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Impact of varying levels of sulphur and boron on growth and yields of mustard under different crop establishment

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Abstract
A field experiment was carried out over two consecutive *rabi* seasons of 2022-23 and 2023-24 at Research Farm, Department of Agronomy, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh to investigate the "Impact of varying levels of sulphur and boron on growth and yield of mustard under different crop establishment methods". The treatments comprised of two crop establishment methods (Direct seeding, Transplanting) in main plots and four levels of sulphur (Control, 20 kg S ha^{-1}, 30 kg S ha^{-1} and 40 kg S ha^{-1}) in sub plots and three levels of boron (control, 1 kg B $ha^{-1}$and 2 kg B ha^{-1}) in sub-sub plots. The experiment was laid out in a split-split plot design with three replications. The results of study revealed that direct seeding produced significantly higher plant height of 37.93, 114.81, 153.64 and 152.19 cm. However, highest dry matter accumulation of 21.72, 54.73 and 85.87 g $plant^{-1}$ was recoded transplanted crop. The highest seed yield and stover yield of 20.72 q ha^{-1} and 49.36 q ha^{-1}, respectively were registered under transplanting method. Application of sulphur @ 40 kg ha^{-1} produced significantly the highest seed and stover yields of 21.88 and 51.00 q ha^{-1} with harvest index of 30.05% and proved superior over rest of the levels except 30 kg S ha^{-1}. Whereas, maximum seed (20.28 q ha^{-1}) and stover yield (48.81 q ha^{-1}) was recoded with boron @ 2 kg ha^{-1}. The experiment concluded that the transplanting mustard, along with application of 40 kg S ha^{-1} and 2 kg B ha^{-1} promote the growth and enhance the productivity of the mustard crop.

Keywords: Mustard, establishment methods, sulphur, boron, yield

Introduction
Oilseeds have a crucial part in the Indian economy. India ranks fourth in vegetable oil production, following the USA, China, and Brazil. Mustard (*Brassica juncea* L.) is a significant oilseed crop that is essential for fulfilling the edible oil needs and nutritional security of nations, particularly the South Asia. Whereas, its productivity is below the potential due to improper sowing management as well as nutrient management practices. Crop establishment is a vital agronomic practice that effects, plant density, root development, nutrient absorption, and crop efficacy which affects growth, development and yields. To optimise limited space available for various cropping systems, transplanting of seedlings instead of direct seeding of mustard will be more advantageous. (Patel and Jat, 2022) [3]. In addition to this a balanced fertilization is a crucial for achieve optium productivity in mustard.

Sulphur plays a crucial role as a secondary nutrient, particularly for oilseed crops such as mustard due to its involvement in the synthesis of amino acids, proteins, chlorophyll, and oil. On the other hands boron is a vital element that is integral to cell division, pollen germination, fertilisation, seed formation, and the transfer of photosynthates, flower abortion, inadequate siliqua development, and consequently lower seed yield occur due to boron deficiency in mustard. (Sharma *et al.*, 2020) [6]. In view of the above fact it is essential to investigate the appropriate crop establishment techniques and the proper nutrition with respect to sulphur and boron as a secondary and trace elements.

Materials and Methods

A field experiment was carried out Research Farm, Department of Agronomy, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (MP) during *rabi* seasons of 2022-23 and 2023-24 in order to assess the impact of varying levels of sulphur and boron on growth and yield of mustard under crop establishment methods. The treatment comprised of two crop establishment methods (M_1: Direct seeding and M_2: transplanting) in main plots and four levels of sulphur (S_1: control, S_2: 20 kg S ha^{-1}, S_3: 30 kg S ha^{-1} and S_4: 40 kg S ha^{-1}) in sub plots and three levels of boron (B_0: control, B_1: 1 kg B ha^{-1} and B_2: 2 kg B ha^{-1}) in sub-sub plots. These treatments were laid out in split-split plot design with three replications. Mustard variety RH-725 used for sowing. Seeds were sown in nursery 14 days prior to schedule date of transplanting. For transplanting, nursery bed of 500m^2 area required was prepared by mixing of vermicompost in soil. The crop was raised by adopting package of practices. Thereafter, a light irrigation was applied to the nursery bed for germination. The recommended dose of fertilizer for Indian mustard crop i.e. 80:40:40 kg ha^{-1} NPK was applied. Full dose of phosphorus, potassium and half dose of nitrogen fertilizer were applied basal in main field just before sowing and transplanting in the form of urea, diammonium phosphate and murate of potash. The sulphur and boron fertilizer applied also as basal. The remaining nitrogen was applied after 25-30 days after sowing. For direct seeding seeds were sown in field at spacing of 45 cm row to row and 15 cm for plant to plant. Observations for plant height were recorded at 30, 60, 90 DAS of crop. For dry matter, plant samples were dried first under shade and later in the oven at 65± 2 ^{0}C till constant weight obtained. At maturity the seed and stover yield was recorded separately.

