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Effect of Different Levels of Zinc and Sulphur on Morpho-Physiological Parameters of Indian Mustard

Vikas Verma[1*], C.L. Maurya[1], Sourabh Tomar[2] and Rishi Pal Singh[3]

[1]Department of Seed Science and Technology, [2]Department of Horticulture, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.) 208 002, India
[3]Department of Entomology, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut- 50110 , India

**Corresponding author*

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ABSTRACT

A field experiment and laboratory experiment was conducted in Split Plot Design with three replications during 2011-12 & 2012-13 on Indian mustard variety Urvashi at New Dairy Farm, Kalyanpur, Kanpur and Seed Testing Laboratory of Department of Seed Science and Technology, respectively. Six doses of zinc and sulphur viz. 0.0, 2.5, 5.0, 7.5, 10.0, 12.5 Kg ha^{-1} and 0, 10, 20, 30, 40, 50 Kg ha^{-1}, respectively were applied as basal dose. Observations were recorded on morpho-physiological characters. Results showed that the application of zinc and sulphur affected significantly to all parameters. The dose 10 Kg Zn ha^{-1} & 50 Kg S ha^{-1} recorded highest leaf area index at 30 DAS (0.65 & 0.68), 60 DAS (1.97 & 2.04) & 90 DAS (1.64 & 1.73), chlorophyll intensity at pre-flowering (47.19 & 48.75%). Like-wise, 12.5 kg Zn and 50 Kg S ha^{-1} had registered maximum chlorophyll intensity at post-flowering (40.73 & 41.21%), canopy temperature depression at pre-flowering (4.93 & 5.07^{0}C) and post-flowering (4.31 & 4.32^{0}C), respectively. The interaction zinc and sulphur did not show significant effect on leaf area index at all stages. However, rest of the characters was affected by the application of zinc and sulphur.

Introduction

Mustrad (*Brasica juncea*, (L) Czem and cross) is important *Rabi* oilseed crop which belongs to family "Cruciferae". India is first position in area and second position in production after China. India is the fourth largest oilseed economy in the world. Oilseed crops hold a sizeable share of the country's gross cropped area (13%) and contribute around 3% of gross national product and 10% of the value of all agricultural commodities (Anonymous, 2014). The area, production and productivity of rapeseed-mustard is 6.70 and 34.19 million ha, 7.96 and 63.09 million tonnes and 1188 and 1850 kg ha^{-1}, respectively in India and world during 2013-2014 (Anonymous, 2014).

The average productivity of oilseeds in the country is only 1153 kg ha^{-1}. As soils of U.P. are deficient in zinc and sulphur, this study will facilitate in the improvement of yield and seed quality in our state. On an average oilseed crops absorb 11-12 kg sulphur to produce one tonne (1000 kg) of seed. Average sulphur content in seed of mustard is 1.1% as compared to 0.3% in pulses and 0.2% in cereals. Sulphur is a key nutrient for oilseed production, because in the plants, sulphur is directly involved in the formation of oil compounds. In rapeseed and mustard sulphur deficient plants have leaves which are more erect than normal and cupped inwards. Initially the underside of the leaves develops a red colour which can extend to the upper surface of leaves as well (Anonymous, 2004).

High crop yield in agriculturally progressive districts of India removed substantial amounts of micronutrients especially zinc from soil, causing yield reduction (Deb and Sakal, 2002). Sulphur increased the yield of mustard by 12 to 48% under irrigation, and by 17-124% under rainfed conditions (Aulakh and Pasricha, 1988). In terms of agronomic efficiency, each kilogram of sulphur increases the yield of mustard by 7.7 kg ha^{-1} (Katyal et al., 1997).

Zinc is an essential micronutrient for plant growth and is absorbed by the plant roots in the form of Zn^{2+}. It is involved in diverse metabolic activities, influences the activities of hydrogenase and carbonic anhydrase, synthesis of cytochrome and the stabilization of ribosomal fractions and auxin metabolism (Tisdale *et al*., 1984). Principle function of zinc in plants is as a metal activator of enzymes. Zinc entered into the constituents of enzyme system that regulate initial metabolic reactions in the plants body. Zinc catalyses the process of oxidation in plant cells and is vital for the transformation of carbohydrates. It regulates the consumption of sugars and increases the source of energy for the production of chlorophyll. Zinc also aids in the formation of auxin and synthesis of protein.

Zinc plays vital role in carbohydrate and proteins metabolism as well as it controls the plant growth hormone IAA. It is essential component of dehydrogenase, proteinase and promotes starch formation, seed maturation and production (Marschner, 1995).

Materials and Methods

The experiment was conducted at the New Dairy Research Farm, Chandra Shekhar Azad University of Agriculture and Technology, Kalyanpur, Kanpur UP during 2011-12 and 2012-13 on Indian mustard variety Urvashi under Split Plot Design with three replications having plant distance 45 cm and 5 cm respectively. Five rows were sown in each plot of 4 × 2.25 m$^{2.}$ The recommended fertilizer was applied at the rate of 120 Kg N, 60 Kg P_2O_5 and 40 Kg K_2O ha^{-1} uniformly in all plots as feeder dose and plant protection measure were Spraying of Malathion 50 EC @ 1 liter dissolved in 1000 liters of water ha^{-1} for the control of hairy caterpillar. Spraying of Imidachloroprid 17.8 EC @ 375 ml in 1000 liters of water ha^{-1} was applied as per requirement for the control of aphids. The study was consisted of two factors *viz*. zinc and sulphur with Six doses of zinc and sulphur viz. 0.0, 2.5, 5.0, 7.5, 10.0, 12.5 Kg ha^{-1} and 0, 10, 20, 30, 40, 50 Kg ha^{-1}, respectively were applied as basal dose. The composition of soil of the experimental plot is alluvial in nature. The soil samples were drawn and analyzed in the Soil Testing Laboratory Chandra Shekhar Azad University of Agriculture and Technology, Kanpur for different physical and chemical composition following the standard procedure.

