Evaluation of Right Source of Boron and Sulphur for Enhancing Yield and Quality of Crops

By M.V. Singh, V. Goswami, and R.H. Wanjari

Sulphur is recognized as the fourth major essential nutrient severely limiting crop production in India. Indian soils have widespread S deficiency to an extent of 46% (Shukla and Tiwari, 2016) and proper S management is critical for higher crop yield and improved quality. In addition to S, increased deficiency of B in several crops (Singh and Goswami, 2014) is also of great concern for sustaining higher yields of modern crop varieties in many cultivated soils. Shrotriya and Phillips (2002) and Wani et al. (2011) reported B deficiency as the second most important micronutrient constraint next to Zn affecting crop production in India. Boron plays an important role in meristematic activities, cell division, root development, stimulation of root nodules, pollen germination, translocation of carbohydrates in plant tissues, and helps in increasing the yield of various crops (Malewar et al., 1992). Boron is relatively immobile in plants, which necessitates its availability in soil solution at all stages of growth, especially during fruit or seed development.

Combined deficiency of B and S within the same site is widely reported in soils, districts, states and agro-ecological regions in India (Singh, 2001a). All India Coordinated Research Projects (AICRP) of micronutrients have reported combined deficiencies of B and S in the soils of Odisha, adversely affecting yields of cereals, oilseeds, vegetables, and horticultural crops (Jena et al., 2008). Similarly, ICRISAT also reported coexistence of S and B deficiencies, where S deficiency ranged from 46 to 96% and B from 56 to 100% in various semi-arid tropical states of India (Rego et al., 2007 and Wani et al., 2011). Further information compiled on the extent of deficiency of S and B in 186 districts covering 14 states of India, revealed 48 and 70% deficiency of B and S (**Table 1**). This indicated that almost two thirds of cultivated soils would need combined application of S and B to ensure balanced nutrition of crops for maximizing crop productivity.

Table 1. Distribution of multinutrient (S plus B) deficiencies in 186 districts surveyed in 14 states of India (Singh, 2015).

Particular	Total no. of districts being surveyed	Distribution of districts in different categories		
		High fertility < 20*	Medium fertility 20-40*	Low fertility > 40*
Boron	155	52.3	20.0	27.7
Sulphur	186	30.1	35.0	34.9

*Based on % deficiency of B and S

Sulphur and B, together, play a pivotal role in the growth and development of plants. Unlike S, which is required in quantities ranging from 20 to 45 kg/ha (Singh, 2001b), B requirement for crops is very small (250 to 300 g/ha). The established synergy between S and B allows the combined application of both nutrients through a single fertilizer source. This ensures uniform application of even a small dose of B, permitting easier blending with granular fertilizers like DAP (diammonium phosphate), Urea and NPK as per the farmers choice.

There is also a very narrow range between B deficiency and toxicity, as more than 5 ppm available B can be toxic to many agronomic crops. Therefore, combined application of B and S through a single fertilizer source should ensure the supply of optimum rate of B to crops, avoid physical mixing and minimize application cost through reduced cost of handling, transportation, and storage, while improving farmer income. Application of small doses of B along with S reduces deficiency of S and B in crops precisely, and helps in enhancing use efficiency of NPK and other micronutrients. Combined application also helps in overcoming toxicity due to uniform and optimum rate of application. Thus, the current study evaluated boronated sulphur granules (BSG) containing 80% S and 1.2% B with bentonite coating, as a right fertilizer source, for its agronomic efficiency in cotton, chilli, and soybean grown in soils deficient in B and S.

SUMMARY

Coexistence of deficiency of B and S in almost two-third of cultivated soils in India necessitates the need for combined application of B and S to crops. Considering a very narrow range between B deficiency and toxicity, a right fertilizer source consisting of B and S along with the other major essential nutrients should supply right rates of B and S. This helps to meet the balanced crop requirement while ensuring combined uniform application of deficient nutrients, minimized application cost and improved farm income.

