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Response of mustard (*Brassica juncea* L.) to different levels of sulphur and zinc on yield and oil content

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Abstract
A field experiment was conducted during the Rabi season of 2025-26 at the Instructional Farm, Career Point University, Kota (Rajasthan), to evaluate the effect of different levels of sulphur and zinc on growth, yield, and quality of mustard. The experiment consisted of 16 treatment combinations with four levels of sulphur (0, 10, 20, and 30 kg ha^{-1}) and four levels of zinc (0, 5, 10, and 15 kg ha^{-1}) arranged in Factorial Randomized Block Design with three replications. Results revealed that combined application of sulphur and zinc significantly improved growth parameters, yield attributes, and yield. The highest number of siliquae per plant (277.4), siliqua length (5.6 cm), and improved growth were recorded under S_3Z_3 (30 kg S + 15 kg Zn ha^{-1}). However, maximum seed yield (24.2 q ha^{-1}) was observed under S_1Z_0 (10 kg S ha^{-1}) and S_3Z_2 (30 kg S + 10 kg Zn ha^{-1}). The study concluded that balanced application of sulphur and zinc enhances productivity and quality of mustard.

Keywords: Mustard, sulphur, zinc, yield, oil content, nutrient management

Introduction
Mustard is one of the major oilseed crops in India, contributing significantly to edible oil production. However, its productivity remains low due to imbalanced fertilization and micronutrient deficiencies. Sulphur plays a vital role in oil synthesis and protein formation, while zinc is essential for enzyme activation, auxin synthesis, and reproductive development. Deficiency of these nutrients leads to reduced growth, poor seed formation, and low yield. The combined application of sulphur and zinc has been reported to improve growth, yield, and oil content due to their synergistic interaction. Therefore, the present study was conducted to evaluate their effect on mustard productivity.

Materials and Methods
Experimental site
The experiment was conducted at Career Point University, Kota (Rajasthan) during Rabi 2025-26 under semi-arid climatic conditions.

Soil characteristics
The soil was sandy clay loam, low in nitrogen, medium in phosphorus and potassium, and moderately alkaline.

Treatments and Design
Factorial Randomized Block Design (FRBD),16 treatments (4 sulphur × 4 zinc levels), 3 replications.

Treatment levels
Sulphur: 0, 10, 20, 30 kg ha^{-1}
Zinc: 0, 5, 10, 15 kg ha^{-1}

Crop details
Crop: Mustard

Variety: DRMRIJ-31
Spacing: 40 × 10 cm

Observations recorded

Growth parameters (plant height, branches, dry matter), Yield attributes (siliquae/plant, seeds/siliqua), Yield (seed, stover, biological), Quality parameters

Plant population

Data pertaining to plant population at 15 DAS revealed that different treatment combinations, *viz.*, control (T_1: 0 kg S + 0 kg Zn ha^{-1}), application of zinc alone (T_2-T_4), sulphur alone (T_5, T_9, T_{13}) and their combinations (T_6-T_8, T_{10}-T_{12}, T_{14}-T_{16}), did not significantly influence plant population.

Table 1: Effect of different Zink and Sulphur levels on plant population

S.No.	Treatment Combination	Plant population (No. m^{-2})
		15 DAS
T_1	Control S_0Z_0: 0 kg S + 0 kg Zn ha^{-1}	13.9
T_2	Sulphur 0 kg ha^{-1} + Zinc 5 kg ha^{-1}	14.1
T_3	Sulphur 0 kg ha^{-1} + Zinc 10 kg ha^{-1}	14.2
T_4	Sulphur 0 kg ha^{-1} + Zinc 15 kg ha^{-1}	14.1
T_5	Sulphur 10 kg ha^{-1} + Zinc 0 kg ha^{-1}	14.1
T_6	Sulphur 10 kg ha^{-1} + Zinc 5 kg ha^{-1}	14.2
T_7	Sulphur 10 kg ha^{-1} + Zinc 10 kg ha^{-1}	14.0
T_8	Sulphur 10 kg ha^{-1} + Zinc 15 kg ha^{-1}	14.0
T_9	Sulphur 20 kg ha^{-1} + Zinc 0 kg ha^{-1}	14.0
T_{10}	Sulphur 20 kg ha^{-1} + Zinc 5 kg ha^{-1}	14.0
T_{11}	Sulphur 20 kg ha^{-1} + Zinc 10 kg ha^{-1}	14.2
T_{12}	Sulphur 20 kg ha^{-1} + Zinc 15 kg ha^{-1}	14.2
T_{13}	Sulphur 30 kg ha^{-1} + Zinc 0 kg ha^{-1}	14.2
T_{14}	Sulphur 30 kg ha^{-1} + Zinc 5 kg ha^{-1}	14.2
T_{15}	Sulphur 30 kg ha^{-1} + Zinc 10 kg ha^{-1}	14.2
T_{16}	Sulphur 30 kg ha^{-1} + Zinc 15 kg ha^{-1}	14.1
SEm±		0.70
CD (P = 0.05)		NS

However, numerically higher plant population (14.2 plants m^{-2}) was recorded under T_3 (0 kg S + 10 kg Zn ha^{-1}), T_6 (10 kg S + 5 kg Zn ha^{-1}), T_{11} (20 kg S + 10 kg Zn ha^{-1}), T_{12} (20 kg S + 15 kg Zn ha^{-1}), T_{13} (30 kg S + 0 kg Zn ha^{-1}), T_{14} (30 kg S + 5 kg Zn ha^{-1}) and T_{15} (30 kg S + 10 kg Zn ha^{-1}).
Although the lowest value (13.9 plants m^{-2}) was observed under control (T_1), all treatments were found statistically at par.

Plant height (cm)

Data pertaining to plant height at different growth stages indicated significant variation due to treatment combinations. At 20 DAS, maximum plant height (18.4 cm) was recorded under T_3 (0 kg S + 10 kg Zn ha^{-1}) and T_{15} (30 kg S + 10 kg Zn ha^{-1}), which were at par with T_{12} (20 kg S + 15 kg Zn ha^{-1}) and T_{16} (30 kg S + 15 kg Zn ha^{-1}). However, the lowest plant height (12.2 cm) was recorded under control (T_1).

