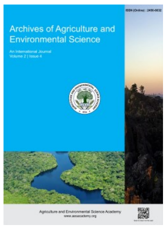
Archives of Agriculture and Environmental Science 5(2): 218-222 (2020)
https://doi.org/10.26832/24566632.2020.0502020

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes



REVIEW ARTICLE

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# Boron in crop production from soil to plant system: A review

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**ARTICLE HISTORY**

Received: 04 November 2019
Revised received: 11 April 2020
Accepted: 20 May 2020

**Keywords**

Boron
Role of boron
Soil and foliar application

**ABSTRACT**

The deficiency of boron is spreading rapidly in Indian soils. Boron deficiency in crops is more widespread than deficiency of any other essential micronutrient. However, imbalanced or excess use of boron fertilizers found to impose negative impact on crops due to very narrow range of boron deficiency and toxicity in soil and plants which increases production cost also. Therefore, optimized boron fertilizer supply in boron deficient soils is important in order to attain normal crop growth, yield and high-quality produce. It this review the role of boron in crop production, its deficiency in crop plants has been discussed.



**Citation of this article:** Singh, A.K., Singh, A.K. and Singh, J.P. (2020). Boron in crop production from soil to plant system: A review. *Archives of Agriculture and Environmental Science*, 5(2): 218-222, https://dx.doi.org/10.26832/24566632.2020.0502020

## INTRODUCTION

The essentiality of boron (B) for the growth and development of higher plants was demonstrated by Warington in the year (1923) and considered as an essential element for plant growth and development (Pollard *et al.*, 1977; Marschner, 1995). B plays an important role in both structural and functional integrity of plasma membrane (Pollard *et al.*, 1977). B has been reported to affect the plant growth due to its role in cell division, expansion, cell wall formation and stabilization, lignification and xylem differentiation (Marschner, 1995). B has been implicated in counteracting toxic effects of aluminum on root growth of dicotyledonous plants (Dale *et al.*, 1998). It imparts drought tolerance to the plant (Rattan and Goswami, 2002). In muskmelon, application of B improved plant growth and fruit quality, and in addition the incidence of chilling injury decreased in harvested fruit during cold storage at 5°C (Combrink *et al.*, 1995). B is continuously required for the normal growth of most plants, otherwise, plants grown in low B containing media exhibit B deficiency symptoms of various forms (Gupta, 1993). The deficiency of B spreading rapidly in Indian soil from 2% in 1980 (Katyal and Vlek, 1985) which reached to 52% soils (Singh, 2012). B deficiency has mostly been reported in the soils of Assam, Bihar, Meghalaya, West Bengal, Jharkhand and Odisha mainly in acid red and lateritic soils including high pH calcareous soils (Behera *et al.*, 2009). Now next to zinc, B has become an important micronutrient in Indian Agrarian (Sathya *et al.*, 2009) required for normal plant growth and obtaining high quality crop yields (Murmu *et al.*, 2014). The important facts pertaining to this important micronutrient is furnished in Table 1.

## BORON IN SOIL SYSTEM

Among the essential micronutrients B is the only non-metal and present in non-ionic form. Total B contents in Indian soils ranged between 7 to 630 mg B $kg^{-1}$ soils (Prasad *et al.*, 2014). Singh *et al.* (2015) observed that soils were highly deficient in available B with mean contents of 0.55, 0.49, 0.66 and 0.62 mg $kg^{-1}$ in Chandauli, Mirzapur, Sant Ravidas Nagar and Varanasi district, respectively. Availability of B in soil is influenced by several factors including soil reaction, soil moisture, active calcium and organic matter content (Dregne and Power, 1942). Light textured soils (sandy loam and loamy sands) found to be deficient in B content because they were well drained and had good leaching (Abid *et al.*, 2002). Most of the tea soils of Darjeeling hills are sandy loam and loamy sand soil (light textured) except