KEYWORDS:
chilli; cotton; soybean; interaction

ABBREVIATIONS AND NOTES:
B = boron; S = sulphur; Zn = zinc

On-farm Trials

On-farm experiments were conducted on hybrid cotton (*Gossypium hirsutum*) and on chilli (*Capsicum annum*) on a mixed red and black clayey soil (Inceptisol) at a location 10 km away from Khargone, Madhya Pradesh (Latitude 21°50' N and Longitude 75°36'53.9" E) during the kharif season of 2015. Another experiment was conducted in soybean (*Glycine max* Merril.) in a black clayey soil at Parvalia Sani of Bhopal district (Latitude 23° 16' N and Longitude 77°36' E) in Madhya Pradesh. Soil pH in the experimental sites ranged from 6.8 to 8.7, while EC ranged from 0.14 to 0.24 dS/m. Soil texture was sandy loam to clay loam, classified as an Inceptisol. The experimental sites had low to marginal B and S fertility status, hot water-soluble B status in surface soil (0 to 15 cm depth) ranged between 0.26 to 0.38 mg/kg and available S (calcium chloride extractable) status ranged between 6.7 to 9.8 mg/kg soil, respectively.

Treatments consisted of (T_1) Farmers' Fertilizer Practice (FFP, predominantly application of NP alone), (T_2) FFP + 0.6 kg B/ha, (T_3) FFP + 40 kg S/ha, (T_4) FFP + 0.6 kg B/ha + 40 kg S/ha. In T_2, B was applied through borax penta hydrate (14.6% B), and in T_3, S was applied using sulphur granular pastilles (90% S) coated with bentonite clay. In T_4, B and S were applied using boronated sulphur granules, consisting of 80% S and 1.2% B. At planting, DAP was applied to each treatment at 125 kg/ha along with $ZnSO_4 \cdot 7H_2O$ at 25 kg/ha to all the three crops. In chilli and cotton, urea was top dressed in each treatment at 125 kg/ha, applied in two equal splits at 30 and 50 days after planting (right time), following the right method of application at 6 to 8 cm apart from main shoot and mixed in through hoeing in moist conditions. In soybean, top dressing of urea was not done. Necessary weeding and plant protection measures were followed in all the three crops. Observations related to plant height, premature fruit/pod shedding, and yield were recorded.

Table 2. Effect of combined application of B and S through Boronated Super Granules on crop yield and farm profit.

Treatment	Cotton: Seed cotton yield, kg/ha	Cotton: Net income, Rs/ha	Chilli: Yield, kg/ha	Chilli: Net income, Rs/ha	Soybean: Yield, kg/ha	Soybean: Net income, Rs/ha
T_1 - *FFP alone	1,640	9,495	7,820	12,120	885	4,655
T_2 - FFP + B	1,870	9,930	9,080	14,700	1,040	5,005
T_3 - FFP + S	2,025	15,525	9,780	23,520	1,197	9,120
T_4 - FFP + B + S	2,220	23,880	10,640	31,620	1,310	12,655
LSD (P = 0.05)	211	-	1,010	-	133	-

*Farmer Fertilizer Practice
Prices used for net income calculation: B - Rs.700/kg; S - Rs. 45/kg (granular); Seed cotton - Rs.45/kg; Soybean - Rs.35/kg; Green chilli - Rs.12/kg pod

Response with NP and B + granular S in chilli (top) vs. farmer's practice (without B and S; bottom) at Khargone, M.P.

Results

On-farm experiments conducted in cotton and chilli revealed that the yield of seed cotton (**Table 2**) varied between 1,640 and 2,220 kg/ha and chilli pod yield was between 7,820 and 10,640 kg/ha. Combined application of B+S through boronated S granules along with FFP (T_4), significantly increased seed cotton and chilli pod yield by 35 and 36%, respectively, compared to FFP alone (**Table 2**).

Application of FFP+B (T_2) or FFP+S (T_3) increased seed cotton yield by 14 and 24%, while that of chilli pod yield by 16 and 25%, compared to FFP alone. Visual observations revealed that plant height, number of sympodial branches, number of bolls per plant were higher in T_4, indicating that combined application of B+S together with FFP had better crop growth in terms of number and size of cotton bolls per plant. Similarly, plant height, number of branches and number of green pods of chilli were higher in T_4 with B+S, which resulted in a higher chilli pod yield (data not shown). In both crops the effect of combined application of B and S was evident, while S attributed to better growth and dark green foliage due to its role in formation of chlorophyll and

Response of cotton to boronated S in black cotton soils of Khargone, M.P.

the effect of B was visible on reduced flower and fruit drop and increased pod/boll setting. Results also showed that seed cotton yield was increased by 230, 385, and 580 kg/ha, due to application of FFP+B, FFP+S, and FFP+B+S over FFP alone. The corresponding increase of chilli pod yield was 1,260, 1,960, and 2,820 kg/ha, respectively. Application of FFP+B+S resulted in a higher net income of Rs.23,880 per ha in cotton and Rs.31,620 per ha in chilli, with a higher B:C ratio of 10.8:1 and 14.2:1, respectively (data not shown).

