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Effect of sulphur, zinc and boron on growth and yield of irrigated Indian mustard (*Brassica juncea* L) in Bundelkhand region

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Abstract

A field experiment was carried out to assess the effect of different levels of sulphur, zinc and boron on growth and yield of Indian mustard (*Brassica juncea* L) during 2019-20. Results revealed that the growth parameters were maximum with the application of 40 kg S ha^{-1} at 60 and 90 days after sowing (DAS) and as well as at harvest, which was statistically at par with 20 kg S ha^{-1} while significantly higher over 0 kg S ha^{-1}. In case of zinc and boron levels maximum value of growth parameters were recorded with 5.0 kg Zn ha^{-1} at 60 and 90 DAS. The highest seed yield, stover yield, harvest index, oil content and oil yield were recorded with the application of 40 kg S ha^{-1}, which was significantly higher over 0 kg S ha^{-1}. Among zinc and boron levels, the application of 2.5 kg Zn + 0.5 kg B ha^{-1} produced higher seed yield, stover yield, harvest index, oil content and oil yield. Interactive effect of S, Zn and B on seed yield and oil yield was also found significant. Maximum seed yield was recorded with the application of 40 kg S along with 2.5 kg Zn + 0.5 kg B ha^{-1} while oil yield was maximum with application of 40 kg S along with 2.5 kg Zn.

Keywords: *Boron, chlorophyll, growth, Indian mustard, sulphur, yield, zinc*

Introduction

Brassica juncea (L) Czernj & Cosson belongs to the family Brassicaceae and commonly called as *Rai* or Indian mustard. It contains good amount of oil usually 30–38 %. India is having 6.23 million ha area under rapeseed-mustard and 9.34 million tonnes production with average productivity of 1499 kg ha^{-1}, which is about three-fourth of the world's average productivity (1960 kg ha^{-1}) (DAC&FW, 2020). The average productivity of rapeseed-mustard crop in Bundelkhand region is very low (763 kg ha^{-1}) as compared to national productivity. Agronomic management practices are the main reason for low productivity of rapeseed-mustard in India as well as in Bundelkhand region. Among that, nutrient management stands first as it helps to increase the productivity of mustard crop up to 18 to 73 % over the traditional packages and practices (Kumar, 2012). The soils of UP Bundelkhand region is low in available N and P, low to high in available K, deficient in sulphur and 40–80 % deficient in available Zn (Singh *et al*., 2018).

Sulphur is the fourth most important nutrient in crop production to increase quality and productivity of mustard. It is essential for synthesis of amino acid, chlorophyll formation, activation of various enzymes and sulphydryl (SH-) linkages, protein and oil synthesis (Rathore *et al*., 2015). Beside sulphur, mustard crop is responsive to micronutrients application especially Zn and B in moderate to low fertile soils. Zn plays an important role in the activation of several enzymes, such as carbonic anhydrase, dehydrogenase, aldolase, alkaline phosphatase, ribulose bi-phosphate carboxylase, RNA polymerase and phospholipase which regulate various metabolic processes in the plants. Boron is the second most essential micronutrient in mustard after Zn (Ahmad *et al*., 2012). Mustard crop responded well to B application with the average response ranging from 21-31 % (Shekhawat *et al*., 2012). It plays an important role in the cell division, differentiation, and elongation of meristemic region and reproductive growth of plant (Havlin *et al*., 2013). Thus, application of nutrient in balanced and adequate amount is necessary for increasing the mustard yield accompanied with improvement in quality of the produce.