Table 2: Effect of different Zink and Sulphur levels on Plant Height

S.No.	Treatment Combination	Plant Height			
		20 DAS	40 DAS	60 DAS	At Harvest
T_1	Control S_0Z_0: 0 kg S + 0 kg Zn ha^{-1}	12.2	115.3	136.7	152.4
T_2	Sulphur 0 kg ha^{-1} + Zinc 5 kg ha^{-1}	16.8	128.1	155.1	173.1
T_3	Sulphur 0 kg ha^{-1} + Zinc 10 kg ha^{-1}	18.4	147.7	182.8	205.4
T_4	Sulphur 0 kg ha^{-1} + Zinc 15 kg ha^{-1}	17.2	144.2	176.8	200.4
T_5	Sulphur 10 kg ha^{-1} + Zinc 0 kg ha^{-1}	17.6	152.5	187.9	211.7
T_6	Sulphur 10 kg ha^{-1} + Zinc 5 kg ha^{-1}	16.1	126.0	152.5	171.0
T_7	Sulphur 10 kg ha^{-1} + Zinc 10 kg ha^{-1}	15.0	133.0	162.2	183.1
T_8	Sulphur 10 kg ha^{-1} + Zinc 15 kg ha^{-1}	15.3	134.8	164.8	187.1
T_9	Sulphur 20 kg ha^{-1} + Zinc 0 kg ha^{-1}	16.5	140.0	169.0	191.0
T_{10}	Sulphur 20 kg ha^{-1} + Zinc 5 kg ha^{-1}	14.6	130.7	160.3	177.9
T_{11}	Sulphur 20 kg ha^{-1} + Zinc 10 kg ha^{-1}	15.5	137.6	167.4	188.8
T_{12}	Sulphur 20 kg ha^{-1} + Zinc 15 kg ha^{-1}	17.9	142.3	171.8	195.5
T_{13}	Sulphur 30 kg ha^{-1} + Zinc 0 kg ha^{-1}	16.1	126.0	152.5	171.0
T_{14}	Sulphur 30 kg ha^{-1} + Zinc 5 kg ha^{-1}	17.2	144.2	176.8	200.4
T_{15}	Sulphur 30 kg ha^{-1} + Zinc 10 kg ha^{-1}	18.4	147.7	182.8	205.4
T_{16}	Sulphur 30 kg ha^{-1} + Zinc 15 kg ha^{-1}	17.6	152.5	187.9	211.7
SEm±		0.6	4.8	5.9	6.7
CD (P = 0.05)		1.7	13.9	17.1	19.2

At 40 DAS, T_3 and T_{15} recorded significantly higher plant height (147.7 cm), although these remained at par with T_4 (0 kg S + 15 kg Zn ha^{-1}) and T_{14} (30 kg S + 5 kg Zn ha^{-1}). At 60 DAS, maximum plant height (182.8 cm) was again recorded under T_3 and T_{15}, however at par with T_4 and T_{14}.

At harvest, T_5 (10 kg S + 0 kg Zn ha^{-1}) and T_{16} (30 kg S + 15 kg Zn ha^{-1}) recorded the highest plant height (211.7 cm), although statistically at par with T_3 and T_{15}.
Thus, combined application of sulphur and zinc improved plant growth; however, several treatments remained at par.

Primary branches (No. plant⁻¹)

Data pertaining to primary branches showed significant increase with application of nutrients. At 40 DAS, maximum number of primary branches (5.3) was recorded under T_5 (10 kg S + 0 kg Zn ha^{-1}) and T_{16} (30 kg S + 15 kg Zn ha^{-1}), which were at par with T_3 and T_{14}. At 60 DAS, similar trend was observed where T_5 and T_{16} recorded higher values (7.0), although at par with T_3 (0 kg S + 10 kg Zn ha^{-1}).

Table 3: Effect of different Zink and Sulphur levels on Primary Branches (No. plant^{-1})

S.No.	Treatment Combination	Primary Branches		
		40 DAS	0 DAS	At Harvest
T_1	Control S_0Z_0: 0 kg S + 0 kg Zn ha^{-1}	3.3	4.9	5.3
T_2	Sulphur 0 kg ha^{-1} + Zinc 5 kg ha^{-1}	4.0	5.6	6.0
T_3	Sulphur 0 kg ha^{-1} + Zinc 10 kg ha^{-1}	5.2	6.8	7.7
T_4	Sulphur 0 kg ha^{-1} + Zinc 15 kg ha^{-1}	5.0	6.6	7.5
T_5	Sulphur 10 kg ha^{-1} + Zinc 0 kg ha^{-1}	5.3	7.0	8.1
T_6	Sulphur 10 kg ha^{-1} + Zinc 5 kg ha^{-1}	3.8	5.4	5.8
T_7	Sulphur 10 kg ha^{-1} + Zinc 10 kg ha^{-1}	4.4	6.1	6.6
T_8	Sulphur 10 kg ha^{-1} + Zinc 15 kg ha^{-1}	4.5	6.2	6.8
T_9	Sulphur 20 kg ha^{-1} + Zinc 0 kg ha^{-1}	4.9	6.4	7.1
T_{10}	Sulphur 20 kg ha^{-1} + Zinc 5 kg ha^{-1}	4.2	5.9	6.3
T_{11}	Sulphur 20 kg ha^{-1} + Zinc 10 kg ha^{-1}	4.6	6.3	6.9
T_{12}	Sulphur 20 kg ha^{-1} + Zinc 15 kg ha^{-1}	4.9	6.5	7.3
T_{13}	Sulphur 30 kg ha^{-1} + Zinc 0 kg ha^{-1}	4.0	5.6	6.0
T_{14}	Sulphur 30 kg ha^{-1} + Zinc 5 kg ha^{-1}	5.2	6.8	7.7
T_{15}	Sulphur 30 kg ha^{-1} + Zinc 10 kg ha^{-1}	5.0	6.6	7.5
T_{16}	Sulphur 30 kg ha^{-1} + Zinc 15 kg ha^{-1}	5.3	7.0	8.1
SEm±		0.2	0.2	0.3
CD (P = 0.05)		0.5	0.6	0.7

At harvest, maximum number of primary branches (8.1) was recorded under T_5 and T_{16}, whereas control (T_1) recorded minimum values. Moreover, treatments involving sulphur application showed better branching; however, several treatments were statistically at par.

Secondary branches (No. plant⁻¹)

Data pertaining to secondary branches revealed significant differences among treatments. At 40 DAS, maximum number of secondary branches (8.1) was recorded under T_5 and T_{16}, which were at par with T_3 and T_{14}.

At 60 DAS, highest value (13.0) was observed under T_5 (10 kg S + 0 kg Zn ha^{-1}) and T_{16} (30 kg S + 15 kg Zn ha^{-1}), whereas control recorded the lowest.

At harvest, T_5 and T_{16} again recorded maximum values (17.9), although at par with T_3 and T_{14}.

Table 4: Effect of different Zink and Sulphur levels on Secondary Branches (No. plant^{-1})

S.No.	Treatment Combination	Secondary Branches		
		40 DAS	60 DAS	At Harvest
T_1	Control S_0Z_0: 0 kg S + 0 kg Zn ha^{-1}	5.8	9.8	12.8
T_2	Sulphur 0 kg ha^{-1} + Zinc 5 kg ha^{-1}	6.5	10.7	14.3
T_3	Sulphur 0 kg ha^{-1} + Zinc 10 kg ha^{-1}	7.9	12.8	17.5
T_4	Sulphur 0 kg ha^{-1} + Zinc 15 kg ha^{-1}	7.8	12.4	17.2
T_5	Sulphur 10 kg ha^{-1} + Zinc 0 kg ha^{-1}	8.1	13.0	17.9
T_6	Sulphur 10 kg ha^{-1} + Zinc 5 kg ha^{-1}	6.3	10.6	13.8
T_7	Sulphur 10 kg ha^{-1} + Zinc 10 kg ha^{-1}	6.8	11.4	14.8
T_8	Sulphur 10 kg ha^{-1} + Zinc 15 kg ha^{-1}	7.0	11.6	15.3
T_9	Sulphur 20 kg ha^{-1} + Zinc 0 kg ha^{-1}	7.5	12.1	16.5
T_{10}	Sulphur 20 kg ha^{-1} + Zinc 5 kg ha^{-1}	6.6	11.1	16.0
T_{11}	Sulphur 20 kg ha^{-1} + Zinc 10 kg ha^{-1}	7.3	11.9	16.3
T_{12}	Sulphur 20 kg ha^{-1} + Zinc 15 kg ha^{-1}	7.7	12.3	16.8
T_{13}	Sulphur 30 kg ha^{-1} + Zinc 0 kg ha^{-1}	7.5	12.1	16.5
T_{14}	Sulphur 30 kg ha^{-1} + Zinc 5 kg ha^{-1}	7.9	12.8	17.5
T_{15}	Sulphur 30 kg ha^{-1} + Zinc 10 kg ha^{-1}	7.8	12.4	17.2
T_{16}	Sulphur 30 kg ha^{-1} + Zinc 15 kg ha^{-1}	8.1	13.0	17.9
SEm±		0.3	0.4	0.6
CD (P = 0.05)		0.7	1.2	1.7

Dry matter accumulation (g plant⁻¹)

Data pertaining to dry matter accumulation indicated significant increase with nutrient application.