Data were Recorded Leaf Area Index was calculated by formula given by Watson (1947). Chlorophyll Intensity was determine by chlorophyll meter SPAD 502 and expressed as per cent. Canopy Temperature Depression was measured by Infrared Thermometer (Teletamp AG. USA) and expressed as ^{0}C.

Results and Discussion

Effect of zinc and sulphur on leaf area index (30 DAS)

Data related to (LAI) leaf area index of Indian mustard at 30 days after sowing as influenced by different levels of zinc and sulphur have been presented in Table 1 and Fig. 5 and their respective mean sum of squares are shown in Appendix I

It is clear from the appendix I that the zinc application had significant effect on leaf area index (LAI) at 30 DAS. It is perceptible from the table 41 that all treatments Zn_0 and Zn_1, Zn_2 and Zn_3 and Zn_4 and Zn_5 which showed non-significant difference to each other. Maximum leaf area index was recorded in the treatment Zn_5 (0.65) while minimum was found in control (0.63). Fig. 5 reveals that leaf area index was increased with increasing level of zinc.

It is obvious from the Appendix I that different doses of sulphur applied had significant effect on leaf area index at 30 DAS. It is perceptible from the Table 1 that all treatments differed significantly to each other except S_4 and S_5, which showed non-significant difference to each other. Every increasing dose of sulphur significantly increased leaf area index at 30 days after sowing during experimentation (Fig. 5). Highest leaf area index was observed in S_5 (0.68) while lowest (0.60) was found in control.

The data pertaining to leaf area index at 30 DAS with different levels of zinc and sulphur application was found non-significant during experimentation (Appendix I). The maximum leaf area index was recorded maximum (0.70) with the treatment combination of $Zn_4 \times S_5$ while minimum (0.59) was obtained with $Zn_0 \times S_0$ (Table 1).

Effect of zinc and sulphur on leaf area index (60 DAS)

The results obtained on leaf area index of Indian mustard at 60 days after sowing as influenced by different levels of zinc and sulphur have been presented in Table 1 and **Fig. 6** and their respective mean sum of squares are shown in Appendix I.

It is evident from the appendix I that the zinc application had significant effect on leaf area index at 60 DAS. Table 1 shows that the treatment has exhibited significant variations. Though, non-significant difference was observed between the treatments Zn_0 and Zn_1 and Zn_4 and Zn_5, however, Zn_2 and Zn_3 showed significant difference. Enhancement in the leaf area index was accompanied by increase in the doses applied (Fig. 6). Maximum LAI (1.97) was recorded in the treatment Zn_4 which showed at par with Zn_5 while minimum (1.91) was found in control.

Appendix I showed significant effect on leaf area index at 60 DAS. Various levels of sulphur differed significantly with respect to Leaf Area Index at 60 DAS (Table 1). The treatments S_0 and S_1, S_2 and S_3 and S_4 and S_5 exhibited non-significant difference. Every increasing dose of sulphur significantly increased leaf area index at 60 days after sowing during experimentation (Fig. 6). The maximum leaf area index (2.04) was noticed in S_5 and minimum (1.83) was reported in control.

Interaction of zinc and sulphur showed non-significant effect with respect to LAI at 60

DAS during experimentation (Appendix I). The maximum leaf area index (2.09) was observed with the treatment combination of $Zn_5 \times S_5$ while the lowest (1.81) was recorded in $Zn_0 \times S_0$ (Table 1).

Effect of zinc and sulphur on leaf area index (90 DAS)

Data pertaining to leaf area index at 90 days after sowing of mustard as influenced by different levels of zinc and sulphur are presented in Table 4.1, 4.4 and Fig. 7 and their respective mean sum of square have been shown in Appendix I. It is clear from the Appendix I that different doses of zinc applied showed significant effect on leaf area index at 90 DAS. Table 4.1 indicates that the treatment Zn_0 and Zn_1, Zn_2 and Zn_3 and Zn_4 and Zn_5 did not show significant difference. Maximum LAI (1.64) was recorded in Zn_4 while minimum (1.57) was found in control (Fig. 7).

Appendix I showed significant effect on leaf area index at 90 days after sowing. Various levels of sulphur expressed significant effect with respect on LAI at 90 DAS. The treatments showed significant difference to each other. Significantly highest leaf area index (1.73) in the treatment S_5 was obtained while minimum (1.49) was reported in control (Table 1).

The interaction of zinc and sulphur did not show significant effect with leaf area index at 90 DAS in Appendix IX. However, numerically maximum leaf area index was found in the treatment combination of $Zn_5 \times S_5$ while lowest recorded in $Zn_0 \times S_0$ (Table 4.4).

Effect of zinc and sulphur on chlorophyll intensity pre-flowering stage

Data on chlorophyll intensity at pre-flowering of Indian mustard as influenced by various levels of zinc and sulphur have been presented in Table 4.5 and 4.6 and their mean sum of square are given in Appendix I. It is apparent from the Appendix I that the application of different levels of zinc significantly influenced the chlorophyll intensity at pre-flowering of Indian mustard. Treatment Zn_0 to Zn_3 differed significantly to one another while the treatment Zn_4 and Zn_5 did not show significant difference (Table 2). Application of highest tested dose of Zn_5 significantly recorded highest chlorophyll intensity at pre-flowering (47.23%) as compared to rest of the doses of zinc while it was at par with Zn_4. It was also observed that the application of Zn_4 produced more chlorophyll intensity at pre-flowering (47.19%) followed by Zn_3 (46.58%), Zn_2 (45.46%) and Zn_1 (44.78%), respectively. The minimum chlorophyll intensity at pre-flowering (43.78%) of Indian mustard was obtained with control plots (Fig. 8).

It is obvious from the Appendix I that the application of different doses of sulphur significantly improved the chlorophyll intensity at pre-flowering of Indian mustard. Every increasing dose of sulphur significantly increased the chlorophyll intensity at pre-flowering stage during experimentation. Table 2 shows that all treatment differed significantly to each other. Significantly highest chlorophyll intensity at pre-flowering (48.75%) stage was obtained with the application of S_5 as compared to rest of the doses of sulphur. Without sulphur applied plots (control) recorded minimum chlorophyll intensity at pre-flowering (42.70%) of Indian mustard (Fig. 8].