**Table 1.** Boron fact sheet.

| S.N. | Important facts |
|---|---|
| 1 | B was discovered by : Agulhan in the year 1910 |
| 2 | Essentiality of B has been established by : Warington, 1923 |
| 3 | Method of B analysis in soil : Hot water extractable B (Berger and Troug, 1939) |
| 4 | Mobility of B in plant : Immobile (Cripps, 1956) |
| 5 | Mobility of B in soil: Mobile |
| 6 | Non ionic forms in which B absorbed by plants : $H_3BO^{-}_3$, $B_4O_7^{2-}$, $H_2BO_3^{2-}$, $HBO^{2-}_3$, $BO^{3-}_3$ (Bingham *et al.*, 1970) |
| 7 | General critical level of B in soil : 0.5 mg $ka^{-1}$ soil (0.5 ppm) |
| 8 | Irrigation water with < 3 mg B $L^{-1}$ is ideal for B tolerant and semi tolerant crops |
| 9 | B containing minerals : Tourmaline |
| 10 | B containing fertilizers : Borax (11% B), Boric acid (17% B), Sodium tetraborate (14-15% B) and solubor (20-21% B), Boronated super phosphate (0.18% B) and Boronated NPK (0.3% B) |
| 11 | Major diseases caused by B deficiency : Heart rot of beat, Internal cork of apple, Brown heart of cabbage, Internal brown spot of sweet potato, Terminal bud breakdown of tobacco, Die-back of olive and Rosetting of alfalfa |
| 12 | Low B requiring crops : wheat, oats and sorghum |
| 13 | Medium B requiring crops : cabbage, lettuce, tomato and spinach |
| 14 | High B requiring crops : sugar beet, turnip and lucerne |