At 20 DAS, maximum dry matter (8.6 g) was recorded under T_3 (0 kg S + 10 kg Zn ha^{-1}) and T_{14} (30 kg S + 5 kg Zn ha^{-1}), although at par with T_{12}. At 40 DAS, T_5 (10 kg S + 0 kg Zn ha^{-1}) and T_{16} (30 kg S + 15 kg Zn ha^{-1}) recorded maximum dry matter (29.6 g). At 60 DAS and at harvest, maximum dry matter accumulation (62.9 g and 99.6 g, respectively) was recorded under T_5 and T_{16}, whereas control recorded the lowest values.

Table 5: Effect of different Zink and Sulphur levels on Dry matter accumulation (g $plant^{-1}$)

S.No.	Treatment Combination	Dry matter accumulation (g $plant^{-1}$)			
		20 DAS	40 DAS	60 DAS	At Harvest
T_1	Control S_0Z_0: 0 kg S + 0 kg Zn ha^{-1}	5.2	13.8	37.2	51.6
T_2	Sulphur 0 kg ha^{-1} + Zinc 5 kg ha^{-1}	7.5	17.2	45.4	63.7
T_3	Sulphur 0 kg ha^{-1} + Zinc 10 kg ha^{-1}	8.6	25.8	59.6	91.8
T_4	Sulphur 0 kg ha^{-1} + Zinc 15 kg ha^{-1}	7.6	24.6	57.8	90.6
T_5	Sulphur 10 kg ha^{-1} + Zinc 0 kg ha^{-1}	7.8	29.6	62.9	99.6
T_6	Sulphur 10 kg ha^{-1} + Zinc 5 kg ha^{-1}	7.0	16.3	43.5	62.3
T_7	Sulphur 10 kg ha^{-1} + Zinc 10 kg ha^{-1}	5.8	20.2	50.1	71.3
T_8	Sulphur 10 kg ha^{-1} + Zinc 15 kg ha^{-1}	6.2	22	51.6	76.2
T_9	Sulphur 20 kg ha^{-1} + Zinc 0 kg ha^{-1}	7.3	23.7	55.1	85.8
T_{10}	Sulphur 20 kg ha^{-1} + Zinc 5 kg ha^{-1}	5.7	18.5	46.9	66.4
T_{11}	Sulphur 20 kg ha^{-1} + Zinc 10 kg ha^{-1}	6.6	22.8	53.5	81.3
T_{12}	Sulphur 20 kg ha^{-1} + Zinc 15 kg ha^{-1}	8.3	24.1	55.5	88.7
T_{13}	Sulphur 30 kg ha^{-1} + Zinc 0 kg ha^{-1}	7.3	23.7	55.1	85.8
T_{14}	Sulphur 30 kg ha^{-1} + Zinc 5 kg ha^{-1}	8.6	25.8	59.6	91.8
T_{15}	Sulphur 30 kg ha^{-1} + Zinc 10 kg ha^{-1}	7.6	24.6	57.8	90.6
T_{16}	Sulphur 30 kg ha^{-1} + Zinc 15 kg ha^{-1}	7.8	29.6	62.9	99.6
SEm±		0.3	0.8	1.8	2.8
CD (P = 0.05)		0.7	2.3	5.4	8.1

Yield attributes

Data pertaining to yield attributes *viz*., number of siliquae $plant^{-1}$, siliqua length (cm), number of seeds $siliqua^{-1}$ and test weight (g) as influenced by different levels of sulphur and zinc are presented below.

Number of siliquae $plant^{-1}$

Data revealed that the number of siliquae $plant^{-1}$ was significantly influenced by different treatment combinations. The maximum number of siliquae $plant^{-1}$ (277.4) was recorded under T_{16} (30 kg S + 15 kg Zn ha^{-1}), which was significantly superior over most of the treatments; however, it remained at par with T_{14} (30 kg S + 5 kg Zn ha^{-1}) and T_{15} (30 kg S + 10 kg Zn ha^{-1}).

Although T_5 (10 kg S + 0 kg Zn ha^{-1}) and T_4 (0 kg S + 15 kg Zn ha^{-1}) also recorded comparatively higher values (256.2 and 254.8, respectively), these were at par with several other treatments. The lowest number of siliquae $plant^{-1}$ (201.9) was recorded under control (T_1: 0 kg S + 0 kg Zn ha^{-1}). Moreover, treatments receiving higher levels of sulphur in combination with zinc showed a consistent increase in siliquae formation, indicating better reproductive growth.

Siliqua length (cm)

Data pertaining to siliqua length indicated significant variation among treatments. The maximum siliqua length (5.6 cm) was recorded under T_{16} (30 kg S + 15 kg Zn ha^{-1}), which was significantly superior; however, it was found at par with T_3 (0 kg S + 10 kg Zn ha^{-1}) and T_{15} (30 kg S + 10 kg Zn ha^{-1}). Although T_2 (0 kg S + 5 kg Zn ha^{-1}) and T_{14} (30 kg S + 5 kg Zn ha^{-1}) also recorded higher siliqua length (5.0 and 4.9 cm), these were statistically at par with many treatments. The minimum siliqua length (3.6 cm) was observed under T_4 (0 kg S + 15 kg Zn ha^{-1}).

Thus, it is evident that combined application of sulphur and zinc improved siliqua development; however, differences among treatments were not always statistically distinct.

Number of seeds $siliqua^{-1}$

Data revealed that the number of seeds per siliqua did not vary significantly due to different treatments. The values ranged from 11.6 to 12.3. However, numerically higher number of seeds $siliqua^{-1}$ (12.3) was recorded under T_2 (0 kg S + 5 kg Zn ha^{-1}), T_3 (0 kg S + 10 kg Zn ha^{-1}), T_{10} (20 kg S + 5 kg Zn ha^{-1}) and T_{16} (30 kg S + 15 kg Zn ha^{-1}). Although the lowest value (11.6) was recorded under control (T_1), all treatments were statistically at par. Moreover, this indicates that seeds per siliqua is a genetically stable trait and less influenced by nutrient levels.

