Madras Agric. J., 104 (4-6): 124-128, June 2017

Boron Fertilization and Its Fate: Maize - Sunflower Cropping System

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A field experiment was conducted in B deficient soil (0.37 mg kg^{-1}) to assess the frequency and level of B application for increasing crop yields in maize - sunflower cropping system, fate of B pools in soils system and to monitor the changes in soil fertility and productivity due to different levels and frequency of B application under continuous cropping system at Tamil Nadu Agricultural University, Coimbatore since 2012. The analysis of initial soil samples indicated that experimental soil was neutral in soil pH and free from salinity with sandy clay in texture. The grain and stover yield of maize crop varied from 5.51-8.38 and 5.16 to 8.00 t ha^{-1} , respectively and significantly differed with rate of B application. Among the B levels application of B @ 1.0 kg ha^{-1} registered the maximum grain and stover yield of 7.55 and 7.00 t ha^{-1} , respectively and was followed by application of 1.5 kg ha^{-1}, however they were on par with each other. After the harvest of maize crop, sunflower was raised and harvested and the grain and stalk yields were recorded. Among the B levels, application of B @ 1.0 kg ha^{-1} registered the maximum seed yield of 2.33 t ha^{-1} respectively and was followed by application of 0.5 kg ha^{-1}. The interaction between the rate of B application and frequency significantly differed with grain and stalk yield. Among the frequency levels, application of B to maize crop alone every year (F3) registered the maximum seed yield as compared to others. The interaction effect revealed that application of B @ 0.5 kg ha^{-1} to all crop registered the highest seed yield of 2.79 t ha^{-1} respectively. Boron fractions like available boron, specifically adsorbed B, oxide B, organically bound B, residual B status and total boron contents were analysed after the harvest of second crop. The results revealed that the available B status varied from 0.277 to 1.940 mg kg^{-1},specifically adsorbed B ranged from 0.190 to 1.332,oxide bound B status in soil varied from 0.127 to 0.89 mg kg^{-1}, organically bound B status in soil varied from 0.235 to 1.644 mg kg^{-1}, residual fraction of B varied from 41.61 to 291.8 and total boron varied from 42.44 to 297.6 mg kg^{-1}. Boron application resulted in significant increase in maize yield as first crop and sunflower as residual crop, respectively. Among the B fractions the order was residual B >organically bound > specifically adsorbed > oxide bound B. Application of B @ 2.0 kg ha^{-1} significantly registered the highest available B in soil (1.038 mg kg^{-1}) and among the frequencies, application of B to all crops registered the highest available B (1.32 mg kg^{-1}). The actual fraction of B fertilizer removed by the crops is only 1-2 % of the total applied fertilizer through soil.

Key words: Boron fertilization, Residual fractions in soil, Maize – Sunflower, Yield

Boron is a non metallic element and the only non-metal of the group 13 of the periodic table and is an essential micronutrient for crops. More than 90% of the B in plants is found in cell walls, and it's most important role is associated with cell wall formation. Boron is involved in the reproduction of plants and germination of pollen spikelet (Bolanos *et al*., 2004). Boron is directly or indirectly involved in several physiological and biochemical processes during plant growth. Boron deficiency causes reduction in cell enlargement in growing tissues because of its structural role. Its deficiency is responsible for creating male sterility and inducing floral abnormalities (Sharma, 2006).