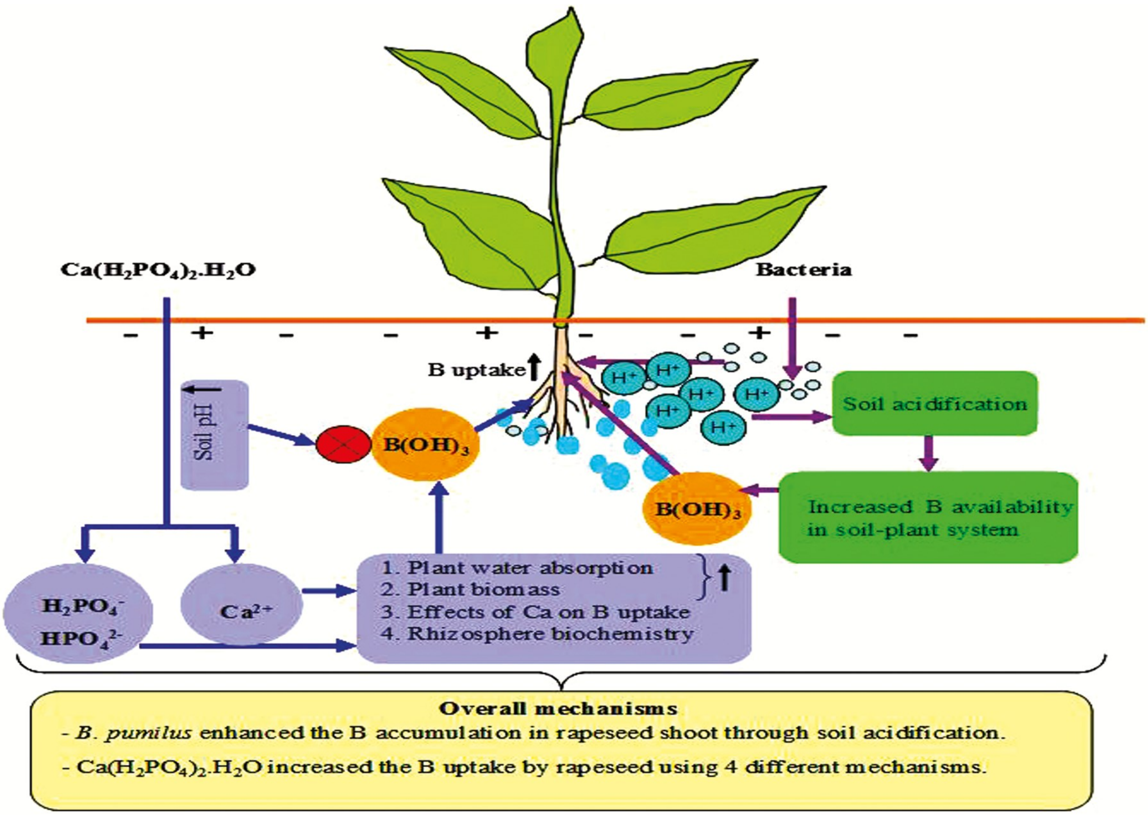


**Figure 1**. *Absorption of B by rapeseed shoot through soil acidification (Source: Masood et al., 2019).*

soils of Thurbo series (Saha *et al.*, 1995) and suppose to low in B content. B being a weakly held anion can be easily leached out from soil, making acid sandy soil more prone to B deficiency (Sakal and Singh, 1995). B uptake by plants is controlled by the B level in soil solution rather than the total B content in soil (Yermiyahu *et al.*, 2001). Total B concentration in soil is considered as a poor indicator of plant available B. Plant available B in a specific soil is controlled by the soils physical and chemical properties such as pH, soil texture, clay mineralogy, organic matter content etc. (Goldberg, 1993). Soil B availability generally decreases with soil drying (Fleming, 1980) and low soil water, especially as top soil dries out, depress B uptake by plants (Hobbs and Bertramson, 1949; Huang *et al.*, 1997). Rainy weather also impacts on plant B nutrition. Besides its effects on soil B leaching rate, low vapour pressure deficits in the atmosphere during the rainy season slow down the transpiration rate, this may inhibit B uptake and transport into growing plant parts (Figure 1) (Oertli, 1994; Rawson, 1996; Masood *et al.*, 2019 ).

## BORON IN PLANT SYSTEM

B deficiency in crops is more widespread than deficiency of any other micronutrient (Gupta, 1993). Tissue expansion is one of the first process influenced by B deficiency (Patrick *et al.*, 1997). B deficiency symptoms include cessation of terminal growth and leaf and stem distortions (Ecke *et al.*, 2004). Symptoms of B deficiency in shoots typically occur in meristematic tissue *i. e.* terminal buds and young leaves (Oertli, 1994; Dobermann and Fairhurst, 2000). The deficiency symptoms of B occur in the form of high die off at the growing points and developed corky excrescences on the undersides of petioles (Chenery, 1958). B deficiency symptoms can be observed in vegetative and reproductive parts, such as growth results inhibition of root and shoot tips, inhibition of flower development, reduced setting and malformation of fruits and seeds, male sterility and seed abortion (Dell and Huang, 1997). These morphological symptoms induced by B deficiency are linked with the structural role of B in cell walls and the poor mobility of B to the growing terminals in most species. However, observations at physiological level suggest that B may also play a key role on membrane structure and functions (Cakmak and Romheld, 1997). The occurrence of B toxicity symptoms in leaf margins of old leaves has long been interpreted as an indication of the immobility of B in plants (Oertli, 1993). Critical level is the concentration where a reduction in plant growth and expression of foliar deficiency symptoms occurs (Heathcote and Smithson, 1974). Deficiency and sufficiency levels of leaf B in mango were 20-49 ppm and 50 -100 respectively (Singh, 2007). Requirements of B for plant growth vary widely among species to species and within species and plant growth stages as well (Gupta 1993; Marschner, 1995; Rerkasem and Jamjod, 1997; Shorrocks, 1997). In general, dicotyledons require more B than monocotyledons (Gupta *et al.*, 1985). Boric acid at 0.25% had no adverse effect on theaflavin and thearubigin contents in made tea. Boric acid at 0.6% (w/v) concentration was found to be phytotoxic leading to severe scorching and defoliation (Barooah, 2008). Important role of B in plants is enlisted in Table 2.