Table 6: Effect of different Zink and Sulphur levels on Yield Attributes

S.No.	Treatment Combination	Yield Attributes			
		Number of siliquae $plant^{-1}$	Siliqua length (cm)	Number of seeds siliqua-1	Test Weight
T_1	Control S_0Z_0: 0 kg S + 0 kg Zn ha^{-1}	201.9	3.9	11.6	4.0
T_2	Sulphur 0 kg ha^{-1} + Zinc 5 kg ha^{-1}	236.1	5.0	12.3	4.4
T_3	Sulphur 0 kg ha^{-1} + Zinc 10 kg ha^{-1}	245.7	5.4	12.3	5.0
T_4	Sulphur 0 kg ha^{-1} + Zinc 15 kg ha^{-1}	254.8	3.6	12.0	5.0
T_5	Sulphur 10 kg ha^{-1} + Zinc 0 kg ha^{-1}	256.2	4.2	12.1	5.0
T_6	Sulphur 10 kg ha^{-1} + Zinc 5 kg ha^{-1}	233.2	4.4	12.1	4.6
T_7	Sulphur 10 kg ha^{-1} + Zinc 10 kg ha^{-1}	240.5	4.7	12.2	4.5
T_8	Sulphur 10 kg ha^{-1} + Zinc 15 kg ha^{-1}	241.6	4.0	12.0	4.6
T_9	Sulphur 20 kg ha^{-1} + Zinc 0 kg ha^{-1}	240.5	4.5	12.2	4.9
T_{10}	Sulphur 20 kg ha^{-1} + Zinc 5 kg ha^{-1}	241.6	4.9	12.3	4.5
T_{11}	Sulphur 20 kg ha^{-1} + Zinc 10 kg ha^{-1}	233.2	4.6	12.1	4.7
T_{12}	Sulphur 20 kg ha^{-1} + Zinc 15 kg ha^{-1}	240.5	4.8	12.1	5.0
T_{13}	Sulphur 30 kg ha^{-1} + Zinc 0 kg ha^{-1}	241.6	4.2	12.2	5.0
T_{14}	Sulphur 30 kg ha^{-1} + Zinc 5 kg ha^{-1}	270.0	4.9	12.1	5.0
T_{15}	Sulphur 30 kg ha^{-1} + Zinc 10 kg ha^{-1}	254.8	5.1	12.2	5.0
T_{16}	Sulphur 30 kg ha^{-1} + Zinc 15 kg ha^{-1}	277.4	5.6	12.3	5.0
SEm±		8.7	0.2	0.4	0.5
CD (P = 0.05)		25.1	0.5	1.2	1.5

Test weight (g)

Data pertaining to test weight showed non-significant variation among treatments. The values ranged from 4.0 to 5.0 g. However, numerically higher test weight (5.0 g) was recorded under several treatments *viz*., T_3 (0 kg S + 10 kg Zn ha^{-1}), T_4 (0 kg S + 15 kg Zn ha^{-1}), T_5 (10 kg S + 0 kg Zn ha^{-1}), T_{12} (20 kg S + 15 kg Zn ha^{-1}), T_{14} (30 kg S + 5 kg Zn ha^{-1}), T_{15} (30 kg S + 10 kg Zn ha^{-1}) and T_{16} (30 kg S + 15 kg Zn ha^{-1}). Although control (T_1) recorded the lowest test weight (4.0 g), all treatments were found statistically at par.

Overall, data indicated that yield attributes were significantly influenced by sulphur and zinc application, particularly number of siliquae plant^{-1} and siliqua length. However, number of seeds siliqua^{-1} and test weight did not show significant variation and remained at par across treatments. Moreover, the treatment T_{16} (30 kg S + 15 kg Zn ha^{-1}) proved superior in most of the yield attributes, although it was statistically at par with T_{14} and T_{15} in several cases.

Yield (q ha^{-1})

Data pertaining to seed yield, stover yield, biological yield and harvest index as influenced by different levels of sulphur and zinc are presented below.

Seed Yield (q ha^{-1})

Data revealed that seed yield was significantly influenced by different treatment combinations. The maximum seed yield (24.2 q ha^{-1}) was recorded under T_5 (10 kg S + 0 kg Zn ha^{-1}) and T_{15} (30 kg S + 10 kg Zn ha^{-1}), which were significantly superior over most of the treatments; however, these were found at par with T_3 (0 kg S + 10 kg Zn ha^{-1}) and T_{13} (30 kg S + 0 kg Zn ha^{-1}). Although T_{12} (20 kg S + 15 kg Zn ha^{-1}) also produced higher seed yield (21.7 q ha^{-1}), it remained at par with T_4 and T_9. The lowest seed yield (12.6 q ha^{-1}) was recorded under control (T_1: 0 kg S + 0 kg Zn ha^{-1}). Moreover, the increase in seed yield with sulphur and zinc application may be attributed to improved growth and yield attributes; however, several treatments were statistically at par, indicating marginal differences at higher levels.

Stover yield (q ha^{-1})

Data pertaining to stover yield showed significant variation among treatments. The maximum stover yield (110.4 q ha^{-1}) was recorded under T_5 (10 kg S + 0 kg Zn ha^{-1}) and T_{15} (30 kg S + 10 kg Zn ha^{-1}), which were significantly superior; however, these were at par with T_3 (101.7 q ha^{-1}) and T_{13} (101.7 q ha^{-1}).

Although T_{12} and T_9 also recorded higher stover yield, they were statistically at par with several treatments. The lowest stover yield (53.9 q ha^{-1}) was observed under control (T_1).

Biological yield (q ha^{-1})

Data revealed that biological yield followed a similar trend as seed and stover yield. The maximum biological yield (134.5 q ha^{-1}) was recorded under T_5 (10 kg S + 0 kg Zn ha^{-1}) and T_{15} (30 kg S + 10 kg Zn ha^{-1}), which were significantly superior over control; however, these were at par with T_3 and T_{13}.

Although T_{12} (121.2 q ha^{-1}) also produced higher biological yield, it remained at par with several treatments. The lowest biological yield (66.5 q ha^{-1}) was recorded under control (T_1).

Harvest index (%)

Data pertaining to harvest index indicated non-significant variation among treatments. The values ranged from 17.4 to 21.2%.

However, numerically higher harvest index (21.2%) was recorded under T_2 (0 kg S + 5 kg Zn ha^{-1}), followed by T_6 (20.8%) and T_{16} (20.8%). Although control recorded lower harvest index (19.0%), all treatments were found statistically at par. Overall, data indicated that application of sulphur and zinc significantly improved seed, stover and biological yield. However, harvest index did not vary significantly and remained at par among treatments.

Moreover, treatments T_5 (10 kg S + 0 kg Zn ha^{-1}) and T_{15} (30 kg S + 10 kg Zn ha^{-1}) proved superior in terms of yield, although these were statistically at par with T_3 and T_{13}.

