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Role of Nutrient Interaction Between Sulphur and Boron on Oilseed Crops

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ABSTRACT: India is one of the world's largest vegetable oil economies- currently accounting for roughly 13% of the world's oilseeds area, 7% of the world's oilseeds output, and 10% of the world's edible oil consumption. For oilseeds, apart from major plant nutrients like nitrogen, phosphorus and potassium, sulphur and boron plays an vital role in the production phenology. Soil samples examined across the country were insufficient in accessible sulphur and boron deficiency holds at about 50 percent. When both elements were applied in conjugation the total enhancement exceeded the additive effect (independently by both nutrients) by the virtue of the synergistic effect shown by sulphur and boron thereby increasing yield attributes of oilseeds *viz.* seed yield, dry matter, number of seeds, seed oil quality and quantity and protein content of seed. Research shows application of sulphur at a rate of 30-40 kg ha^{-1} and boron at 2.5-3 kg ha^{-1} proved to be most beneficial for oilseeds like rapeseed and sunflower. Interaction between boron and sulphur also led to increased availability and uptake of other primary and secondary nutrients by the plants. The synergistic impact aided post harvest soil of oilseed crops counted as in increased nutrient content and organic carbon content without effecting the pH and EC also the higher nutritional content of food, such as increased oil and protein content, is another strategy to future food safety.

Keywords: Boron, Interaction, oilseed crops, Sulphur.

INTRODUCTION

India, along with the United States and China, is one of the world's largest vegetable oil economies. India currently accounts for roughly 13% of the world's oilseeds area, 7% of the world's oilseeds output, and 10% of the world's edible oil consumption. Groundnut is the country's most important oilseed crop, followed by mustard which accounts for about 25-30% of overall oilseed production. Similarly, sunflower is ranked third in India and the globe. Specifically, for India, Soyabean was the highest produced oilseed with nearly 13 million metric tons produced in the country in the year 2021. For oilseeds, apart from major plant nutrients like nitrogen, phosphorus and potassium; sulphur and boron plays an vital role in the production phenology and these crops respond well to applied sulphur and boron as they directly affect the oil quality and quantity (Chatterjee 1985). Sulphur is involved in the synthesis of cystein, methionine, chlorophyll, and the oil content of oilseed crops, among other things. In crucifers, it is also important for the synthesis of some vitamins (B, biotin, and thiamine), carbohydrate metabolism, protein and oil creation, and the development of flavouring chemicals (Rameeh *et al.,* 2021). In the same way, boron is important for cell wall production, root elongation, glucose metabolism, nucleic acid synthesis, lignification, and tissue differentiation. Boron deficiency in plants appears to coincide with a decrease in water insoluble Boron (Koshiba *et al.,* 2009). The soils are becoming increasingly deprived of secondary plant nutrients such as sulphur as agricultural intensification increases. According to the most recent data, 41 percent of soil samples examined in the country were insufficient in accessible sulphur (Singh 2008; Singh and Kumar 2012; Singh *et al.,* 2015). Boron deficiency, on the other hand, was found in soils with little organic matter to the tune of 50% (Shukla *et al.,* 2014). Since both Sulphur and Boron have their importance in production of oilseeds it was necessary to put light on the interaction of both the nutrients and how collectively they impacted the oilseed production and that is what drives this review.