## BORON MANAGEMENT

Slight variation in the recommended dose of B, crops may face either deficiency or toxicity in a single growing season (Batabyal *et al.*, 2015). Therefore, optimized B fertilizer supply in B deficient soils is important in order to normal growth, yields and quality of produce due to very narrow range of B deficiency and toxicity in soils and plants (Singh and Goswami, 2013). B application frequency depends on doses and the nature of the crop. Basal application of B, through broadcasting, gave the best response. However, foliar sprays of 2.0-2.5 g $l^{-1}$ of boric acid or solubor can be used for correcting the B deficiency whenever appeared (Prasad *et al.*, 2014). Some important findings pertaining to performance of various crop influenced due to B fertilizer application (method and time) have been summarized and presented in Table 3.

**Table 2.** Important outcome of research on role of B in plants.

| Salient finding | Reference |
|---|---|
| B imparts drought tolerance in the plants | Rattan and Goswami (2002) |
| B improved fruit quality and decrease chilling injury in muskmelon | Combrink *et al.* (1995) |
| B required in the cell wall structure | O'Neill *et al.* (2004) |
| B deficiency caused low grain set and poor-quality seeds and fruits | Dell *et al.* (2002) and Bell and Dell (2008) |
| Deficiency of B typically occurs in terminal buds and young leaves | Oertli (1994) |
| B is considered a fertilizer for quality in fruits | Prasad *et al.* (2014) |
| B reduces incidence of many diseases in plants | Graham *et al.* (1987) |
| Dicotyledonous plants require more B than monocotyledonous | Gupta *et al.* (1985) |
| B reduces mite population in wheat | Singh (1986) |
| B soil application with IPNS increased made tea yield in Darjeeling | Singh *et al.* (2011) |
| B supposed to be most important micronutrient for tea as its deficiency adversly affect the economic part *i. e.* growing tip | Singh *et al.* (2014) |
| Positive interaction of B reported with N, K and S | Smithson and Herthcote, (1976); Shekhawat and Shivay (2008) |

**Table 3.** Influence of B application on the performance of various crops.

| Salient achievement | Reference |
|---|---|
| Application of B in sunflower @ 1.5 kg $ha^{-1}$ gave the highest seed yield (2.01 t $ha^{-1}$). | Shekhawat and Shivay (2008) |
| Application of B @ 1.5 kg $ha^{-1}$ progressively increased the B concentration and uptake by onion, maize, sweet potato, mustard and sunflower | Sinha *et al.* (1991) |
| B application increased the dry matter yield and uptake of B by green gram | Mani and Haldar (1996) |
| Growth and yield of groundnut was positively affected by both soil and foliar application of B. | Ansari *et al.* (2013) |
| Boronated super phosphate application produced significantly higher dry matter and yield of sunflower | Ateeque *et al.* (1993) |
| Significant interaction effect of PxSxB was found for seed and oil yield of castor | Naik *et al.* (1993) |
| At par soybean grain yield was found with either soil application of 20 kg sodium tetraborate (14% B) or two foliar sprays of 0.2% solution of the same salt. | Dwivedi *et al.* (1990) |
| B foliar application @ 0.2% at flowering stage found to be optimum for realizing optimum economic yield of summer mungbean in West Bengal. | Mondal *et al.* (2012) |
| B fertilization significantly increased tuber number and yield of potato | Sarkar *et al.* (2018) |

## Conclusion

This review paper summarizes up-to-date knowledge pertaining to the importance of B in crop/ plant production, growth and quality in changing climate along with its dynamics in the soil system. Imbalanced or excess use of B fertilizers found to impose negative impact on crop which increases costs of production. Region and crop specific (as requirement vary species to species) time and method of B fertilizer application need to be work out and readjusted (existing one) for optimum utilization of applied as well as native B. Possibility and feasibility of development of B bio-fertilizer need to be explored.



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