Interaction effect of various levels of zinc and sulphur was significant on chlorophyll intensity at pre-flowering in Table 4.6. Maximum chlorophyll intensity at pre-flowering (51.30%) was obtained with the combined application of $Zn_4 \times S_5$ and the second best treatment (50.58%) found in $Zn_5 \times S_5$ while minimum chlorophyll intensity at pre-flowering (41.45%) was obtained in absolute control plot (Fig.9)

Effect of zinc and sulphur on chlorophyll intensity at post- flowering stage

The pertained data on chlorophyll intensity at post-flowering of Indian mustard as influenced by various levels of zinc and sulphur have been presented in Table 4.5 and 4.7 and their mean sum of square are given in Appendix I.

It is clear from the Appendix I that the application of different levels of zinc significantly influenced chlorophyll intensity at post-flowering of Indian mustard. All treatments differed significantly to one another. Application of highest tested dose of Zn_5 significantly recorded highest chlorophyll intensity at post-flowering (40.73%) as compared to rest of the doses of zinc. The minimum chlorophyll intensity at post-flowering (35.63%) of Indian mustard was obtained with control plot (Fig. 10).

It is obvious from the Appendix I that the application of different doses of sulphur significantly improved the chlorophyll intensity at post-flowering of Indian mustard. Every increasing dose of sulphur significantly increased the chlorophyll intensity at post-flowering stage during experimentation. Table 4.5 shows that all treatments differed significantly to one other. The highest chlorophyll intensity at post-flowering (41.21%) stage was obtained with the application of S_5 as compared to rest of the doses of sulphur. Without sulphur applied plots (control) recorded minimum chlorophyll intensity at post-flowering stage (35.82%) of Indian mustard (Fig. 10).

The interaction effect of various levels of zinc and sulphur was significant on chlorophyll intensity at post-flowering in Table 2. Maximum chlorophyll intensity at post-flowering (44.60%) was obtained with the combined application of $Zn_5 \times S_4$ and statistically to be at par with $Zn_4 \times S_4$ while minimum chlorophyll intensity at post-flowering (34.05%) was obtained in absolute control plot (Fig. 11).

Effect of zinc and sulphur on canopy temperature depression (^{0}c) at pre-flowering stage

Data pertaining to canopy temperature depression (^{0}C) at pre-flowering of Indian mustard as influenced by different doses of zinc and sulphur have been presented in Table 4.8 and 4.9 and their respective mean sum of square are given in Appendix I.

Appendix I expressed the significant effect on canopy temperature depression (^{0}C) at pre-flowering stage of Indian mustard. Table 3 indicates that the treatment Zn_0, Zn_1, Zn_2, Zn_3, Zn_4 and Zn_5 exhibited significant difference to each other. The highest canopy temperature depression (^{0}C) at pre-flowering (4.93^{0}C) of Indian mustard was recorded with the application of Zn_5 as compared to rest of the doses of zinc. The minimum canopy temperature depression (4.19^{0}C) at pre-flowering of Indian mustard was recorded in control (Fig. 12).

It is evident from the Appendix I that the application of various doses of sulphur significantly increased the canopy temperature depression (^{0}C) at pre-flowering stage of Indian mustard. Table 4.8 reveals that every increasing dose of sulphur significantly increased canopy temperature depression at pre-flowering of Indian mustard. Application of highest tested dose of sulphur i.e. S_5 recorded significant highest canopy temperature depression at pre-flowering (5.06^{0}C) stage of Indian mustard than the other levels of sulphur application. Minimum canopy temperature depression at pre-flowering (4.09^{0}C) was obtained in control plot (Fig. 12).

The interaction effect on canopy temperature depression at pre-flowering stage was significantly influenced due to various levels of sulphur and zinc (Appendix X). Highest canopy temperature depression (5.47^{0}C) at pre-flowering was observed in $Zn_5 \times S_5$ and it was statistically at par to the interaction of $Zn_4 \times S_5$ and $Zn_5 \times S_4$. Lowest (3.85^{0}C) was reported in the treatment combination of without sulphur and zinc applied plot (Zn_0S_0), (Fig. 13 and Table 3).

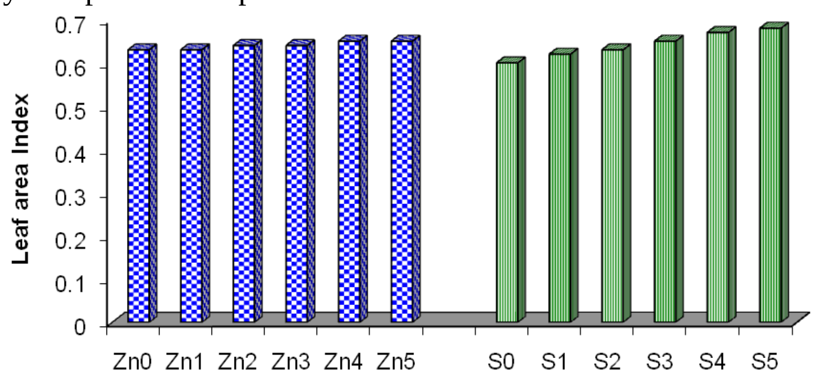
Effect of zinc and sulphur on canopy temperature depression (^{0}c) at post–flowering stage

The results obtained on canopy temperature depression (^{0}C) at post-flowering stage of Indian mustard as influenced by different doses of zinc and sulphur have been presented in Table 4.8 and 4.10 and their respective mean sum of square are given in Appendix I.

It is clear from the Appendix I that the application of various doses of zinc had influence the canopy temperature depression at post-flowering. Table 4.8 reveals that the treatment Zn_0, Zn_1, Zn_2, Zn_3, Zn_4 and Zn_5 showed significant difference to each other. The treatment Zn_5 showed highest canopy temperature depression (4.31^{0}C) followed by Zn_4 (Fig. 14). The minimum canopy temperature depression (3.74^{0}C) of Indian mustard was recorded in control. Increasing trends in canopy temperature depression at post-flowering stage due to zinc application were observed as dose increased.