The range of toxic level to adequate level of B is narrower from other nutrient elements (Mortvedt and Woodruff, 1993). B availability in soil and irrigation water is an important determinant of agricultural production (Tanaka and Fujiwara 2007) because of its low sufficiency level in soil. Boron exists in the soil in five fractions. Zerrari *et al.* (1999) reported that these fractions are readily soluble, specific adsorbed, oxide bound, organic matter bound and residual (these are in silicate minerals, and cannot be used by plants). It has also been specified that the amount of these different fractions depends on the soil properties and the availability levels of these fractions differ. Ellis and Knezek (1972) stated that B is more strongly adsorbed by soil when compared with other anions such as Cl and NO_3, and this adsorption is realized through inorganic substance such as Fe and Al oxides and hydroxides, clay minerals and especially mica type clay, $Mg(OH)_2$ and organic matter. In this context, a field experiment was conducted at Tamil Nadu

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Agricultural University, Coimbatore under All India Coordinated Research Project on "Micro nutrients, secondary nutrients and polluted elements in soils and plants" with the objectives *viz*., i) to assess the effect of B application on maize - sunflower cropping system, to assess the fate of B pools in soil system and to monitor the changes in soil fertility and productivity due to different levels and frequency of B application under continuous cropping system and the results obtained from 2012 – 2014 were discussed in this paper.

Material and Methods

To assess the frequency and level of B application for increasing crop yields in maize - sunflower cropping system, fate of B pools in soil system and to monitor the changes in soil fertility and productivity due to different levels and frequency of B application under continuous cropping system, a field experiment was conducted in Periyanaickenpalayam soil series (Field No.75, Eastern block, TNAU Farm situated at 11 º 00 N Latitude and 76º 93 E Longitude) at Tamil Nadu Agricultural University, Coimbatore. Totally twenty treatment combinations were replicated thrice in a split plot design using main treatment as frequency of B application (F1: One time application to maize crop in I year), F2: Alternate years (I^{st}, 3^{rd}, 5^{th} year – maize crop alone), F3: Every year (maize crop alone) and F4: All crop (Every year maize and sunflower crops) and levels of B as sub plots (5 levels *viz*.,0,0.5,1.0,1.5 and 2.0 kg ha^{-1}) First crop as maize and residual crop as sunflower was raised. Recommended dose of fertilizers 250:75:75 for maize and 60:90:60 NPK kg ha^{-1} for sunflower was followed, common fertilizer borax was used and harvested the crop at maturity. The analysis of initial soil samples indicated that experimental soil was neutral in soil pH and free from salinity with sandy clay in texture. The soil was low in available nitrogen (269.7 kg ha^{-1}), medium in available P (16.2 kg ha^{-1}) and K (265.3 kg ha^{-1}) and high in available S (38.2 mg kg^{-1}). The DTPA extractable Fe and B was deficient (3.30 and 0.39 mg kg^{-1}) and Mn, Zn and Cu were sufficient (5.1, 1.52 and 1.54 mg kg^{-1}, respectively).

Post harvest soil samples were analysed for B fractions by spectrophotometric technique using a colorimetric reaction with azomethine-H and hot water and 0.5 M HCl as extractants. Boron fractions like available boron, specifically adsorbed B, oxide B, organically bound B, residual B status and total boron contents were analysed after the harvest of second crop by adopting the sequential extraction procedure given by Raza *et al., (*2002).

Results and Discussion

The grain yield of maize crop due to varied frequency and doses of boron application varied from 5.51 – 8.38 t ha^{-1} and significantly differed with rate of B application. Among the B levels application of B @ 1.0 kg ha^{-1} registered the maximum grain yield of 7.55 t ha^{-1} and was followed by application of 1.5 kg ha^{-1}, however they were on par with each other. Boron plays major role in cell wall formation, transport of sugars, pollen formation and seed set. This might the reason for getting higher yield in the treatments. Similar results were reported by Mishra and Shukla (1986) in maize. After the harvest of maize crop, sunflower was raised and harvested and the grain yield was recorded. Among the B levels, application of B @ 1.0 kg ha^{-1} registered the maximum seed yield of 2.33 kg ha^{-1} and was followed by application of 1.5 kg ha^{-1} (Table.1). The interaction between the rate of B application and frequency was significantly differed. Among the frequency levels, application of B to maize crop every year alone (F3) registered the maximum seed yield as compared to others. The interaction effect revealed that application of B @ 0.5 kg ha^{-1} to all the crops registered the highest seed yield of 2.790 kg ha^{-1}.