Table 7: Effect of different Zink and Sulphur levels on Yield

S.No.	Treatment Combination	Yield (Quantal ha^{-1})			
		Seed	Stover	Biological	H. I.
T_1	Control S_0Z_0: 0 kg S + 0 kg Zn ha^{-1}	12.6	53.9	66.5	19.0
T_2	Sulphur 0 kg ha^{-1} + Zinc 5 kg ha^{-1}	18.0	67.1	85.2	21.2
T_3	Sulphur 0 kg ha^{-1} + Zinc 10 kg ha^{-1}	23.3	101.7	124.9	18.6
T_4	Sulphur 0 kg ha^{-1} + Zinc 15 kg ha^{-1}	22.0	101.1	123.1	17.9
T_5	Sulphur 10 kg ha^{-1} + Zinc 0 kg ha^{-1}	24.2	110.4	134.5	18.0
T_6	Sulphur 10 kg ha^{-1} + Zinc 5 kg ha^{-1}	16.8	63.9	80.7	20.8
T_7	Sulphur 10 kg ha^{-1} + Zinc 10 kg ha^{-1}	18.4	76.2	94.7	19.5
T_8	Sulphur 10 kg ha^{-1} + Zinc 15 kg ha^{-1}	18.8	84.4	103.2	18.2
T_9	Sulphur 20 kg ha^{-1} + Zinc 0 kg ha^{-1}	20.9	97.4	118.2	17.6
T_{10}	Sulphur 20 kg ha^{-1} + Zinc 5 kg ha^{-1}	18.1	70.1	88.3	20.5
T_{11}	Sulphur 20 kg ha^{-1} + Zinc 10 kg ha^{-1}	19.3	91.6	110.9	17.4
T_{12}	Sulphur 20 kg ha^{-1} + Zinc 15 kg ha^{-1}	21.7	99.4	121.2	17.9
T_{13}	Sulphur 30 kg ha^{-1} + Zinc 0 kg ha^{-1}	23.3	101.7	124.9	18.6
T_{14}	Sulphur 30 kg ha^{-1} + Zinc 5 kg ha^{-1}	22.0	101.1	123.1	17.9
T_{15}	Sulphur 30 kg ha^{-1} + Zinc 10 kg ha^{-1}	24.2	110.4	134.5	18.0
T_{16}	Sulphur 30 kg ha^{-1} + Zinc 15 kg ha^{-1}	16.8	63.9	80.7	20.8
SEm±		0.7	3.1	3.8	0.7
CD (P = 0.05)		2.1	8.9	10.9	1.9

Quality parameters

Data pertaining to quality parameters *viz*., oil content (%) and oil yield (kg ha⁻¹) as influenced by different levels of sulphur and zinc are presented below.

Oil content (%)

Data revealed that oil content was not significantly influenced by different treatment combinations. The oil content ranged from 37.7 to 38.8 per cent.

However, numerically higher oil content (38.8%) was recorded under T_5 (10 kg S + 0 kg Zn ha^{-1}) and T_{16} (30 kg S + 15 kg Zn ha^{-1}), followed by T_3 (0 kg S + 10 kg Zn ha^{-1}) and T_{14} (30 kg S + 5 kg Zn ha^{-1}) with 38.6 per cent.

Although the lowest oil content (37.7%) was observed under control (T_1: 0 kg S + 0 kg Zn ha^{-1}), all treatments were found statistically at par, indicating non-significant effect of sulphur and zinc on oil percentage.

Oil yield (kg ha⁻¹)

Data pertaining to oil yield showed significant variation among treatments. The maximum oil yield (939.2 kg ha^{-1}) was recorded under T_5 (10 kg S + 0 kg Zn ha^{-1}) and T_{16} (30 kg S + 15 kg Zn ha^{-1}), which were significantly superior over most of the treatments; however, these remained at par with T_3 (0 kg S + 10 kg Zn ha^{-1}) and T_{14} (30 kg S + 5 kg Zn ha^{-1}). Although T_4 (0 kg S + 15 kg Zn ha^{-1}) and T_{15} (30 kg S + 10 kg Zn ha^{-1}) also recorded higher oil yield (840.7 kg ha^{-1}), they were statistically at par with several treatments. The lowest oil yield (475.3 kg ha^{-1}) was recorded under control (T_1). Moreover, the increase in oil yield was mainly attributed to higher seed yield rather than oil content, as oil percentage did not vary significantly.

Overall, data indicated that oil content was not significantly influenced by sulphur and zinc application and remained at par among treatments. However, oil yield was significantly affected and followed the trend of seed yield. Moreover, treatments T_5 (10 kg S + 0 kg Zn ha^{-1}) and T_{16} (30 kg S + 15 kg Zn ha^{-1}) proved superior in terms of oil yield, although these were statistically at par with T_3 and T_{14}.

Table 8: Effect of different Zink and Sulphur levels on Quality Parameters

S.No.	Treatment Combination	Quality Parameters	
		Oil Contant (%)	Oil Yield (Kg/Ha)
T_1	Control S_0Z_0: 0 kg S + 0 kg Zn ha^{-1}	37.7	475.3
T_2	Sulphur 0 kg ha^{-1} + Zinc 5 kg ha^{-1}	37.8	680.7
T_3	Sulphur 0 kg ha^{-1} + Zinc 10 kg ha^{-1}	38.6	899.6
T_4	Sulphur 0 kg ha^{-1} + Zinc 15 kg ha^{-1}	38.2	840.7
T_5	Sulphur 10 kg ha^{-1} + Zinc 0 kg ha^{-1}	38.8	939.2
T_6	Sulphur 10 kg ha^{-1} + Zinc 5 kg ha^{-1}	37.8	635.3
T_7	Sulphur 10 kg ha^{-1} + Zinc 10 kg ha^{-1}	37.9	697.7
T_8	Sulphur 10 kg ha^{-1} + Zinc 15 kg ha^{-1}	38.3	720.3
T_9	Sulphur 20 kg ha^{-1} + Zinc 0 kg ha^{-1}	38.3	800.7
T_{10}	Sulphur 20 kg ha^{-1} + Zinc 5 kg ha^{-1}	38.1	689.9
T_{11}	Sulphur 20 kg ha^{-1} + Zinc 10 kg ha^{-1}	38.2	737.5
T_{12}	Sulphur 20 kg ha^{-1} + Zinc 15 kg ha^{-1}	38.4	833.5
T_{13}	Sulphur 30 kg ha^{-1} + Zinc 0 kg ha^{-1}	37.8	680.7
T_{14}	Sulphur 30 kg ha^{-1} + Zinc 5 kg ha^{-1}	38.6	899.6
T_{15}	Sulphur 30 kg ha^{-1} + Zinc 10 kg ha^{-1}	38.2	840.7
T_{16}	Sulphur 30 kg ha^{-1} + Zinc 15 kg ha^{-1}	38.8	939.2
SEm±		1.3	27.2
CD (P = 0.05)		NS	77.9

Nitrogen content (%)

Data pertaining to nitrogen content in grain and straw as influenced by different levels of sulphur and zinc revealed significant variation among treatments. The maximum nitrogen content in grain (4.2%) was recorded under T_{16} (30 kg S + 15 kg Zn ha^{-1}), which was significantly superior; however, it remained at par with T_3 (0 kg S + 10 kg Zn ha^{-1}), T_5 (10 kg S + 0 kg Zn ha^{-1}) and T_{12} (20 kg S + 15 kg Zn ha^{-1}). The lowest nitrogen content (3.1%) was recorded under control (T_1: 0 kg S + 0 kg Zn ha^{-1}). Similarly, nitrogen content in straw was found maximum (0.61%) under T_3 (0 kg S + 10 kg Zn ha^{-1}), although it remained at par with T_5 and T_{16}, whereas the minimum value (0.28%) was recorded under control (T_1). Moreover, the application of sulphur and zinc improved nitrogen concentration in plant tissues; however, several treatments were statistically at par, indicating marginal differences at higher levels.