Materials and Methods

A field experiment was conducted to assess the effect of sulphur, zinc and boron on growth and yield of irrigated Indian mustard during the *Rabi* season of 2019-20 at the research farm of Rani Lakshmi Bai Central Agricultural University, Jhansi which lies in the Bundelkhand Agro-climatic Zone (6) of Uttar Pradesh. In the Bundelkhand region, the annual rainfall ranges from 850 to 1000 mm, classifying it as a sub-humid region. During the experimental period from November 2019 to March 2020, the total rainfall recorded was 41.6 mm. Out of this, December received 8.2 mm, January received 24.6 mm, and March received 8.8 mm. The average maximum temperature during this period was 24.5 °C, while the average minimum temperature was 10.0 °C. In contrast, the cumulative pan evaporation for the entire cropping period was measured at 60.8 mm. The soil in the experimental field was loam in texture and had the following characteristics: pH of 6.8, electrical conductivity (EC) of 0.20 dS m^{-1} at 25 °C, organic carbon content of 0.51 %, available nitrogen of 260.5 kg ha^{-1}, available phosphorus of 18.1 kg ha^{-1}, available potassium of 241.8 kg ha^{-1}, available sulphur of 21.5 kg ha^{-1}, available zinc of 0.57 mg kg^{-1} and available boron of 1.28 mg kg^{-1}. These values represent the initial fertility status of the soil. The experiment was laid out in split-plot design where S levels allotted to the main plot, while Zn and B levels were allotted to sub-plots treatments with three replications. The factors under study are as follows: (A) three sulphur levels were S_0 – control, S_{20} – 20 kg S ha^{-1}, S_{40} – 40 kg S ha^{-1}; and (B) six zinc and boron levels were Zn_0+B_0 – control, $Zn_{2.5}$ – 2.5 kg Zn ha^{-1}, $Zn_{5.0}$ – 5.0 kg Zn ha^{-1}, $B_{0.5}$ – 0.5 kg B ha^{-1}, $B_{1.0}$ – 1.0 kg B ha^{-1} and $Zn_{2.5}+B_{0.5}$ – 2.5 kg Zn ha^{-1} + 0.5 kg B ha^{-1}. Indian mustard variety DRMRIJ-31 (Giriraj) was sown at a seed rate of 4 kg ha^{-1}, spacing 45 cm × 10 cm and recommended dose of fertilizer N, P_2O_5 and K_2O *i.e.*,80, 40 and 40 kg ha^{-1} were supplied. The requisite quantity of each sulphur, zinc and boron treatments were applied plot-wise as per treatment through basal application. S was applied in the form of bentonite-S, which contained 90 % of sulphur as SO_4^{-2}, while Zn was applied in the form of zinc oxide (78 % Zn) and B was applied in the form of borax (10.5 % B).

Before sowing, mustard seeds were treated with thiram at a rate of 2.5 g kg^{-1} seed. Pre-sowing irrigation was applied one week prior to sowing, followed by two additional irrigations at 29 and 67 days after sowing (DAS). To manage weeds effectively, a pre-emergence application of pendimethalin at the rate of 1 kg *a.i.* ha^{-1} was carried out, and one-hand weeding was done at 30 DAS. For protection against *Lipaphis erysimi* (Aphids) infections, dimethoate @ 1 ml per liter of water was sprayed twice at the flowering and pod development stages. Various growth and yield attributes 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 crop was harvested on 20^{th} March 2020 when approximately 80 % of the siliquae colour had turned yellowish. Initially, the border rows of the individual plots were harvested. Subsequently, the net plots were harvested individually, and the harvested bundles were tagged and stored within the plots for the purpose of sun drying. The total produce from each net plot was weighed to determine the biological yield, followed by threshing and cleaning. The seed yield was determined by recording the weight of the seeds obtained and while the stover yield was calculated by subtracting the seed yield from the total biological yield of the respective plots and measured in tons per hectare (t ha^{-1}). The harvest index (HI) was calculated using the formula developed by Donald and Hamblin (1976). Oil content in mustard seed was measured by soxhlet extraction procedure (AOAC, 1970). The mustard seeds of individual plots were dried at 60°C for 6 hours; grinded in pestle & mortar and 2 g sample was weighed in thimble and placed in soxhlet extractor. The oil was extracted with petroleum ether (40-60°C) for 6 hours in a distillation flask. After distillation of sample, petroleum ether was evaporated in an oven for one hour at 100-105°C. The sample was cooled and weighed and oil percentage was then calculated as per the given formula:

Oil content in seed (%) = (Weight of extracted oil/ Weight of sample) × 100

Oil yield was calculated from oil content of individual sample multiplied by respective seed yield and expressed in kg/ha. Data collected on growth, yield and quality were tabulated and statistically analysed as per the standard "analysis of variance" to draw valid conclusions (Gomez and Gomez, 1984). The treatment differences were tested by 'F' test on the basis of null hypothesis. Critical differences were worked out at 5 % level of significance where 'F' test was significant.