Table 1. Effect of frequency and rate of B application on yield of maize and sunflower

Treatments	Levels of boron (kg ha^{-1})	Yield (t ha^{-1})	
		Maize grain	Sunflower seed
F1 - once	0	5.56	1.57
	0.5	5.81	1.81
	1.0	6.78	1.87
	1.5	7.07	2.12
	2.0	7.35	2.37
F2 - alternate years	0	5.51	1.59
	0.5	5.88	1.82
	1.0	6.84	1.91
	1.5	7.09	2.15
	2.0	7.42	2.39
F3 - maize crop alone	0	5.51	1.61
	0.5	7.07	2.15
	1.0	8.38	2.71
	1.5	8.11	2.61
	2.0	6.98	2.56
F4 - all crop	0	5.52	1.62
	0.5	7.89	2.79
	1.0	8.21	2.47
	1.5	7.72	2.26
	2.0	6.69	2.01
CD (P=0.05)	F	0.76	0.93
	T	0.94	0.84

B fraction studies

Boron fractions like available boron, specifically adsorbed B, oxide bound B, organically bound B and residual B status were analysed after the harvest of second crop. Boron may bind with organic matter or with carbohydrates released during humification. Boron associated with humic colloids is the principal B pool for plant growth in most of the agricultural soils (Jones, 2003). The results revealed that the available B (Hot water soluble boron – HSWB) status in soil due to different frequency and increased doses of boron increased the contents and it varied from 0.277 to 1.940 mg kg^{-1} (Fig.1). The HWSB content in the initial was 0.37 mg kg^{-1}, and it showed declined status due to removal when compared to treated soil, where in the status maintained and increased after the crop removal. Similar findings are in accordance with the findings of Bandit Jena *et al*., (2017). Readily soluble boron (HWSB and Non specifically adsorbed B) is the boron fraction present in the soil solution and adsorbed weekly by various soil particles. This form is mostly available to plant uptake.

Specifically adsorbed B in soil

The second most plant available form is specifically adsorbed B **(**sp.B), it may be adsorbed onto clay surfaces or associated with organic matter in soil.

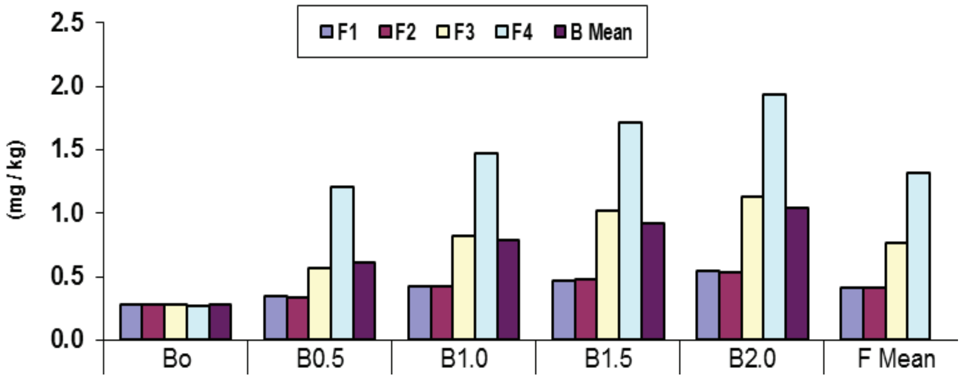

Fig.1. Effect of frequency and levels of boron on HWSB in post harvest soil

(Padbhushan and Kumar, 2017). The specifically adsorbed B status in soil after the harvest of sunflower crop significantly differed with rate of B application and in soil, it varied from 0.19 to 1.332 mg kg^{-1} (Fig.2). Among the varied B levels, application of B @ 2.0 kg/ ha registered the highest specifically adsorbed B in soil (0.712 mg kg^{-1}). A significant difference between the frequency of B application and also the interaction between the rate of B application and frequency application was noticed. The application of B to every crop recorded the highest amount of specifically adsorbed B in soil (0.907 mg kg^{-1}). The interaction