It is evident from the Appendix X that the application of various doses of sulphur significantly increased the canopy temperature depression (^{0}C) at post-flowering stage of Indian mustard. Table 4.8 shows that the treatment S_5 recorded significantly higher canopy temperature depression at post-flowering (4.32^{0}C) of Indian mustard than rest of doses applied except S_4. The treatment S_4 and S_5 was found to be differed non-significantly. The progressive increase in canopy temperature depression at post-flowering of Indian mustard was accompanied by increase in sulphur levels. Minimum canopy temperature depression at post-flowering (3.74^{0}C) was observed in control plot, respectively (Fig. 14).

Appendix X depicted canopy temperature depression at post-flowering stage was significantly influenced due to various levels of sulphur and zinc. Most of the treatment combination differed significantly to each other. Table 4.10 reveals that interaction of Zn_5 x S_5 recorded significantly highest canopy temperature depression at post-flowering (4.63^{0}C) and it was statistically at par to the interaction of $Zn_4 \times S_5$ and $Zn_5 \times S_4$. While minimum (3.27^{0}C) was reported in the treatment combination of without zinc and sulphur applied plot ($Zn_0 \times S_0$) (Fig. 15).



Effect of Zinc and Sulphur on Laf Area Index at 30 DAS (Days after sowing) in Indian Mustard Variety Urvashi

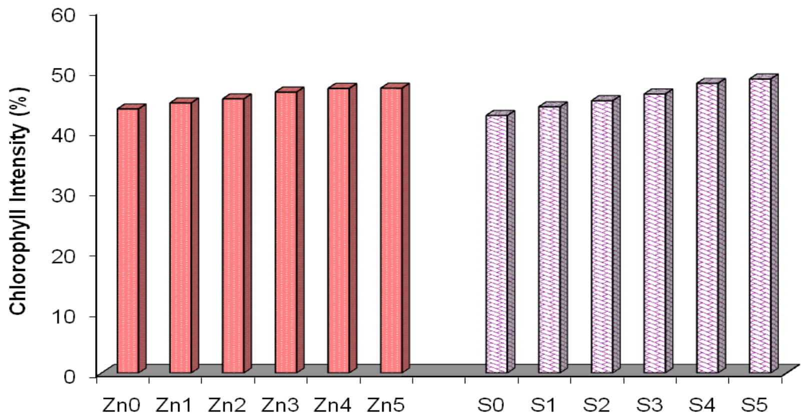


Fig. 8: Effect of Zinc and Sulphur on Chlorophyll intensity (%) at Pre-flowering in Indian Mustard Variety Urvashi

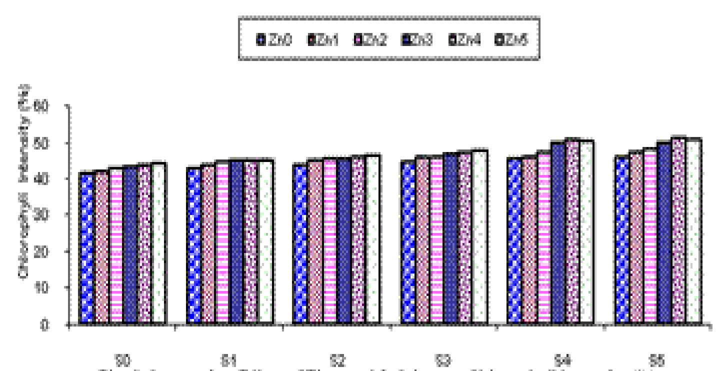


Fig. 9: Interaction Effect of Zinc and Sulphur on Chlorophyll Intensity (%) at Pre-flowering in Indian Mustard Variety Urvashi (Pooled)

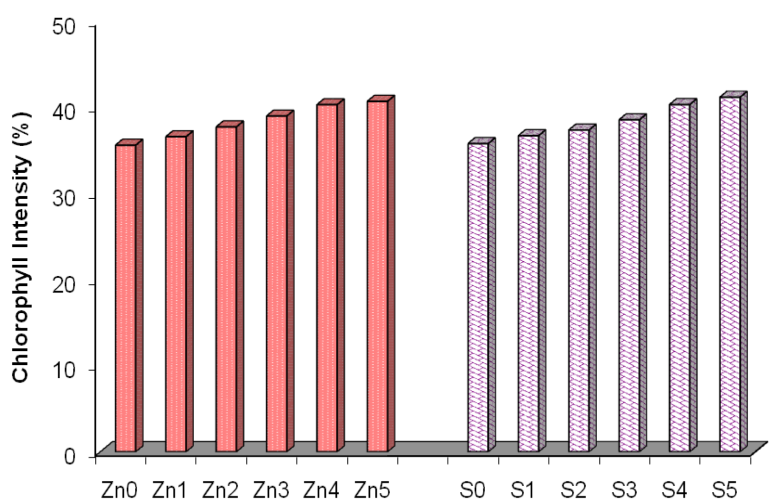


Fig 10. : Effect of Zinc and Sulphur on Chlorophyll intensity (%) at Post-flowering in Indian Mustard Variety Urvashi

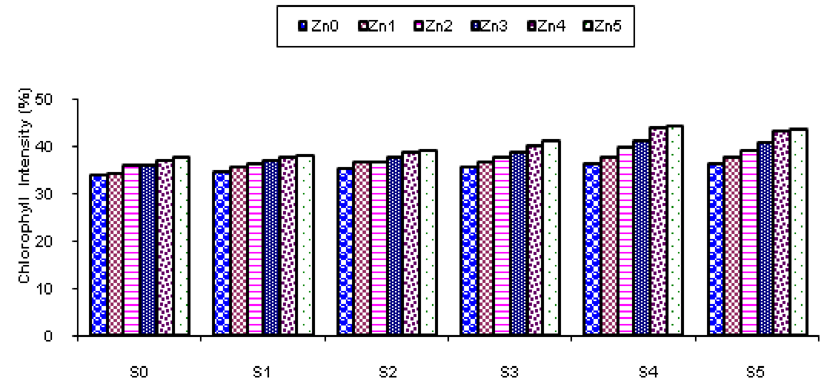


Fig. 11: Interaction Effect of Zinc and Sulphur on Chlorophyll Intensity at Post-flowering in Indian Mustard Variety Urvashi (Pooled)