Results and Discussion

Effect of sulphur, boron and zinc on growth parameters

The data in Table 1 and 2 showed that all growth parameters increased gradually with increasing levels of

Table 1: Effect of sulphur, zinc and boron on plant height and dry matter accumulation (DMA) of mustard

Treatment	Plant height (cm)				DMA (g plant^{-1})		
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS
S levels							
S_0	21	118	207	210	1.45	22.7	44.8
S_{20}	22	124	216	219	1.44	24.5	47.6
S_{40}	22	128	222	224	1.45	25.4	49.3
SEm±	0.3	1.7	2.7	2.6	0.01	0.4	0.8
CD (P=0.05)	NS	7.0	10.7	10.1	NS	1.8	3.2
Z and B levels							
Control (Zn_0B_0)	21	119	211	213	1.44	22.8	45.2
$Zn_{2.5}$	22	124	216	219	1.45	24.5	47.6
Zn_5	22	128	220	222	1.45	25.2	48.7
$B_{0.5}$	21	121	213	216	1.44	13.6	46.3
B_1	22	122	214	217	1.44	24.1	47.0
$Zn_{2.5}B_{0.5}$	22	125	218	220	1.45	24.9	48.4
SEm±	0.3	1.1	1.6	1.5	0.01	0.2	0.4
CD (P=0.05)	NS	3.2	4.5	4.3	NS	0.7	1.2

Table 2: Effect of sulphur, zinc and boron on primary branches, secondary branches and chlorophyll content (SPAD) of mustard

Treatment	Primary branches plant^{-1}		Secondary branches plant^{-1}		SPAD values		
	60 DAS	90 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
S levels							
S_0	6.1	6.7	3.4	14.3	37.5	38.0	35.7
S_{20}	6.5	7.3	3.8	15.2	39.1	39.8	37.2
S_{40}	6.9	7.5	4.1	15.7	40.7	41.2	39.3
SEm±	0.1	0.1	0.1	0.2	0.6	0.6	0.6
CD(P=0.05)	0.4	0.4	0.3	0.8	2.4	2.2	2.3
Zn and B levels							
Control (Zn_0B_0)	6.2	6.9	3.6	14.5	38.4	38.8	36.6
$Zn_{2.5}$	6.6	7.2	3.8	15.2	39.1	40.0	37.5
Zn_5	6.8	7.4	3.9	15.7	40.1	40.7	38.2
$B_{0.5}$	6.4	7.0	3.7	14.7	38.7	39.0	37.0
B_1	6.5	7.1	3.7	14.9	38.8	39.1	37.2
$Zn_{2.5}B_{0.5}$	6.7	7.3	3.9	15.4	39.4	40.2	37.8
SEm±	0.1	0.1	0.04	0.2	0.5	0.4	0.4
CD (P=0.05)	0.3	0.4	0.1	0.7	NS	1.0	1.0

S up to 40 kg ha^{-1}, except at 30 DAS. Maximum plant height, dry matter accumulation, primary branches, secondary branches and chlorophyll content were observed with 40 kg S ha^{-1} at all growth stages, which was statistically similar to 20 kg S ha^{-1} but significantly higher than 0 kg S ha^{-1}. The presence of adequate sulphur availability may contribute to enhanced cell division, elongation, tissue development, multiplication, and synthesis of essential amino acids (cysteine, cystine, methionine). In addition, an adequate supply of sulphur may facilitate the availability of sulfolipids, Fe-S clusters, co-enzyme A, and amino acids, which collectively contribute to the development of chlorophyll. Similar results have been reported by Kapur *et al*. (2010), Kumar *et al*. (2011) and Parmar and Parmar (2012). The levels of Zn and B did not significantly affect the growth parameters at 30 DAS. However, all growth parameters *i.e.,* plant height, dry matter accumulation per plant, primary and secondary branches and chlorophyll content were highest with 5.0 kg Zn ha^{-1} at all growth stages. The increased growth parameters may be due to the role of Zn in carbohydrate metabolism as being a constituent of enzymes involved in photosynthesis and a precursor of IAA biosynthesis in auxin metabolism (Alloway, 2008). The results of the present investigation corroborated the findings of Pachauri and Trivedi (2012), Yadav *et al*. (2016), and Kour *et al*. (2017).