Results and Discussion

Effect of crop establishment methods

Plant height and dry matter accumulation increased with increase in age of plant upto maturity of crop. Data presented in Table 1 shows that direct seeding recorded significantly taller plants over to transplanted crop in all the growth stages. The highest plant heights of 37.93, 114.81, 153.64, and 152.19 cm were recorded under direct seeding crop as compared to the transplanting at 30, 60, 90 days after sowing and at harvest, respectively. The highest dry matter accumulation of 21.72, 54.73 and 85.87 g plant^{-1} was recorded under transplanted crop at 60, 90 DAS and at harvest of crop, respectively, as compared to direct seeding. While at 30 DAS direct seeding recorded significantly higher dry matter accumulation (4.37 g plant^{-1}) over to transplanting. Extended crop duration and favourable environment conditions contributed to increase in DMA in transplanted crop.

The seed and stover yield of crop significantly influenced by crop establishment methods (Table 2). Transplanted crop recoded significantly higher seed (20.72 q ha^{-1}) and stover yields of 49.36 q ha^{-1} over direct seeding of mustard. Increase in seed yield under transplanting accrued from better vegetative growth and consequently enhanced reproductive period as compared to direct seeding. Similarly, transplanting of mustard resulted in significantly higher harvest index of 29.57% than direct seeding.

Effect of Sulphur

The plant height and dry matter accumulation both found to be significantly influenced by levels of sulphur (Table 1). Increasing the levels of sulphur significantly increased the growth parameters at different interval of crop growth except 30 DAS. The 40 kg S ha^{-1} recorded significantly highest plant height of 116.68, 156.15 and 154.55 cm closely followed by 30 kg S ha^{-1} at 60, 90 DAS and at harvest. Lowest plant height of 103.15 137.39 and 135.79 cm was recorded under control. The significant increased plant height might be due to enhanced nutritional conditions for plant growth during active vegetative stages, resulting in increased cell multiplications, elongation, and expression in the plant body, thereby contributing to increase the plant height. These results are in accordance with the findings of Singh *et al.* (2016) [9].

The highest dry matter accumulation of 21.33, 57.78 and 88.03 g plant^{-1} at 60, 90 and at harvest of crop was recorded with 40 kg S ha^{-1} and found at par to 30 kg S ha^{-1} but significantly superior to control and 20 kg S ha^{-1}. Moreover, lowest dry matter accumulation of 17.22, 40.48 and 72.26 g plant^{-1} was noted under control at 60, 90 and at harvest of crop, respectively. This might attributed to increase in plant dry weight due to increased amino acid synthesis, higher levels of chlorophyll in the growing medium, and enhanced photosynthetic activity, which ultimately leads in increased cell division and accelerated plant growth. An adequate supply of sulphur improved photosynthetic output and easier transport of the chemical to the sink. These results are in accordance with the findings of Pravalika and Dawson (2023) [4].

A significant increase in seed and stover yield was found with addition of sulphur over control (Table 2). The highest seed and stover yield of 21.88 and 51.00 q ha^{-1} was recorded at 40 kg S ha^{-1} which was on par with at 30 kg S ha^{-1} However, both the levels were significantly superior to the control and 20 kg S ha^{-1} in pooled data, respectively. This might be attributed to increasing levels of S increased the greater accumulation of carbohydrates, protein and their translocation towards the reproductive organs, hence, improved the yield attributing characters, resulting higher seed yield. The findings confirm the results of Yadav and Sharma (2002) [8] and Sharma *et al.* (2009) [5]. The highest harvest index of 30.05% was recorded with application of 40 kg S ha^{-1}. Whereas, lowest harvest index of (27.69%) was recorded in control.