Synergistic Effect of Boron and Sulphur. Although both the elements- Sulphur and Boron are essential for the oilseed crops for their own effects on the crop and increased quantities of application of either element showed an increase in the yield and other attributes but when both the elements were applied in conjugation the total enhancement exceeded the additive effect (independently by both nutrients) by the virtue of the synergistic effect shown by sulphur and boron. A study conducted in Assam for three consecutive rabi seasons in rapeseed (cv.TS-38) to assess the impact of S and B fertilisation on crop yield, soil chemical properties, and nutrient status found that among the various soil chemical properties, the combined application of S and B level of $S_{30}B_{1.5}$ (30 kg S ha^{-1} + 1.5 kg B ha^{-1}) significantly augmented the SOC, while soil pH, Fe_2O_3, and Al_2O_3 content in soil were found to be unaffected. Fertilisation with conjugative sulphur and boron documented maximum available N (298.7 kg ha^{-1}), P (31.0 kg ha^{-1}), and K (126.2 kg ha^{-1}), the interaction effect between S and B had a substantial impact on available primary nutrients as well. Combined application increased the status of exchangeable Ca and Mg, as well as accessible sulphur and boron by 0.90 cmol(p+) kg^{-1}, 0.50 cmol(p+) kg^{-1}, 13.67 mg kg^{-1}, and 0.65 mg kg^{-1}, respectively. On scaling both the S and B levels, the NUE in soil was observed to improve. Although graded quantities of S and B had no effect on yield attributing features, there was a considerable enhancement in seed yield, stover yield, and biological yield of rapeseed. Higher amounts of both S and B could increase the soil fertility status and rapeseed production (Sikorska *et al.,* 2020). S and B functioned synergistically in increasing biometric characters, root characters, sesame yield and yield attributes, and nutrient uptake by grain and straw in sandy soils of Kerala. Sulphur at 30 kg ha^{-1} and B at 2.5 kg ha^{-1}, in addition to the necessary doses of N, P, and K, led in higher grain yields (1460 kg ha^{-1}). The availability of other soil nutrients increased as the level of applied sulphur and boron rose (Mathew *et al.,* 2013)

Approaches. The amount of food we produce today versus the amount required to feed everyone in 2050 is vastly different. By 2050, the world's population will have swelled to about 10 billion people, with roughly 3 billion more mouths to feed than in 2010. To feed 10 billion people sustainably by 2050, a land gap of 593 million hectares (almost twice the size of India) must be closed between worldwide agricultural land area in 2010 and predicted agricultural increase by 2050. Fertilizer use has been critical in improving food production and maintaining soil fertility, and it will continue to be so in the future. To achieve this level of crop output, existing land intensification must account for the majority of the expansion, and fertiliser consumption must climb from 123 million tonnes of nutrients in 1994/95 to over 400 million tonnes in 2021. Owing to declining yield levels due to nutrient deficiency and continuous population growth, there are few signs that fertiliser use will increase in the near future to slow soil degradation and generate the necessary food. As the use of fertilisers continues to rise, increasing the crop's Nutrient Use Efficiency becomes increasingly crucial in order to prevent irreversible soil deterioration. Because of their synergistic effect, conjugated application of boron and sulphur has been shown to improve NUE and increase the availability of critical nutrients like as nitrogen, potassium, phosphorus, sulphur, and boron. Higher nutritional content of food, such as increased oil and protein content, is another strategy to future food safety, which is also aided by the synergistic impact (Kaur *et al.,* 2022).

Interaction Effect on Plant Morphology. As discussed earlier, both S and B have synergistic effect complementing each other which translates to better yield attributes of the crop in production. For instance, in mustard, adding S and B beyond the recommended dose of NPK fertilisers resulted in a considerable increase in seed output, as indicated in Table 1, with a maximum seed yield of 1.97 t ha^{-1} in RD (Recommended dose) + 40 kg S ha^{-1} + 2 kg B ha^{-1}. However, adding simply S (RD + 40 kg S ha^{-1}) had no significant influence on mustard seed output over RD, demonstrating the need of applying both elements to the soil together. Not only the seed production, but also the surplus output of mustard grew greatly, as shown in Table 1. The use of S and B has a considerable impact on the dry matter and seed production of mustard as well (Chakraborty and Das 2000). With the addition of S and B, the protein content and yield of mustard improved considerably over control (Table 1).

Table 1: Impact of independent and conjugated applications of sulphur and boron on yield attributesand Biochemical constituents of mustard.