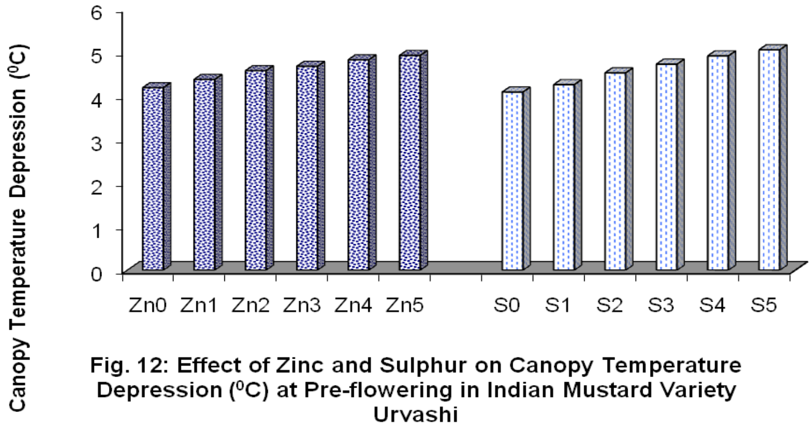


Fig. 12: Effect of Zinc and Sulphur on Canopy Temperature Depression (⁰C) at Pre-flowering in Indian Mustard Variety Urvashi

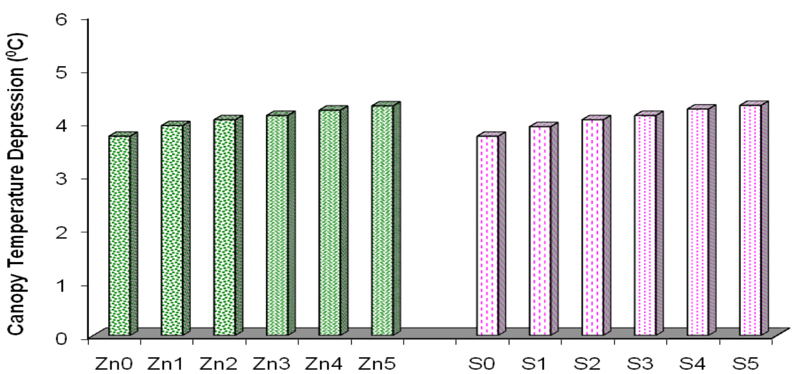


Fig. 14: Effect of Zinc and Sulphur on Canopy Temperature Depression (⁰C) at Post-flowering in Indian Mustard Variety Urvashi

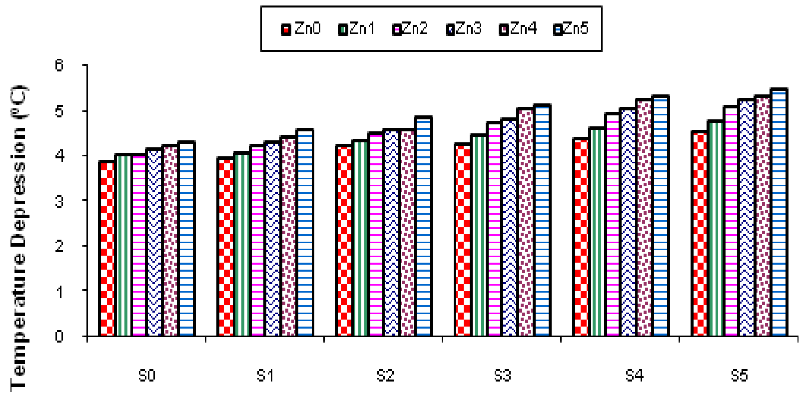


Fig. 13: Interaction Effect of Zinc and Sulphur and on Canopy Temperature Depression (°C) at Pre-flowering in Indian Mustard Variety Urvashi (Pooled)

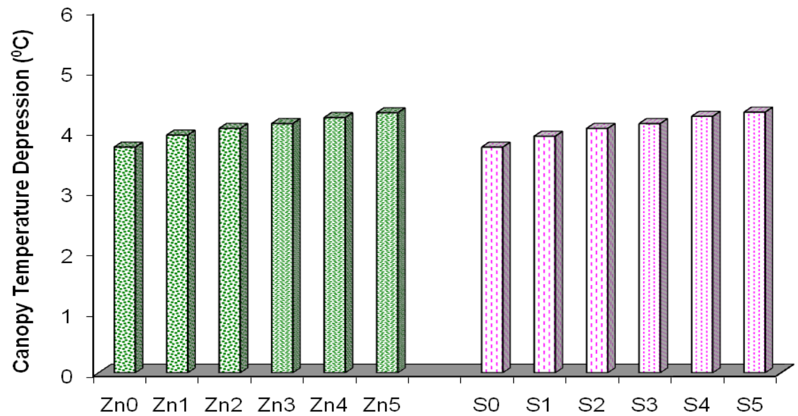


Fig. 14: Effect of Zinc and Sulphur on Canopy Temperature Depression (°C) at Post-flowering in Indian Mustard Variety Urvashi

Table.1 Interaction Effect of Zinc and Sulphur on Leaf Area Index at 30, 60 and 90 DAS in Indian Mustard Variety Urvashi (Pooled).