Effect of boron

Addition of boron as basal brings out significant changes with respect to plant height and dry matter accumulation at all the growth stages of crop except 30 DAS. (Table 1). The application of boron @ 2 kg ha^{-1} recorded significantly highest plant height of 115.36, 152.63 and 150.98 cm and found at par with 1 kg B ha^{-1} at 60, 90 DAS and harvest. However, the lowest plant height of 104.76, 141.32 and 139.77 cm was recorded in control treatment. The significantly increase in plant height might be attributed to the positive effect on rapid development on meristematic tissues. Singh *et al.,* (2022) [7]. Further, the significantly highest dry matter accumulation was recorded with an application of boron @ 2 kg ha^{-1} (22.31, 51.76 and 83.33 g plant^{-1}, respectively) at 60, 90 DAS and harvest closely followed by 1 kg B ha^{-1}. Moreover, lowest dry matter accumulation of 20.44, 46.78 and 76.59 g plant^{-1} was recorded in control treatment.

The maximum seed and stover yield (20.28 and 48.81 q ha^{-1}) was recorded in 2 kg B ha^{-1} and minimum seed and stover yield was recorded in control (15.77 and 39.21 q ha^{-1}) with harvest index of 28.63%. The increase in seed yield might be due to positive effect of boron on number of siliqua plant^{-1}, length of siliqua and number of seeds siliqua^{-1}. These traits are contribute in yield. These finding are in similar line as reported by Dey and Nath (2015) [1] and Jaiswal *et al.* (2015) [2].

Table 1: Effect of levels of sulphur and boron on growth of mustard crop under crop establishment methods. (Pooled data of two years)

Treatments	Plant height (cm)				Dry matter accumulation (g plant^{-1})			
	30 DAS	60 DAS	90DAS	Harvest	30 DAS	60 DAS	90DAS	Harvest
Crop Establishment Methods								
Direct seeding	37.93	114.81	153.64	152.19	4.37	17.19	44.01	74.53
Transplanting	25.51	105.78	140.91	139.16	3.62	21.72	54.73	85.87
S.Em±	0.84	1.28	1.61	1.58	0.11	0.33	0.78	1.11
CD (*P*=0.05)	5.11	7.76	9.81	9.61	0.65	2.01	4.76	6.74
Sulphur Levels (S)								
Control	29.53	103.15	137.39	135.79	3.53	17.22	40.48	72.26
20 kg ha^{-1}	31.18	108.25	144.84	143.24	3.88	18.84	46.39	76.75
30 kg ha^{-1}	32.32	113.90	150.70	149.10	4.13	20.45	52.84	83.74
40 kg ha^{-1}	33.86	116.68	156.15	154.55	4.46	21.33	57.78	88.03
S.Em±	1.38	1.35	1.95	1.93	0.32	0.37	1.63	1.43
CD (*P*=0.05)	NS	4.15	6.02	5.96	NS	1.15	5.03	4.43
Boron Levels (B)								
Control	30.18	104.76	141.32	139.77	3.76	20.44	46.78	76.59
1 kg ha^{-1}	31.86	110.99	147.86	146.26	4.02	21.74	49.58	80.67
2 kg ha^{-1}	33.11	115.36	152.63	150.98	4.21	22.31	51.76	83.33
S.Em±	1.23	1.48	1.97	1.97	0.16	0.24	0.86	1.03
CD (*P*=0.05)	NS	4.27	5.68	5.69	NS	0.68	2.48	2.97

Table 2: Effect of levels of sulphur and boron on yield of mustard crop under crop establishment. (Pooled data of two years)

Treatments	Seed yield (q ha^{-1})	Stover yield (q ha^{-1})	Harvest index (%)
Crop Establishment Methods			
Direct seeding	16.53	41.37	28.44
Transplanting	20.72	49.36	29.57
S.Em±	0.31	0.97	0.19
CD (*P*=0.05)	1.89	5.92	1.14
Sulphur Levels (S)			
Control	13.06	34.61	27.69
20 kg ha^{-1}	18.49	46.10	28.58
30 kg ha^{-1}	21.07	49.76	29.76
40 kg ha^{-1}	21.88	51.00	30.05
S.Em±	0.32	0.56	0.21
CD (*P*=0.05)	0.98	1.74	0.64
Boron Levels (B)			
Control	15.77	39.21	28.63
1 kg ha^{-1}	19.82	48.08	29.09
2 kg ha^{-1}	20.28	48.81	29.29
S.Em±	0.16	0.31	0.16
CD (*P*=0.05)	0.46	0.91	0.46

Conclusion

From the above findings it is concluded that the transplanting of crop with application of sulphur 40 kg ha^{-1} along with boron 2 kg ha^{-1} proved beneficial for growth and yields of mustard. It also concluded that establishment of Indian mustard through transplanting technique could be an alternative option to enhance the productivity of Indian mustard.

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