Effect of sulphur, boron and zinc on seed yield

The data presented in Table 3 demonstrated that increasing levels of sulphur application up to 40 kg ha^{-1} significantly influenced the seed yield, stover yield, and harvest index of mustard. The application of 40 kg S ha^{-1} resulted in a 21.05 % increase in seed yield, 7.20 % increase in stover yield, and 9.63 % increase in harvest index compared to 0 kg S ha^{-1}. However, no significant difference was observed between 20 and 40 kg S ha^{-1}. The higher yield attributes and growth attributes observed with the highest sulphur application level (40 kg S ha^{-1}) contributed to the increased seed yield and stover yield. Similar results were reported by Singh *et al.* (2023) and Kumar *et al.* (2019). The highest seed yield was obtained with the combined application of 2.5 kg Zn + 0.5 kg B ha^{-1}, which was significantly superior to all other treatments and comparable to the application of 5.0 kg Zn ha^{-1}. Application of 2.5 kg Zn + 0.5 kg B ha^{-1} resulted in significantly higher stover yield compared to 0.5 kg B ha^{-1} and the control, but similar to other treatments. The highest harvest index was observed with the application of 2.5 kg Zn + 0.5 kg B ha^{-1}, comparable to all other treatments except 1 kg B ha^{-1}, 0.5 kg B ha^{-1}, and the control. Similar findings have been reported by Kour *et al*. (2017).

Table 3: Effect of sulphur, zinc and boron on oil and seed yield of Indian mustard

Treatments	Seed yield(t ha^{-1})	Stover yield(t ha^{-1})	Harvest index(%)	Oil content (%)	Oil yield (kg ha^{-1})
S levels					
S_0	1.52	4.58	24.9	37.5	568
S_{20}	1.72	4.80	26.4	39.2	676
S_{40}	1.84	4.91	27.3	40.1	739
SEm±	0.03	0.06	0.41	0.5	13
CD (P=0.05)	0.13	0.23	1.61	2.0	52
Zn and B levels					
Control (Zn_0B_0)	1.57	4.67	25.1	38.3	599
$Zn_{2.5}$	1.70	4.78	26.3	39.1	668
Zn_5	1.77	4.83	26.8	39.6	705
$B_{0.5}$	1.64	4.70	25.8	38.5	633
B_1	1.69	4.75	26.2	38.7	654
$Zn_{2.5}B_{0.5}$	1.79	4.86	26.9	39.3	706
SEm±	0.02	0.05	0.24	0.3	7
CD (P=0.05)	0.04	0.13	0.68	0.8	22

Table 4: Interactive effect of sulphur, zinc and boron on seed yield (t ha^{-1}) of mustard

Levels of sulphur	Levels of zinc and boron					
	Zn_0B_0	$Zn_{2.5}$	$Zn_{5.0}$	$B_{0.5}$	$B_{1.0}$	$Zn_{2.5}B_{0.5}$
S_0	1.45	1.52	1.55	1.49	1.51	1.57
S_{20}	1.59	1.74	1.81	1.66	1.71	1.83
S_{40}	1.66	1.85	1.96	1.76	1.84	1.98

	SEm±	CD (P=0.05)
Zn and B levels on same level of S	0.03	0.08
S at same or different levels of Zn and B	0.04	0.14

Interactive effect of varying levels of S at different levels of Zn and B application on seed yield was found significant and presented in Table 4. Maximum seed yield was obtained with $Zn_{2.5}$ + $B_{0.5}$, which was statistically at par with $Zn_{5.0}$ at all levels of S application except S_0. However, under S_0, seed yield was found maximum with $Zn_{2.5}$ + $B_{0.5}$, which were statistically at par with $Zn_{5.0}$, $Zn_{2.5}$ and $B_{1.0}$ and significantly higher than rest of the treatments. Among different levels of S application, maximum seed yield was recorded under S_{40} treatment while S_0 treatment obtained minimum seed yield at same or different levels of Zn and B. Maximum seed yield was recorded with S_{40} along with $Zn_{2.5}$ + $B_{0.5}$ treatments, which was at par with S_{40} along with $Zn_{5.0}$ and S_{40} along with $Zn_{2.5}$ while significantly higher over rest of the treatments. This was due to the combined application of S, Zn and B application, which provided balanced and adequate amounts of all the nutrients required by the mustard crop to produce higher seed yield. Thus, balanced application of these nutrients was responsible for the higher seed yield of mustard. The results are in close conformity with Kour *et al.* (2017) and Meena *et al.* (2022).