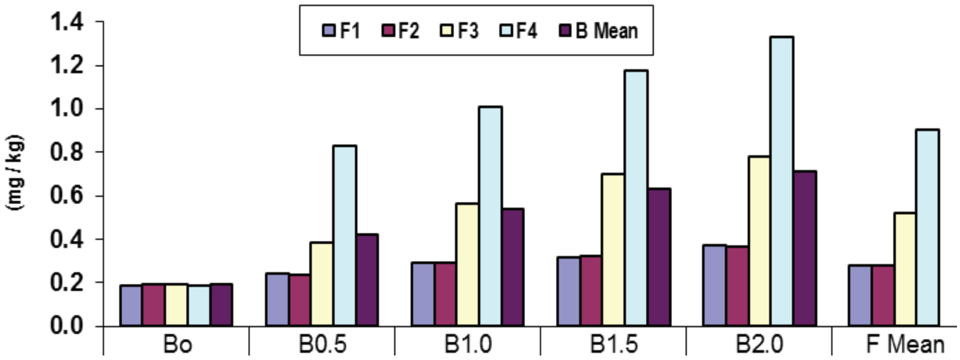

Fig.2. Effect of frequency and levels of boron on specifically adsorbed B in post harvest soil

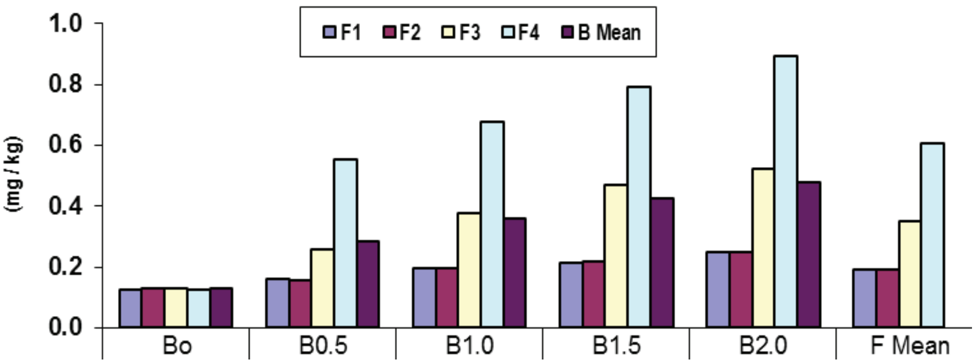

Fig.3. Effect of frequency and levels of boron on oxide bound in post harvest soil

effect between B levels and frequency of B application revealed that application of 2.0 kg of B to every crop (F4) registered the highest specifically adsorbed B in soil (1.332 mg kg^{-1}). This sp.B content accounted for <1% of total B content.

Oxide B in soil

The remaining fractions oxide bound, organically bound and residual boron are unavailable for plant uptake (Padbhushan and Kumar, 2017). It includes

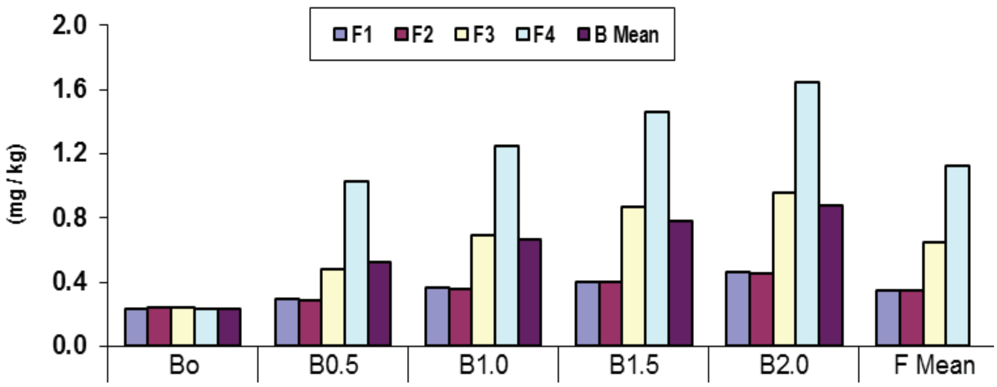

Fig.4. Effect of frequency and levels of boron organically bound B in post harvest soil