Sulphur **Zinc**	**0 Kg S ha^{-1} (S_0)**	**10 Kg S ha^{-1} (S_1)**	**20 Kg S ha^{-1} (S_2)**	**30 Kg S ha^{-1} (S_3)**	**40 kg S ha^{-1} (S_4)**	**50 kg S ha^{-1} (S_5)**	**0 Kg S ha^{-1} (S_0)**	**10 Kg S ha^{-1} (S_1)**	**20 Kg S ha^{-1} (S_2)**	**30 Kg S ha^{-1} (S_3)**	**40 kg S ha^{-1} (S_4)**	**50 kg S ha^{-1} (S_5)**	**0 Kg S ha^{-1} (S_0)**	**10 Kg S ha^{-1} (S_1)**	**20 Kg S ha^{-1} (S_2)**	**30 Kg S ha^{-1} (S_3)**	**40 kg S ha^{-1} (S_4)**	**50 kg S ha^{-1} (S_5)**
0.0 Kg Zn ha^{-1} (Zn_0)	0.59	0.61	0.62	0.63	0.65	0.67	1.81	1.85	1.89	1.92	1.96	2.00	1.46	1.50	1.54	1.60	1.64	1.69
2.5 Kg Zn ha^{-1} (Zn_1)	0.59	0.60	0.62	0.64	0.66	0.68	1.82	1.86	1.90	1.93	1.96	2.01	1.47	1.50	1.56	1.61	1.66	1.71
5.0 kg Zn ha^{-1} (Zn_2)	0.60	0.62	0.63	0.65	0.67	0.68	1.83	1.87	1.91	1.95	1.99	2.04	1.48	1.52	1.58	1.62	1.68	1.72
7.5 Kg Zn ha^{-1} (Zn_3)	0.61	0.62	0.64	0.65	0.68	0.69	1.84	1.88	1.92	1.97	2.02	2.05	1.50	1.53	1.60	1.64	1.69	1.74
10.0 kg Zn ha^{-1} (Zn_4)	0.61	0.63	0.64	0.66	0.68	0.70	1.85	1.90	1.95	2.00	2.05	2.09	1.52	1.56	1.62	1.67	1.73	1.77
12.5 kg Zn ha^{-1} (Zn_5)	0.61	0.63	0.64	0.66	0.68	0.69	1.85	1.89	1.94	1.99	2.04	2.07	1.51	1.55	1.61	1.66	1.72	1.75
SE (d)	0.09						**0.03**						0.02					
CD (p = 0.05)	**N.S.**						**N.S.**						**N.S.**					

Table.2 Interaction Effect of Zinc and Sulphur on Chlorophyll Intensity (%) at Pre-flowering and Post- flowering in Indian Mustard Variety

Sulphur / Zinc	Chlorophyll Intensity (%) Pre-flowering						Chlorophyll Intensity (%) Post-flowering					
	0 Kg S ha^{-1} (S_0)	**10 Kg S ha^{-1} (S_1)**	**20 Kg S ha^{-1} (S_2)**	**30 Kg S ha^{-1} (S_3)**	**40 kg S ha^{-1} (S_4)**	**50 kg S ha^{-1} (S_5)**	**0 Kg S ha^{1} (S_0)**	**10 Kg S ha^{-1} (S_1)**	**20 Kg S ha^{-1} (S_2)**	**30 Kg S ha^{-1} (S_3)**	**40 kg S ha^{-1} (S_4)**	**50 kg S ha^{-1} (S_5)**
0.0 Kg Zn ha^{-1} (Zn_0)	41.45	42.55	43.40	44.40	45.10	45.80	34.05	34.60	35.30	35.85	36.45	36.50
2.5 Kg Zn ha^{-1} (Zn_1)	41.93	43.70	44.65	45.60	45.95	46.85	34.57	35.75	36.95	36.80	37.80	37.85
5.0 kg Zn ha^{-1} (Zn_2)	42.43	44.23	45.23	45.85	46.88	48.13	36.00	36.50	36.70	38.00	39.95	39.40
7.5 Kg Zn ha^{-1} (Zn_3)	42.98	44.63	45.50	46.83	49.68	49.83	36.20	37.30	38.05	39.05	41.38	41.15
10.0 kg Zn ha^{-1} (Zn_4)	43.45	44.85	45.82	47.27	50.48	51.30	37.10	38.05	39.05	40.42	44.10	43.35
12.5 kg Zn ha^{-1} (Zn_5)	43.95	44.87	46.30	47.60	50.05	50.58	37.98	38.25	39.30	41.40	44.60	43.85
SE (d)	0.33											
CD (p = 0.05)	**0.66**						0.42					
							0.82					

Table.3 Interaction Effect of Zinc and Sulphur on Canopy Temperature Depression (^{0}C) at Pre-flowering and Post-flowering in Indian Mustard Variety Urvashi (Pooled)

Sulphur / Zinc	Depression (^{0}C) at Pre-flowering						Depression (^{0}C) at Post-flowering					
	0 Kg S ha^{-1} (S_0)	10 Kg S ha^{-1} (S_1)	20 Kg S ha^{-1} (S_2)	30 Kg S ha^{-1} (S_3)	40 kg S ha^{-1} (S_4)	50 kg S ha^{-1} (S_5)	0 Kg S ha^{1} (S_0)	10 Kg S ha^{-1} (S_1)	20 Kg S ha^{-1} (S_2)	30 Kg S ha^{-1} (S_3)	40 kg S ha^{-1} (S_4)	50 kg S ha^{-1} (S_5)
0.0 Kg Zn ha^{-1} (Zn_0)	3.85	3.96	4.20	4.26	4.37	4.52	3.27	3.65	3.78	3.87	3.92	3.97
2.5 Kg Zn ha^{-1} (Zn_1)	4.00	4.06	4.33	4.45	4.62	4.78	3.70	3.77	3.95	4.05	4.07	4.12
5.0 kg Zn ha^{-1} (Zn_2)	4.03	4.22	4.48	4.72	4.93	5.07	3.78	3.88	4.03	4.13	4.22	4.27
7.5 Kg Zn ha^{-1} (Zn_3)	4.12	4.28	4.56	4.80	5.05	5.23	3.85	3.97	4.13	4.15	4.30	4.40
10.0 kg Zn ha^{-1} (Zn_4)	4.23	4.42	4.57	5.02	5.25	5.32	3.90	4.08	4.17	4.22	4.45	4.55
12.5 kg Zn ha^{-1} (Zn_5)	4.28	4.58	4.83	5.12	5.31	5.47	3.97	4.17	4.22	4.33	4.57	4.63
SE (d)	0.09						0.09					
CD (p = 0.05)	**0.18**						**0.17**					

Appendix.I Data for the year 2011-12 and 2012-12 for the character, Chlorophyll Intensity (%) and Canopy Temperature Depression (ºC) at Pre and Post-Flowering Stage