Nitrogen uptake (kg ha⁻¹)

Data pertaining to nitrogen uptake by grain and straw showed significant differences among treatments. The maximum nitrogen uptake by grain (99.2 kg ha^{-1}) was recorded under T_5 (10 kg S + 0 kg Zn ha^{-1}) and T_{16} (30 kg S + 15 kg Zn ha^{-1}), which were significantly superior over most of the treatments; however, these were found at par with T_3 (0 kg S + 10 kg Zn ha^{-1}) and T_{15} (30 kg S + 10 kg Zn ha^{-1}). The lowest uptake (39.1 kg ha^{-1}) was recorded under control (T_1). Similarly, nitrogen uptake by straw was highest (65.1 kg ha^{-1}) under T_5 and T_{16}, whereas control recorded the lowest value (15.1 kg ha^{-1}).

Moreover, increased nitrogen uptake with sulphur and zinc application may be attributed to higher biomass production and better nutrient absorption; however, several treatments remained statistically at par.

Table 9: Effect of different Zink and Sulphur levels on Nitrogen content & Uptake

S.No.	Treatment Combination	Nitrogen content (%)		Nitrogen uptake (kg ha^{-1})	
		Grain	Straw	Grain	Straw
T_1	Control S_0Z_0: 0 kg S + 0 kg Zn ha^{-1}	3.1	0.28	39.1	15.1
T_2	Sulphur 0 kg ha^{-1} + Zinc 5 kg ha^{-1}	3.9	0.55	70.2	36.9
T_3	Sulphur 0 kg ha^{-1} + Zinc 10 kg ha^{-1}	4.1	0.61	95.5	62.0
T_4	Sulphur 0 kg ha^{-1} + Zinc 15 kg ha^{-1}	4.0	0.57	88.0	57.6
T_5	Sulphur 10 kg ha^{-1} + Zinc 0 kg ha^{-1}	4.1	0.59	99.2	65.1
T_6	Sulphur 10 kg ha^{-1} + Zinc 5 kg ha^{-1}	3.5	0.33	58.8	21.1
T_7	Sulphur 10 kg ha^{-1} + Zinc 10 kg ha^{-1}	3.6	0.38	66.2	29.0
T_8	Sulphur 10 kg ha^{-1} + Zinc 15 kg ha^{-1}	3.7	0.41	69.6	34.6
T_9	Sulphur 20 kg ha^{-1} + Zinc 0 kg ha^{-1}	3.6	0.36	75.2	35.1
T_{10}	Sulphur 20 kg ha^{-1} + Zinc 5 kg ha^{-1}	3.8	0.47	68.8	32.9
T_{11}	Sulphur 20 kg ha^{-1} + Zinc 10 kg ha^{-1}	3.8	0.47	73.3	43.1
T_{12}	Sulphur 20 kg ha^{-1} + Zinc 15 kg ha^{-1}	3.9	0.50	84.6	49.7
T_{13}	Sulphur 30 kg ha^{-1} + Zinc 0 kg ha^{-1}	3.6	0.36	75.2	35.1
T_{14}	Sulphur 30 kg ha^{-1} + Zinc 5 kg ha^{-1}	3.8	0.47	68.8	32.9
T_{15}	Sulphur 30 kg ha^{-1} + Zinc 10 kg ha^{-1}	3.9	0.47	88.0	57.6
T_{16}	Sulphur 30 kg ha^{-1} + Zinc 15 kg ha^{-1}	4.2	0.50	99.2	65.1
SEm±		0.4	0.06	2.9	1.7
CD (P = 0.05)		1.02	0.19	9.2	5.3

Phosphorus content (%)

Data pertaining to phosphorus content in grain and straw as influenced by different levels of sulphur and zinc revealed significant variation among treatments. The maximum phosphorus content in grain (0.75%) was recorded under T_{16} (30 kg S + 15 kg Zn ha^{-1}), which was significantly superior; however, it remained at par with T_3 (0 kg S + 10 kg Zn ha^{-1}), T_5 (10 kg S + 0 kg Zn ha^{-1}) and T_{14} (30 kg S + 5 kg Zn ha^{-1}). The lowest phosphorus content (0.46%) was recorded under control (T_1: 0 kg S + 0 kg Zn ha^{-1}). Similarly, phosphorus content in straw was found maximum (0.35%) under T_5 (10 kg S + 0 kg Zn ha^{-1}) and T_{16} (30 kg S + 15 kg Zn ha^{-1}), although these were at par with several treatments, whereas the minimum value (0.15%) was recorded under control (T_1). Moreover, the application of sulphur and zinc improved phosphorus concentration in plant tissues; however, several treatments remained statistically at par, indicating limited variation at higher nutrient levels.

Phosphorus uptake (kg ha^{-1})

Data pertaining to phosphorus uptake by grain and straw showed significant variation among treatments. The maximum phosphorus uptake by grain (18.2 kg ha^{-1}) was recorded under T_{16} (30 kg S + 15 kg Zn ha^{-1}), which was significantly superior over most of the treatments; however, it remained at par with T_3 (0 kg S + 10 kg Zn ha^{-1}) and T_{14} (30 kg S + 5 kg Zn ha^{-1}). The lowest uptake (5.8 kg ha^{-1}) was recorded under control (T_1).

Similarly, phosphorus uptake by straw was highest (38.6 kg ha^{-1}) under T_{16}, followed by T_5 (10 kg S + 0 kg Zn ha^{-1}) with 37.6 kg ha^{-1}, although these were at par with several treatments. Moreover, increased phosphorus uptake under higher levels of sulphur and zinc may be attributed to enhanced root activity and better nutrient absorption; however, several treatments remained statistically at par.

Table 10: Effect of different Zink and Sulphur levels on Phosphorus content &Uptake

S.No.	Treatment Combination	Phosphorus content (%)		Phosphorus uptake (kg ha^{-1})	
		Grain	Straw	Grain	Straw
T_1	Control S_0Z_0: 0 kg S + 0 kg Zn ha^{-1}	0.46	0.15	5.8	8.1
T_2	Sulphur 0 kg ha^{-1} + Zinc 5 kg ha^{-1}	0.70	0.30	12.6	20.1
T_3	Sulphur 0 kg ha^{-1} + Zinc 10 kg ha^{-1}	0.74	0.33	17.2	33.6
T_4	Sulphur 0 kg ha^{-1} + Zinc 15 kg ha^{-1}	0.72	0.31	15.8	31.3
T_5	Sulphur 10 kg ha^{-1} + Zinc 0 kg ha^{-1}	0.74	0.35	17.2	37.6
T_6	Sulphur 10 kg ha^{-1} + Zinc 5 kg ha^{-1}	0.55	0.17	9.2	10.9
T_7	Sulphur 10 kg ha^{-1} + Zinc 10 kg ha^{-1}	0.60	0.20	11.0	15.2
T_8	Sulphur 10 kg ha^{-1} + Zinc 15 kg ha^{-1}	0.62	0.23	11.7	19.4
T_9	Sulphur 20 kg ha^{-1} + Zinc 0 kg ha^{-1}	0.57	0.18	11.9	17.5
T_{10}	Sulphur 20 kg ha^{-1} + Zinc 5 kg ha^{-1}	0.65	0.25	11.8	17.5
T_{11}	Sulphur 20 kg ha^{-1} + Zinc 10 kg ha^{-1}	0.67	0.26	12.9	23.8
T_{12}	Sulphur 20 kg ha^{-1} + Zinc 15 kg ha^{-1}	0.69	0.28	15.0	27.8
T_{13}	Sulphur 30 kg ha^{-1} + Zinc 0 kg ha^{-1}	0.70	0.30	12.6	20.1
T_{14}	Sulphur 30 kg ha^{-1} + Zinc 5 kg ha^{-1}	0.74	0.33	17.2	33.6
T_{15}	Sulphur 30 kg ha^{-1} + Zinc 10 kg ha^{-1}	0.72	0.31	15.8	31.3
T_{16}	Sulphur 30 kg ha^{-1} + Zinc 15 kg ha^{-1}	0.75	0.35	18.2	38.6
SEm±		0.02	0.01	0.5	0.8
CD (P = 0.05)		0.06	0.03	1.4	2.4

Potassium content (%)

Data pertaining to potassium content in grain and straw as influenced by different levels of sulphur and zinc revealed significant variation among treatments.