boron tightly bound at the mineral surfaces and boron replaced by Al and Fe ions. The oxide bound due to various frequency and doses of boron varied from 0.127 to 0.892 mg kg^{-1} (Fig.3) and application of B @ 2.0 kg ha^{-1} could register the highest oxide B in soil (0.477 mg kg^{-1}) which significantly differed with other

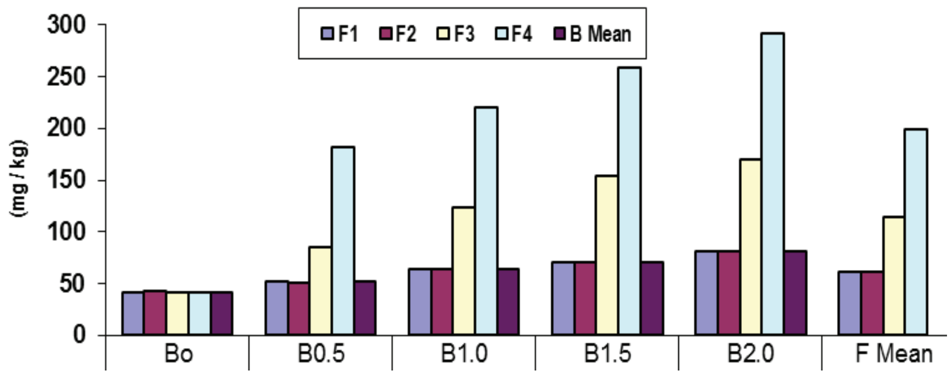

Fig.5. Effect of frequency and levels of boron on residual B in post harvest soil

levels of B application. Among the varied frequency of B application, the application of B to all crops registered the highest oxide bound B in soil. The content increased with levels and frequency of B application and it was more in application to all crop. The interaction effect revealed that application of 2.0 kg of B to all crop (F4) registered the highest oxide B in soil (0.892 mg kg^{-1}). Diana (2006) reported that boron concentrations in soil vary from 2 to 200 mg B kg^{-1}, but generally less than 5-10% is available to plants. Besides aluminium and iron oxides, calcium carbonate and organic matter, clay minerals are considered to be amongst the primary B adsorbing surfaces in soils (Goldberg, 1997).

Organically bound B in soil

Organically bound form of boron present as complexed forms with humic substances. The organically bound fractions of B in soil after the harvest of sunflower crop revealed that application of B @ 2.0 kg ha^{-1} registered the highest oxide B in soil (0.879 mg kg^{-1}) which significantly differed with other levels of B application (Fig.4). The organically bound B status in soil varied from 0.235 to 1.644 mg kg^{-1}. Among the varied frequency of B application, the application of B to all crops registered the highest organically bound B in soil and there existed a significant difference between the frequency of B application and their levels. The interaction effect revealed that application of 2.0 kg of B to every crop (F4) registered the highest organically bound B in soil (1.644 mg kg^{-1}). Similar findings are reported by Bandit Jena *et.al.*, (2017).