Effect of sulphur, boron and zinc on oil content and oil yield

The highest oil content was observed with the application of 40 kg S ha^{-1}, which was statistically similar to 20 kg S ha^{-1} and significantly higher than 0 kg S ha^{-1}. Moreover, the maximum oil yield was obtained with the application of 40 kg S ha^{-1}, resulting in a 9.32 % increase compared to 20 kg S ha^{-1} and a 30.11 % increase compared to 0 kg S ha^{-1}. These findings were similar with the previous studies conducted by Singh *et al*. (2010) and Kumar *et al*. (2011). The highest oil content was observed with the application of 5.0 kg Zn ha^{-1}, which was comparable to the combined application of 2.5 kg Zn + 0.5 kg B ha^{-1} and 2.5 kg Zn ha^{-1}, while significantly superior to the other treatments. However, the maximum oil yield was obtained with the combined application of 2.5 kg Zn + 0.5 kg B ha^{-1}, which was comparable to a higher dose of zinc alone (5.0 kg ha^{-1}) and significantly higher than the other treatments. This can be attributed to the combined effect of increased seed yield and oil content achieved with the application of 2.5 kg Zn + 0.5 kg B ha^{-1}. The interactive effect of varying levels of S at different levels of Zn and B on oil yield was found significant (Table 5). Maximum oil yield under S_0 treatment was obtained with $Zn_{2.5}$ $B_{0.5}$ and remained statistically at par with $Zn_{5.0}$. However, under S_{20} and S_{40}, application of $Zn_{5.0}$ had maximum oil yield, which was statistically at par with $Zn_{2.5}B_{0.5}$ and $Zn_{2.5}$ while significantly higher to rest of the treatments. Among different levels of S application, maximum oil yield recorded under S_{40} treatment while S_0 treatment associated with minimum oil yield at same or different level of Zn and B application. Maximum oil yield was recorded with S_{40} along with Zn_5 treatment, which was at par with S_{40} along with $Zn_{2.5}B_{0.5}$ and S_{40} along with $Zn_{2.5}$ while significantly higher over rest of the treatments. Increment in oil yield was due to balanced and adequate availability of S, Zn and B nutrients, resulted higher oil content and seed yield under well fertilized crop, responsible for higher oil yield.

Table 5: Interactive effect of sulphur, zinc and boron on oil yield (kg ha^{-1}) of mustard

Levels of sulphur	Levels of zinc and boron					
	Zn_0B_0	$Zn_{2.5}$	$Zn_{5.0}$	$B_{0.5}$	$B_{1.0}$	$Zn_{2.5}B_{0.5}$
S_0	535	573	589	555	564	592
S_{20}	613	685	719	648	669	720
S_{40}	650	746	806	697	729	804
				SEm±	CD (P=0.05)	
Zn and B levels on same level of S		12	35			
S at same or different levels of Zn and B		17	60			

Conclusion

It has been identified that productivity of mustard crop in Bundelkhand region is very low due to poor fertility status especially secondary and micro nutrients. Therefore, there is need to apply nutrients in balanced manner to increase mustard productivity in Bundelkhand region. The result of the experiment showed that the crop growth, seed yield, stover yield, harvest index, oil content and oil yield of Indian mustard were observed significantly higher with the application of 40 kg S ha^{-1}. Zinc application @ 5 kg ha^{-1} increased growth parameters while significant increase in seed yield, stover yield, harvest index, oil content and oil yield were recorded with combined application of Zn @ 2.5 kg + B @ 0.5 kg ha^{-1}. Thus, in addition to the recommended dose of NPK, application of 40 kg S ha^{-1} along with 2.5 kg Zn + 0.5 kg B ha^{-1} can be recommended for obtaining higher yield from mustard crop in Bundelkhand region.

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