Treatments	Chlorophyll Intensity (%)				Canopy Temperature Depression (^{o}C)			
	Pre-flowering		Post-flowering		Pre-flowering		Post-flowering	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
S_0Zn_0	42.4	40.5	35.4	32.7	3.8	3.9	3.3	3.3
S_0Zn_1	42.6	41.3	35.6	33.5	4.0	3.9	3.7	3.7
S_0Zn_2	43.0	41.9	37.2	34.8	4.1	4.0	3.8	3.8
S_0Zn_3	43.5	42.5	37.2	35.2	4.2	4.0	3.8	3.9
S_0Zn_4	43.9	43.0	37.7	36.5	4.2	4.3	3.9	3.9
S_0Zn_5	44.1	43.8	37.9	36.1	4.3	4.3	4.0	4.0
S_1Zn_0	43.0	42.1	36.0	33.2	3.9	4.2	3.7	3.6
S_1Zn_1	43.6	43.8	36.7	34.8	4.0	4.1	3.8	3.8
S_1Zn_2	44.3	44.2	37.5	35.5	4.2	4.2	3.9	3.9
S_1Zn_3	44.6	44.7	38.2	36.4	4.3	4.3	4.0	4.0
S_1Zn_4	44.7	45.0	38.8	37.3	4.4	5.4	4.0	4.1
S_1Zn_5	44.5	45.2	39.4	37.1	4.6	4.6	4.1	4.2
S_2Zn_0	43.5	43.3	36.6	34.3	4.2	4.2	3.8	3.8
S_2Zn_1	44.8	44.5	37.1	34.9	4.3	4.3	3.9	4.0
S_2Zn_2	45.3	45.2	37.7	35.7	4.6	4.4	4.0	4.1
S_2Zn_3	45.4	45.6	38.3	37.5	4.7	4.6	4.1	4.2
S_2Zn_4	45.7	45.9	39.2	38.9	4.8	4.7	4.1	4.2
S_2Zn_5	46.1	46.5	40.0	38.6	4.9	4.7	4.2	4.2
S_3Zn_0	44.0	44.8	37.6	34.8	4.2	4.3	3.9	3.9
S_3Zn_1	45.3	45.9	38.1	35.5	4.5	4.3	4.0	4.1
S_3Zn_2	45.3	46.4	39.3	36.7	4.9	4.6	4.1	4.1
S_3Zn_3	46.2	47.5	40.5	31.6	4.9	4..6	4.1	4.2
S_3Zn_4	46.6	47.9	41.3	40.2	5.1	4.9	4.2	4.2
S_3Zn_5	46.7	48.5	42.7	40.1	5.3	4.9	4.4	4.3
S_4Zn_0	44.7	45.5	37.7	35.3	4.3	4.4	3.9	3.9
S_4Zn_1	45.8	46.1	38.9	36.8	4.7	4.5	4.0	4.1
S_4Zn_2	46.5	47.3	40.2	38.6	4.8	4.7	4.2	4.2
S_4Zn_3	50.6	48.8	41.8	40.5	5.1	4.9	4.3	4.3
S_4Zn_4	47.9	51.5	43.0	43.7	5.3	5.2	4.4	4.5
S_4Zn_5	48.8	51.3	43.5	43.5	5.3	5.3	4.6	4.5
S_5Zn_0	45.4	46.2	38.1	36.4	4.5	4.5	4.0	4.0
S_5Zn_1	47.2	46.5	39.7	37.9	4.7	4.8	4.1	4.1
S_5Zn_2	48.5	47.8	40.4	39.5	5.1	5.0	4.3	4.3
S_5Zn_3	50.3	49.4	42.2	42.6	5.2	5.2	4.4	4.4
S_5Zn_4	50.1	52.5	43.2	44.7	5.3	5.3	4.5	4.6
S_5Zn_5	49.0	52.2	45.3	43.9	5.5	5.4	4.6	4.6
SE (d)	0.07	0.25	0.07	0.25	0.04	0.05	0.06	0.03
CD (p=0.05)	**0.17**	**0.55**	**0.16**	**0.55**	**0.09**	**0.11**	**0.13**	**0.13**

Note: Pooled data has already been presented under the chapter (IV) Experimental Finding.

In the present investigation, all morpho-physiological parameters were affected significantly due to application of various doses of zinc and sulphur. The linear increase in values related to morpho–physiological parameters due to application of zinc and sulphur was observed. The dose 10 Kg ha^{-1} zinc and 50 Kg ha^{-1} sulphur exhibited profound effect at 90 DAS with respect to leaf area index. Though the same dose has also shown increasing results 60 DAS. At 30 DAS least effect of zinc and sulphur doses were recorded as compared to 60 and 90 DAS. No interaction effect of zinc and sulphur was recorded at any stages of days after sowing. As far as concerned with chlorophyll intensity at pre-flowering and post-flowering stages, 10 (Zn_4) and 12.5 (Zn_5) Kg ha^{-1} zinc recorded highest chlorophyll intensity per cent, respectively. However, application of 50 Kg S ha^{-1} recorded highest chlorophyll intensity per cent that is 48.47% and 41.21% at pre-flowering and post-flowering stages, respectively. It has also been visualized that all treatments of zinc and sulphur expressed significant difference to one another.

Significant interaction of zinc and sulphur were recorded with respect to chlorophyll intensity at pre-flowering and post-flowering stages, a combination of 10 Kg Zn ha^{-1} + 50 Kg S ha^{-1} ($Zn_4 \times S_5$) produced maximum chlorophyll intensity that is 51.30%. However, at post-flowering stage a combined effect of 10 Kg Zn ha^{-1} + 40 Kg S ha^{-1} ($Zn_4 \times S_4$) were found to be beneficial by scoring 44.10% as compared to rest of the combinations. As far as concerned to canopy temperature depression at pre-flowering and post-flowering stage, upto the application of 12.5 Kg Zn and 50 Kg S had produced highest canopy temperature depression recorded with 4.93 and 4.31^0C and 5.06 and 4.32^0C, respectively. Linear increased in canopy temperature depression was recorded with every increasing dose of zinc and sulphur. Interaction of zinc and sulphur exhibited significant effect of canopy temperature depression at pre-flowering stage. An application of 10 Kg Zn ha^{-1} + 50 Kg S ha^{-1} ($Zn_4 \times S_5$) was found to be best among all combination applied during the investigation. It seems that the application of zinc and sulphur interacts with physiological activities of the plant that helps better in growth of the plants. The increase in leaf area index of Indian mustard due to Zinc and sulphur application have also been reported by Upasani and Sharma (1986), Khanpara *et al.* (1993), Patel and Sheeke (1998), Upadhyay *et al.* (2000), Chandel *et al.* (2003), Mankar *et al.* (2004), Raut *et al.* (2004), Husain *et al.* (2004), Sahu *et al.* (2004), Kumar (2005), Singh *et al.* (2007), Jain *et al.* (2008), Verma *et al.* (2012), Sharifi (2012), Singh *et al.* (2012).