Treatment	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Protein content (%)	Protein yield (kg ha^{-1})	Oil content (%)	Oil yield (kg ha^{-1})
Control	0.60	1.60	20.9	125.4	32.3	194.2
With recommended NPK dose	1.47	2.53	21.8	380.4	36.8	539.5
RD+ 40 kg S ha^{-1}	1.60	2.67	22.4	358.4	38.2	610.3
RD+1 kg B ha^{-1}	1.67	2.68	23.3	390.7	37.5	625.7
RD+2 kg B ha^{-1}	1.80	2.91	22.3	401.4	38.3	690.7
RD+ 40 kg S + 1 kg Bha^{-1}	1.87	3.00	21.7	405.7	38.8	724.3
RD+ 40 kg S + 2 kg B ha^{-1}	1.97	3.20	24.0	472.8	40.8	806.8

The protein content of the mustard crop was found to be as high as 24%. Sulphur is an essential component of amino acids such as cystein, cystine, and methionine, hence its administration increased the amount of protein in mustard seed. Increased protein levels could also be as a result of enhanced nitrogen uptake and content in the seed (Vaiyapuri *et al.,* 2010). The addition of both S and B together to soil boosted oil content and yield considerably, whereas adding either B or S alone had no effect. RD + 40 kg S + 2 kg B ha^{-1} had the highest oil content (40.8 percent), which was 11% greater than RD. Sulphur is a component of glucosinolate, which is essential for the production of mustard oil. Sulphur may have favoured the production of CoA and lipoic acid, resulting in a rise in oil content (Mathew and George 2013). Sulphur assimilation by mustard seed and stover risen considerably when sulphur was applied, and it increased much more when boron Dudekula *et al.* (2021) was added (Table 2). The uptake of boron by mustard seed and stover was greatly increased when boron was applied to the soil as borax, but it even increased further when boron was applied in conjunction with sulphur (Table 2).

Table 2: Impact of independent and conjugated applications of sulphur and boron on nutrient uptake by plants parts.

Treatment	Sulphur (kg ha^{-1})			Boron (kg ha^{-1})		
	Seed	Stover	Total	Seed	Stover	Total
Control	1.20	2.56	3.76	13.3	33.0	46.3
With recommended NPK dose	5.88	6.33	12.21	40.5	59.2	99.7
RD+ 40 kg S ha^{-1}	8.00	6.94	14.94	48.7	69.5	118.3
RD+ 1 kg B ha^{-1}	10.02	6.16	16.14	69.0	99.6	168.6
RD+2 kg B ha^{-1}	12.60	7.28	19.88	91.5	131.4	223.0
RD+ 40 kg S + 1 kg B ha^{-1}	14.96	8.10	23.06	85.3	127.8	213.0
RD+ 40 kg S + 2 kg B ha^{-1}	17.73	9.28	27.01	111.5	167.4	278.9

The dry matter and seed yields of sunflower crop increased with increasing amounts of boron and sulphur, according to a greenhouse study as depicted in Table 3. The interaction impact between B and S altered the dry matter yield of sunflower in a considerable and synergistic way. Sunflower seed yield increased dramatically from 10.3 g pot^{-1} in control to 34.6 g pot^{-1} at 2 mg kg^{-1} B and 60 mg kg^{-1} S, with the maximum yield at 2 mg kg^{-1} B and 60 mg kg^{-1} S (Ravikumar *et al.,* 2021). The response of oilseeds to sulphur has been recorded by many workers. The addition of boron to oilseeds has also been reported to have a positive effect (Gangadhara *et al.,* 1990; Choudhary *et al.,* 1991; Sharma, 1994). Because of the complementary effect of both nutrients on each other, boron uptake by sunflower seeds increased from 192 g in the pot control experiment to 797 g with increasing levels of sulphur, and sulphur uptake by sunflower seeds increased from 257.3 to 377.1 mg per pot with increasing levels of boron.The application of boron and sulphur has a considerable and synergistic effect on the oil and protein content of oilseeds. The interaction impact of boron and sulphur synergistically altered sunflower seed oil content, which increased considerably from 30.7 percent in the blank to 41.8 percent, while protein content increased from 13.3 to 17.1 percent (Table 4).

Table 3: Interactive Effect between different boron and sulphur levels on seed yield and dry matter yield of sunflower.

