.98

Table 15: Interactive effect of zinc and sulphur application on Suptake in seed of Gobhi sarson (pooled data).

Treatments	Pooled			
	S_0	S_1	S_2	S_3
Z_0	12.13	13.59	15.41	16.20
Z_1	15.28	17.18	19.40	19.91
Z_2	16.37	19.55	23.93	24.93
Z_3	16.87	21.20	24.06	26.30
SEm±	0.54			
CD (P=0.05)	1.52			

CONCLUSION

The plant height (cm), fresh weight (g), dry weight(g), number of leaf/plant, chlorophyll content (mg/g), number of primary leaf and number of secondary leaf was recorded maximum under Z_3-3 appl. (three spray @ 15 + 45 + 75 DAS) and which was at par with Z_2-2 appl. (two spray @ 15 + 45 DAS) and similar trend were also found in N, P, K, S and Zn uptake by stover and seed. In sulphur levels highest plant height (cm), fresh weight (g), dry weight(g), number of leaf/plant, chlorophyll content (mg/g), number of primary leaf and number of secondary leaf, N, P, K, S and Zn uptake by stover and seed were found under S_3 (30 kg ha^{-1}).

Conflict of interest

All authors declare that they have no conflict of interest.

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