References

Anonymous (2004). Sulphur in oil Seed Production, Fertilizer Development and Consultation Organization (FDCO) 204-204. A Bharat Corner Pomposh Enclave, Ne Delhi-110048.

Anonymous (2014). Status Paper on Oil Seeds. Oil Seeds Division, Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India, Krishi Bhawan, New Delhi. pp: 133-136 and 176-177.

Aulakh, M.S. and Pasricha, N.S. (1988). "Sulphur Fertilization of Oil Seeds for Yield and Quality", in Proceedings of the TSI-FAI Symposium. *Sulphur in Agriculture*-S-11/3.

Deb, D.L. and Sakal, R. (2002). Micronutrients: Fundamental of soil science, I.S.S.S. New Delhi. P. 401.

Husain, M.F.; Kumar, R. and Pal, S. (2004). Influence of Sulphur on the Performance of Mustard in South West Semi arid Zone of Uttar Pradesh. *Prog. Agric*., 4 (2): 112-114.

Jain, A.K.; Kumar, S.; Panwar, J.D.S. and Singh, O.P. (2008). Impact of Nitrogen and

Sulphur Application on Yield, Dry Matter Production and Seed Oil Content in Rape Seed-mustard. *Advances Plant Sci.*, 21 (3): 531-532.

Katyal, J. C.; Sharma, K. L. and Srinivas, K. (1997). Sulphur in Indian Agriculture. pp. KS-2/1-2/12.

Khanpara, V. D.; Porwal, B. L. and Patel, J. C. (1993). Effect of Levels and Modes of Sulphur Application on Biochemical Changes in Mustard (*Brassica Juncea* L.) Leaves. *Indian J. Agron*., 38 (3): 410-413.

Kumar, M. (2005). Effect of Nutrients on Yield and Seed Quality of Indian Mustard [*Brassica Juncea* (L.) Czern and Coss.]. *Thesis Ph.D. C.S.A. Univ. of Agri. And Tech., Kanpur, Uttar Pradesh,* PP.105-113.

Mankar, S.M.; Deotle, R.D.; Wandile, R.M. and Dighe, R.S. (2004). Post-harvest Studies in *M*ustard as Influenced by Foliar Application of Zinc Sulphate. *J. Soils and Crops,* 14 (1): 83 -86.

Marschner, H. (1995). Mineral Nutrition of Higher Plants. Second Edition, *Academic Press New York*, pp. 231- 255 and 889.

Patel, J.J.; Gupta, D.G. and Dabhi, M. K. (2010). Response of Sulphur Application on Growth, Yield Attributes and Yield of Mustard Under Gujarat Conditions. *Green Farming*, 1 (3): 272- 273.

Raut, R.F.; Hamid, A. and Ganvir, M.M. (2004). Effect of Irrigation and Sulphur on Growth and Yield of Mustard. *Annals Plant Physiol.*, 17 (1): 12-16.

Sahu, B.; Vivek, Kwatara and Nema, M.L. (2004). Response of Mustard (*Brassica Juncea* (L.) Czern and Coss.) to Phosphorus and Sulphur Levels in Rice Lowlands. *J. Oilseeds Res.*, 21 (1): 181-182.

Sharifi, R.S. (2012). Study of Yield and Yield Attribute and Dry Matter Accumulation of Canola (*B. Napus* L.) in Relation to Sulphur Fertilizers. International *J. Agric. and Crop Sci.*, 4 (7): 409-415.

Singh, A. and Meena, N.L. (2004). Effect of Nitrogen and Sulphur on Growth, Yield Attributes and Seed Yield of Mustard (*Brassica Juncea* L.) in Eastern Plains of Rajasthan . *Indian J. Agron.*, 49 (3): 126-188.

Singh, B.; Sharma, Y. and Rathore, B.S. (2012). Effect of Sulphur and Zinc on Growth, Yield and Quality of Mustard [*Brassica Juncea* (L). Czern and Coss.]. *Research on Crops*, 13 (3): 963-969.

Tisdale, S.L.; Nelson, W.L. and Beaten, J.D. (1984). Zinc in Soil Fertility and Fertilizers, *4th Ed., Macmillan Publishing Company, New York, USA,* pp: 382-391.

Upadhyay, R.G.; Singh, B.B. and Sharma, S. (2000). Effect of Various Levels of Zinc and Irrigation on Growth, Yield and Yield Contributing Characters of Indian Mustard (*Brassica Juncea* L.). *Agric. Sci. Digest*, 20 (1): 68-70.

Upasani, R.R. and Sharma, M.C. (1986). Effect of Nitrogen and Sulphur on Some Growth Parameters, Evapotranspiration and Moisture Use Efficiency of Mustard Under Dryland Condition. *Indian J. Agron*. 31(3): 222-228.

Watson, D.J. (1947). Comparative Physiological Studies on Growth of Field Crops. I. Variation in Net Assimilation Rate and Leaf Area Between Species and Varieties and Within Years. *Ann. Bot.*, 11: 41-76.

Verma, C.K.; Prasad, K and Yadav, D.D. (2012). Studies on Response of Sulphur, Zinc and Boron Levels on Yield, Economics and Nutrients Uptake of Mustard [*Brassica Juncea* (L.) Czern and Coss.]. *Crop Res. (Hisar)*, 44 (1/2): 75-78.

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