Residual B status in soil

Residual boron form is the major form of boron in soil and it accounts nearly 87 to 99% of the total boron in soil. The residual fraction of B status in soil due to varied frequencies and doses significantly differed, varied from 41.61 to 291.78 mg kg^{-1}.Among the varied B levels, application of B @ 2.0 kg ha^{-1}registered the highest residual fraction of B in soil (81.2 mg kg^{-1}). The interaction effect revealed that application of 2.0 kg of B to every crop (F4) registered the highest residual B in soil (291.7 mg kg^{-1}) (Fig.5). The residual boron is associated with the structures of primary and secondary minerals. Russell (1973) reported the equilibrium status between the soil solution and adsorbed Boron exists in the soil in five fractions. Zerrari *et al*., (1999) reported that these fractions are easily soluble, and adsorbed, oxide bound, organic matter bound and residual (these are in silicate minerals, and cannot be used by plants). It has also been specified that the amount of these different fractions depends on the soil properties and the availability levels of these fractions differ. Diana and Beni (2006) determinate that in soils water soluble and adsorbed B fractions represented only a small proportion of the total soil B content (0.66-1.21 % of total soil B) although in most of the soil, residual B fraction accounted for 86.3 to 88.2 % of the total soil B. Boron concentration in soil increased with the application of increased doses of boron and distributed to various labile and non labile pools in soil, thus maintained the availability to increase the crop yields of both maize and sunflower.

Conclusion

Boron (B) is a unique micronutrient required for normal plant growth and optimum yield of crops. Its deficiency is widespread in alkaline/calcareous, coarse-textured and low organic matter soils in many countries of the world. Prevention and/or correction of B deficiency in crops on B-deficient soils can have a dramatic effect on yield. Source, rate, formulation, time and method of B fertilizer application and proper balancing of B with other nutrients in soil will all affect crop yield on B-deficient soils. Soil applied B leaves residual effect for years on succeeding crops grown on B-deficient soils in the same field. In the present study, boron application resulted in significant increase in yield in maize as first crop and sunflower as residual crop, respectively. Application of B @ 2.0 kg ha^{-1} significantly registered the highest available B in soil (1.038 mg kg^{-1}) and the frequencies of application B to all crop registered the highest available B (1.321 mg kg^{-1}) in soil. Among the B fractions the order was residual B > organically bound > specifically adsorbed > oxide bound B.

References

Bandita Jena, Suravi Mohapatra, RK. Nayak, J.Das and A.K.Ahukla. 2017. Effect of boron fertilization on fate of soil boron pool under a rice-vegetable cropping system grown in an Inceptisols of Odisha. *International Journal of Chemical Studies*. **5 (1)**.74-78

Diana, G. 2006. Boron in the soil, from deficit to toxicity. *Informatore Agrario*., **62**:54-58.

Diana, G and C. Beni.2006. Effect of organic and mineral fertilization on soil boron fractions. *Agr. Med*.,**136** :70-78.

Ellis,B.G and B.D.Knezek.1972. Adsorption reactions of micronutrients in soils. In: “Micronutrients in Agriculture*”* Vol.4.Soil Sci. Soc. of America, Madison, USA.pp:59-78.

Mishra, L. C. and K.N. Shukla. 1986. Effects of fly ash deposition on growth, metabolism

and dry matter production of maize and soybean. *Environmental Pollution Series A:Ecol. Biol* .,**42**, 1-13.

Saviour Naveen,M and P.Stalin.2014. Nutrient release pattern of Different Boron Fractions in Maize growing Sandy loam soils. *International Journal of Agriculture, Environment and Biotechnology*.**7(3):**507-515

Padbhushan and D.Kumar.2017. Fractions of Soil boron: a review. *The Journal of Agricultural Sciences*. **155**(7): 1023-1032

Takano, J., K. Miwa and T. Fujiwara. 2008. Boron transport mechanisms: collaboration of channels and transporters. *Trends in Plant Sci*., **13**: 451-457.

Zerrari N, D. Moustaoui and M. Verloo.1999. The forms of boron in soil, effect of soil characteristics and availability for the plants. *Agrochimica*. **43**:77-88.

Received after revision : March 24, 2017; Accepted : April 27, 2017