Treatments	Seed Yield (g pot^{-1})				Dry matter Yield (g pot^{-1})			
	Blank	B 1 mg kg^{-1}	B 2 mg kg^{-1}	B 3 mg kg^{-1}	Blank	B 1 mg kg^{-1}	B 2 mg kg^{-1}	B 3 mg kg^{-1}
Blank	10.3	12.9	13.7	15.1	37.3	41.8	45.0	48.7
S 20 mg kg^{-1}	14.5	17.6	22.2	24.1	50.7	61.9	67.3	69.1
S 40 mg kg^{-1}	23.5	26.0	30.4	30.9	63.7	68.6	77.7	77.2
S 60 mg kg^{-1}	28.6	29.2	34.6	33.2	72.1	73.9	83.1	84.9

Table 4: Interactive Effect between different boron and sulphur levels on Biochemical Constituents of sunflower.

Treatments	Oil content (%)				Protein content (%)			
	Blank	B 1 mg kg^{-1}	B 2 mg kg^{-1}	B 3 mg kg^{-1}	Blank	B 1 mg kg^{-1}	B 2 mg kg^{-1}	B 3 mg kg^{-1}
Blank	30.7	32.6	34.4	35.2	13.3	13.6	14.0	14.2
S 20 mg kg^{-1}	33.6	36.4	38.5	38.9	14.4	14.6	14.9	15.5
S 40 mg kg^{-1}	36.2	37.5	39.3	40.3	15.3	15.9	16.8	16.9
S 60 mg kg^{-1}	36.9	38.5	41.5	41.8	15.2	16.0	16.8	17.1

Synergistic Effect on Nutrient Availability in Post Harvest Soil. The crops continually treated with recommended doses of sulphur and boron the post harvested soil sample showed increased levels of nutrient concentration of not only sulphur and boron but also organic carbon, nitrogen, phosphorus and potassium. As recorded in oilseeds the organic carbon increased by 21.4 percent, nitrogen by 17.13 percent, phosphorus by 75.5 percent and potassium by 41.42 percent pertaining to the synergistic impact of sulphur and boron altogether (Ravi *et al.,* 2019). Sulphur and boron themselves increased by 257.18 and 381.03 percent, respectively in post-harvest soil of Sesame crop. Sulphur and boron levels in the soil were impacted by increased sulphur and boron levels in fertilization (Bhagyalakshmi *et al.,* 2009). The treatment of these nutrients had a synergistic effect on the available nutrient status; application of sulphur up to 30 kg ha^{-1} improved the availability of soil nutrients including sulphur and boron (Mathew *et al.,* 2013).

Boron application at 2 kg ha^{-1} resulted in considerable evidence of increased accessible potash in soil, although sulphur levels in soil indicate a significant association with available nitrogen, phosphorus, and potash. Nutrient availability rose as well (Kumar *et al.,* 2017). Both sulphur and boron are positively correlated with available phosphorus (r = 0.875*), available nitrogen (r = 0.935*), phosphorus (r = 0.891*) and potash (r = 0.882*) (Arvind and Rai, 2018). The synergistic effect and increased nutrient concentration and availability is proven on varied type of soils from time to time: sandy loam soils by Tamak *et al.* (1997), silty loam soil by Chakraborty and Das (2000), Alluvial soil by Shukla *et al.* (1983) and in black soils by Joshi *et al.* (1991).

CONCLUSION

It is clearly stated over the years that adding sulphur and boron beyond the recommended dose of NPK fertilizers in oilseed crops results in considerable increase in Seed yield, stover yield and increased content of protein and oil in the seeds- the increased protein content of the seeds results in a more nutrition rich crop for consumption. The post harvest soil is also benefited from the conjugative applications of boron and sulphur because of increased levels of Organic carbon, primary nutrients like nitrogen, phosphorus and potassium along with some secondary nutrients like sulphur and micronutrients like boron. The uptake of nutrients by the succeeding crop in also improved. As the cropping system intensifies due to increased demand for food in the coming years, the nutrient supplying capacity of the soils gets destroyed therefore, it becomes essential to improve the fertilizer use efficiency and utilizing the complimentary and synergistic effects of the nutrients on a wide scale.

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Conflict of Interest. None.

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