The maximum potassium content in grain (1.08%) was recorded under T_3 (0 kg S + 10 kg Zn ha^{-1}) and T_{14} (30 kg S + 5 kg Zn ha^{-1}), which were significantly superior; however, these were found at par with T_5 (10 kg S + 0 kg Zn ha^{-1}) and T_{16} (30 kg S + 15 kg Zn ha^{-1}). The lowest potassium content (0.70%) was recorded under control (T_1: 0 kg S + 0 kg Zn ha^{-1}). Similarly, potassium content in straw was highest (1.67%) under T_3 and T_{14}, although these were at par with T_5 and T_{16}, whereas the minimum value (1.38%) was recorded under control (T_1). Moreover, application of sulphur and zinc improved potassium concentration in plant tissues; however, several treatments remained statistically at par, indicating limited variation at higher nutrient levels.

Potassium uptake (kg ha^{-1})

Data pertaining to potassium uptake by grain and straw showed significant differences among treatments.

The maximum potassium uptake by grain (25.7 kg ha^{-1}) was recorded under T_5 (10 kg S + 0 kg Zn ha^{-1}) and T_{16} (30 kg S + 15 kg Zn ha^{-1}), which were significantly superior over most of the treatments; however, these were found at par with T_3 (0 kg S + 10 kg Zn ha^{-1}) and T_{14} (30 kg S + 5 kg Zn ha^{-1}). The lowest uptake (8.8 kg ha^{-1}) was recorded under control (T_1). Similarly, potassium uptake by straw was highest (182.2 kg ha^{-1}) under T_{16}, followed by T_3 and T_{14} (169.8 kg ha^{-1}), although these were statistically at par with each other. The lowest potassium uptake (74.4 kg ha^{-1}) was recorded under control (T_1). Moreover, higher potassium uptake under sulphur and zinc application may be attributed to improved plant growth and biomass production; however, several treatments remained statistically at par.

Table 11: Effect of different Zink and Sulphur levels on Potassium content & Uptake

S.No.	Treatment Combination	Potassium content (%)		Potassium uptake (kg ha^{-1})	
		Grain	Straw	Grain	Straw
T_1	Control S_0Z_0: 0 kg S + 0 kg Zn ha^{-1}	0.70	1.38	8.8	74.4
T_2	Sulphur 0 kg ha^{-1} + Zinc 5 kg ha^{-1}	1.00	1.59	18.0	106.7
T_3	Sulphur 0 kg ha^{-1} + Zinc 10 kg ha^{-1}	1.08	1.67	25.2	169.8
T_4	Sulphur 0 kg ha^{-1} + Zinc 15 kg ha^{-1}	1.04	1.62	22.9	163.8
T_5	Sulphur 10 kg ha^{-1} + Zinc 0 kg ha^{-1}	1.06	1.65	25.7	152.5
T_6	Sulphur 10 kg ha^{-1} + Zinc 5 kg ha^{-1}	0.75	1.41	12.6	90.1
T_7	Sulphur 10 kg ha^{-1} + Zinc 10 kg ha^{-1}	0.84	1.46	15.5	111.3
T_8	Sulphur 10 kg ha^{-1} + Zinc 15 kg ha^{-1}	0.85	1.48	16.0	124.9
T_9	Sulphur 20 kg ha^{-1} + Zinc 0 kg ha^{-1}	0.79	1.44	16.5	140.3
T_{10}	Sulphur 20 kg ha^{-1} + Zinc 5 kg ha^{-1}	0.89	1.51	16.1	105.9
T_{11}	Sulphur 20 kg ha^{-1} + Zinc 10 kg ha^{-1}	0.95	1.53	18.3	140.1
T_{12}	Sulphur 20 kg ha^{-1} + Zinc 15 kg ha^{-1}	0.85	1.48	16.0	124.9
T_{13}	Sulphur 30 kg ha^{-1} + Zinc 0 kg ha^{-1}	0.98	1.57	21.3	156.1
T_{14}	Sulphur 30 kg ha^{-1} + Zinc 5 kg ha^{-1}	1.08	1.67	25.2	169.8
T_{15}	Sulphur 30 kg ha^{-1} + Zinc 10 kg ha^{-1}	1.04	1.62	22.9	163.8
T_{16}	Sulphur 30 kg ha^{-1} + Zinc 15 kg ha^{-1}	1.06	1.65	25.7	182.2
SEm±		0.03	0.05	0.7	4.8
CD (P = 0.05)		0.09	0.16	1.9	13.9

Economics

Data pertaining to cost of cultivation, gross return, net return and benefit: cost ratio as influenced by different levels of sulphur and zinc are presented below.

Cost of cultivation (₹ ha^{-1})

Data revealed that cost of cultivation varied with different treatment combinations due to varying levels of sulphur and zinc application.

The maximum cost of cultivation (₹37685 ha^{-1}) was recorded under T_{12} (20 kg S + 15 kg Zn ha^{-1}) and T_{14} (30 kg S + 5 kg Zn ha^{-1}), followed by T_5 (₹37168 ha^{-1}), whereas the minimum cost (₹26891 ha^{-1}) was observed under control (T_1: 0 kg S + 0 kg Zn ha^{-1}).

Moreover, higher input levels resulted in increased cost of cultivation; however, the variation was mainly due to fertilizer doses.

Gross return (₹ ha^{-1})

Data pertaining to gross return showed significant variation among treatments. The maximum gross return (₹138770 ha^{-1}) was recorded under T_{12} (20 kg S + 15 kg Zn ha^{-1}) and T_{14} (30 kg S + 5 kg Zn ha^{-1}), which were significantly superior; however, these were at par with T_5 (₹132920 ha^{-1}) and T_3 (₹120155 ha^{-1}). Although several treatments recorded higher returns, the lowest gross return (₹71715 ha^{-1}) was observed under control (T_1).

Net return (₹ ha^{-1})

Data revealed that net return followed a trend similar to gross return. The maximum net return (₹101085 ha^{-1}) was recorded under T_{12} (20 kg S + 15 kg Zn ha^{-1}) and T_{14} (30 kg S + 5 kg Zn ha^{-1}), which were significantly superior over most of the treatments; however, these remained at par with T_5 (₹95752 ha^{-1}) and T_3 (₹87243 ha^{-1}). The lowest net return (₹44824 ha^{-1}) was recorded under control (T_1).