Another set of on-farm experiments conducted in soybean revealed that grain yield was significantly influenced by combined application of FFP+B+S (T_4). The soybean yield recorded in FFP+B+S (T_4) was 1,310 kg/ha, which was 48, 26, and 9% higher than FFP, FFP+B, and FFP+S, respectively. The results indicated that application of B+S together with FFP helped in better crop growth coupled with increased nodulation, number of branches and pods compared to soybean grown with the other treatments (data not shown). The combined application of B+S in soybean resulted in increased oil content in seed from 18.7 to 19.6%, and finally helped the farmer with a higher net income (Rs.12,655 per ha) and higher B:C ratio (5.7:1). These results agree with the findings of Rego et al. (2007), who showed positive response to the application of B+S to groundnut, finger millet, pigeon pea, soybean, chickpea, maize, and black gram compared to application of either B or S alone or over FFP in India.

Post-harvest soil available B and S at the on-farm experimental sites significantly improved over the initial levels at the time of planting due to combined application of B+S along with FFP over the other treatments. The experimental soils initially had hot water-soluble B concentrations ranging from 0.26 to 0.38 mg/kg, which increased at the time of harvest, ranging from 0.35 to 0.43 mg B/kg soil due to combined application of B+S. Similarly, the initial available S status of the experimental sites ranged from 6.8 to 8.7 mg/kg soil, which increased to 9.8 to 11.5 mg S/kg soil at harvest, indicating that application of B+S through boronated S granules helped in meeting the nutrient requirement of crops as well as enhancing the fertility status of soil, while increasing the productivity of crops. Earlier studies on combined application of B+S through boronated single super phosphate (BSSP, having 0.18% B+12% S+16% P_2O_5) in sugarcane reported taller canes, longer internodes, improved cane girth, and increased cane yield in the range of 12 to 19% over non-application B (Vaidya et al., 1984). Similarly, application of BSSP increased the onion bulb yield from 9.2 to 18% over S alone in Madhya Pradesh and Maharashtra (Deshmukh, 1985). Application of BSSP significantly increased the economic yield of peanut by 33%, and improved several quality parameters such as protein by 3.84%, oil by 4.09% and shelling by 2.87% (Patil and Patil, 1985). However, the authors feel that BSG seemed to be a better option to combat B and S deficiency compared to BSSP. The recommended rate of application of BSG did not leave any adverse effect on crop growth due to a lower rate of B (0.24 to 0.48 kg/ha) through addition of 20 to 40 kg/ha S granules as compared to 1.2 to 2 kg/ha B added through BSSP on account of its application of 60 to 100 kg/ha P_2O_5 even in soils with marginal to adequate B fertility status. Addition of higher rates of B through BSSP may pose adverse effect on a crop over the long run due to B sensitivity and the very narrow range between B deficiency and toxicity. BSG could be a better choice for regular application with the right rate of B to crops as it provides a crop-safe option for long-term improvement of crop yield, soil health, and the environment.

Summary

Coexistence of B and S deficiency is widely reported in several crops and agro-ecological zones of India. Almost half of the soils in India are tested to be deficient in B and S, which needs immediate attention through balanced fertilization. Application of right rate of BSG having 80% S and 1.2% B proved to be right source of B and S, as its application helped in maximizing crop growth, improved fruit/seed setting and in achieving higher crop productivity. BSG could be an alternative replacement to BSSP, and application of BSG at 25 and 50 kg/ha to different crops can give much higher yields and farm profits without any adverse effect on soil health. **BCSA**

Dr. Singh is a consultant at Rio Tinto and former Project Coordinator at ICAR-All India Coordinated Research Project of Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants, Indian Institute of Soil Science, Bhopal, e-mail: drmvsingh@gmail.com; Mr. Goswami is Sales Development Manager Agriculture-South West Asia at Rio Tinto, Gurgaon, India; and Dr. Wanjari is Senior Scientist (Agronomy), ICAR-Indian Institute of Soil Science, Bhopal, India.

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