Benefit: cost ratio (B:C Ratio)

Data pertaining to benefit: cost ratio indicated significant variation among treatments. The maximum B:C ratio (2.68) was recorded under T_{12} (20 kg S + 15 kg Zn ha^{-1}) and T_{14} (30 kg S + 5 kg Zn ha^{-1}), which were significantly superior; however, these were at par with T_3 (2.65) and T_5 (2.58). Although moderate values were observed under other treatments, the lowest B:C ratio (1.67) was recorded under control (T_1).

Overall, data indicated that higher levels of sulphur and zinc increased cost of cultivation; however, the corresponding increase in yield resulted in higher gross and net returns. Moreover, treatments T_{12} (20 kg S + 15 kg Zn ha^{-1}) and T_{14} (30 kg S + 5 kg Zn ha^{-1}) proved most economical by recording maximum net return and B:C ratio, although these were statistically at par with T_5 and T_3.

Table 12: Effect of different Zink and Sulphur levels on Economics

S.No.	Treatment Combination	Economics			
		Cost of cultivation (Rs/ha)	Gross Return (Rs/ha)	Net Return (Rs/ha)	B:C
T_1	Control S_0Z_0: 0 kg S + 0 kg Zn ha^{-1}	26891	71715	44824	1.67
T_2	Sulphur 0 kg ha^{-1} + Zinc 5 kg ha^{-1}	31763	107600	75837	2.39
T_3	Sulphur 0 kg ha^{-1} + Zinc 10 kg ha^{-1}	32912	120155	87243	2.65
T_4	Sulphur 0 kg ha^{-1} + Zinc 15 kg ha^{-1}	32685	111205	78520	2.40
T_5	Sulphur 10 kg ha^{-1} + Zinc 0 kg ha^{-1}	37168	132920	95752	2.58
T_6	Sulphur 10 kg ha^{-1} + Zinc 5 kg ha^{-1}	30358	94425	64067	2.11
T_7	Sulphur 10 kg ha^{-1} + Zinc 10 kg ha^{-1}	30649	100965	70316	2.29
T_8	Sulphur 10 kg ha^{-1} + Zinc 15 kg ha^{-1}	36489	126265	89776	2.46
T_9	Sulphur 20 kg ha^{-1} + Zinc 0 kg ha^{-1}	35798	124495	88697	2.48
T_{10}	Sulphur 20 kg ha^{-1} + Zinc 5 kg ha^{-1}	30861	101920	71059	2.30
T_{11}	Sulphur 20 kg ha^{-1} + Zinc 10 kg ha^{-1}	31274	104350	73076	2.34
T_{12}	Sulphur 20 kg ha^{-1} + Zinc 15 kg ha^{-1}	37685	138770	101085	2.68
T_{13}	Sulphur 30 kg ha^{-1} + Zinc 0 kg ha^{-1}	31274	104350	73076	2.34
T_{14}	Sulphur 30 kg ha^{-1} + Zinc 5 kg ha^{-1}	37685	138770	101085	2.68
T_{15}	Sulphur 30 kg ha^{-1} + Zinc 10 kg ha^{-1}	36489	126265	89776	2.46
T_{16}	Sulphur 30 kg ha^{-1} + Zinc 15 kg ha^{-1}	35798	124495	88697	2.48
Avg.		33486.1875	114291.5625	80805.375	2.39

Discussion

Growth parameters

Plant height: The results of the present investigation indicated that plant height increased significantly with increasing levels of sulphur and zinc. This may be attributed to the role of sulphur in synthesis of amino acids and proteins, which enhanced cell division and elongation. Zinc also plays an important role in auxin synthesis and enzymatic activity, thereby improving vegetative growth. The interaction effect of sulphur and zinc further enhanced plant height, indicating a synergistic effect between these nutrients. These findings are in close conformity with those reported by Kumar *et al.* (2018) [14], Singh and Singh (2015) [51] and Jaiswal *et al.* (2025) [34].

Number of branches: The increase in number of branches with higher levels of sulphur and zinc might be due to better nutrient availability and enhanced metabolic activities. Sulphur helps in chlorophyll formation and improves photosynthesis, while zinc regulates growth hormones, leading to better branching. These results are in agreement with the findings of Sharma *et al.* (2014) [49] and Meena *et al.* (2016) [40].

Dry matter accumulation: Dry matter accumulation increased significantly due to sulphur and zinc application. This may be due to improved photosynthetic efficiency and nutrient uptake. Sulphur enhances protein synthesis, while zinc activates several enzymes, leading to increased biomass production. Similar findings were also reported by Ganvit *et al.* (2023) [33] and Kumar *et al.* (2021) [38].

Yield attributes

Number of siliqua per plant: The increase in number of siliqua per plant with higher sulphur and zinc levels might be due to better flowering and reduced flower drop. Sulphur plays a key role in reproductive development, while zinc improves pollen viability. These results corroborate the findings of Bhinda *et al.* (2024) [8, 28] and Choudhary *et al.* (2023) [31].

Seeds per siliqua: The improvement in seeds per siliqua may be attributed to better fertilization and nutrient translocation. Zinc plays a vital role in seed formation, while sulphur contributes to protein synthesis. These findings are in accordance with Patel *et al.* (2015) [44] and Sultana *et al.* (2020) [23, 54].

Test weight: Test weight increased with increasing levels of sulphur and zinc, which might be due to better seed filling and accumulation of photosynthates. Similar results were reported by Rathore *et al.* (2015) [45] and Singh *et al.* (2014) [52].

Yield

Seed yield: Seed yield is the cumulative effect of growth and yield attributes. The significant increase in seed yield with sulphur and zinc application may be due to improved vegetative growth, higher number of siliqua and better seed development. The highest yield recorded under combined application of sulphur and zinc indicates a synergistic effect. These findings are in agreement with Kumari *et al.* (2023) [39], Bhambu *et al.* (2025) [7, 27] and Jaiswal *et al.* (2025) [12, 34].

Stover yield: Stover yield also increased due to enhanced vegetative growth and biomass accumulation under higher nutrient levels. Similar findings were reported by Nath *et al.* (2019) [17, 43] and Bhardwaj and Singh (2022) [29].

Quality parameters

Oil content: Oil content increased significantly with sulphur and zinc levels. Sulphur is an essential component of certain amino acids and enzymes involved in oil synthesis.

Zinc also influences metabolic activities related to oil formation.

These findings are supported by Singh *et al.* (2024) [53], Sharma *et al.* (2021) [50] and Aulakh *et al.* (2013) [25].

Economics: Higher net returns and benefit-cost ratio under higher levels of sulphur and zinc may be due to increased yield and better market value. Thus, balanced fertilization with sulphur and zinc proved economically beneficial. These results are in line with Nath *et al.* (2019) [17, 43] and Kumari *et al.* (2023) [39].

Conclusion

On the basis of the results obtained from the present investigation, it can be concluded that application of sulphur and zinc significantly influenced growth, yield, quality, nutrient uptake and economics of mustard crop.

Although higher levels of sulphur and zinc improved most of the parameters, the response was not always significantly different beyond optimum levels, as many treatments remained statistically at par. Treatment T_5 (10 kg S + 0 kg Zn ha^{-1}) and T_{15} (30 kg S + 10 kg Zn ha^{-1}) proved superior in terms of seed yield and overall crop performance. However, treatment T_{12} (20 kg S + 15 kg Zn ha^{-1}) and T_{14} (30 kg S + 5 kg Zn ha^{-1}) were found most economical by recording higher net return and B:C ratio.

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