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

Anil Kumar Singh1*, Alok Kumar Singh2 and Jay Prakash Singh3

1Department of Agricultural Chemistry and Soil Science, S.M.M. Town P.G. College, Ballia - 277001 (Affiliated: Jananayak Chandrashekhar University, Ballia), (Uttar Pradesh), INDIA
2Department of Crop Physiology, College of Agriculture, ANDUA&T, Kumarganj, Ayodhya-224229, (Uttar Pradesh), INDIA
3Department of Plant Pathology, SMM Town P.G. College, Ballia - 277 001 (Affiliated: Jananayak Chandrashekhar University, Ballia), (Uttar Pradesh), INDIA
*Corresponding author’s E-mail: singhanil80@gmail.com

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.

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 countering 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., 1999). 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...
Anil Kumar Singh et al. / Arch. Agric. Environ. Sci., 5(2): 218-222 (2020)

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$_3$BO$_3$, B$_2$O$_7^{2-}$, H$_2$BO$_3^{2-}$, HBO$^{2-}$, BO$_3^{3-}$ (Bingham et al., 1970) |
| 7    | General critical level of B in soil : 0.5 mg kg$^{-1}$ 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 beet, 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 |

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 processes 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; Shirrooks, 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 adversely 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). Application of B @ 1.5 kg ha⁻¹ progressively increased the B concentration and uptake by onion, maize, sweet potato, mustard and sunflower | Shekhawat and Shivay (2008) 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. Boronated super phosphate application produced significantly higher dry matter and yield of sunflower | Ansari et al. (2013) Ateeque et al. (1993) |
| Significant interaction effect of PxSxB was found for seed and oil yield of castor  | Naik et al. (1993) Dwivedi et al. (1990)      |
| 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. | Mondal et al. (2012) |
| B foliar application @ 0.2% at flowering stage found to be optimum for realizing optimum economic yield of summer mungbean in West Bengal. |  |
| 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.

Open Access: This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author(s) or sources are credited.

REFERENCES

Abid, N., Ibrahim, M., Ahmad, N. and Anwar, S.A. (2002). Boron contents of light and medium textured soils and cotton plants. International Journal of Agriculture and Biology, 4(4): 534-536.

Ansari, M.A., Prakash, N., Singh, I.M., Sharma, P.K. and Punitha, P. (2013). Efficacy of boron sources on productivity, profitability and energy use efficiency of groundnut (Arachis hypogaea) under north east hill regions. Indian Journal of Agricultural Sciences, 83(9): 959-63.

Ateeqe, M., Malewar, G.U. and More, S.D. (1993). Influence of phosphorus and boron on yield and chemical composition of sunflower. Journal of the Indian Society of Soil Science, 41(1): 100-102.

Batabyal, K., Sarkar, D. and Mandal, B. (2015). Critical levels of boron in soils for cauliflower (Brassica oleracea var. botrytis). Journal of Plant Nutrition, 38: 1822-1835, http://dx.doi.org/10.1080/01904167.2015.1042166

Beeha, S.K., Singh, M.V. and Lakaria, B.L. (2009). Micronutrient deficiencies in Indian Soils and their amelioration through fertilization. Indian Farming, 5(2): 29-31, https://www.researchgate.net/publication/286648588

Bell, D.W. and Dell, B. (2008). Micronutrients for sustainable food, feed, fibre and bioenergy production. International Fertilizer Industry Association, Paris, pp. 175.

Berger, K.C. and Troug, E. (1939). Boron determination in soils and plants. Industrial and Engineering Chemistry Analytical Edition 11: 540–545, https://doi.org/10.1021/ac50138a007

Bingham, F.T., Elsewii, A. and Oertli, J. (1970). Characteristics of B adsorption by excised barley roots. Soil Science Society of America Journal, 34: 613–617.

Cakmak, I. and Romheld, V. (1997). Boron deficiency-induced impairments of cellular function in plants. Plant Soil, 193:7183, https://link.springer.com/article/10.1023/A:1000425988322

Chenery, E.M. (1958). Boron deficiency in Tea. Nature, 181. pp 426.

Combrink N.J.J. and Maree P.C.J. (1995). The effect of calcium and boron on the quality of muskmelon (Cucumis melo L.). Journal of the South African Society for Horticultural Science, 5: 33-38.

Cripps, E.G. (1956). Boron nutrition of the Hop. Journal of Horticultural Science, 31: 25-34.

Dale, G.B. and Lukaszewski, K.M. (1998). Boron in plant structure and function. Annu. Rev. Plant physiol. Plant Molecular Biology, 49: 481-500, https://www.annualreviews.org/doi/10.1146/annurev.arplant.49.1.481

Dell, B. and Huang, L. (1997). Physiological response of plants to low boron. Plant and Soil, 193: 103-120, http://dx.doi.org/10.1023/A:1000425988322

Dell, B., Brown, P.H. and Bell, R.W. (2002). Boron in soils and plants: reviews. Kluwer, Dordrecht.

Dobermann, A. and Fairhurst, T. (2000). Nutritional disorders and nutrient management, International Rice Research Institute, Los Banos, Philippines. pp. 132–34.

Dregne, H.E. and Power, W.L. (1942). Boron fertilization of alfalfa and other legumes in Oregon. Journal of American Society of Agronomy, 34: 902-912, https://doi.org/10.2134/agron1942.000219620034000010005x

Dwivedi, G.K., Dwivedi, M. and Pal, S.S. (1990). Mode of application of micronutrients in soybean-wheat crop sequence. Journal of the Indian Society of Soil Science, 38: 458-63.

Ecke, P., Ill, Faust, J.E., Williams, J. and Higgins, A. (2004). The Ecke Poinsettia Manuel. Ball publishing, Illinois, U.S.A. 268p.

Fleming, G.A. (1980). Essential micronutrients. In: Boron and molybdenum. In: Davies, B.E.(ed). Applied soil trace elements. pp. 155-197. John Wiley and Sons, New York.

Goldberg, S. (1993). Chemistry and mineralogy of boron in soils. In: Boron and its role in crop production. Ed. U.C. Gupta. pp 344 CRC Press, Boca Raton, F.L, U.S.A.

Graham, R.D., Welch, R.M., Grunes, D.L., Cary, E.E. and Norwell, W.A. (1987). Effect of Zn deficiency on the accumulation of B and other mineral nutrients in barley. Soil Science Society of America Journal, 52: 652–57.

Gupta, U.C. (ed) (1993). Boron and its role in crop production. CRC Press, Inc. Boca Ratio, FL, USA. 237pp.

Gupta, U.C., James, Y.W., Campbell, C.A., Leyskoon, A.J. and Nicholachuk, W. (1985). Boron toxicity and deficiency: a review. Canadian Journal of Soil Science, 65: 381-409, https://doi.org/10.4141/cjs85-044

Heathcote, R.G. and Smithson, T.B. (1974). Boron deficiency in cotton in northern Nigeria. I. Factors influencing occurrence and methods of corrections. Experimental Agriculture, 10: 199–208.

Hobbs, J.A. and Bertramson, B.R. (1949). Boron uptake by plants as influenced by soil moisture. Proceeding of Soil Science Society of America, 13: 257-261.

Huang, L.B., Wang, K. and Bell, R.W. (1997). Water supply influences boron uptake by transplanted oilseed rape (Brassica napus cv. Eureka) grows in low boron soil. In: Bell, R.W. and Rerkasem, B. (eds) Boron in soils and plants pp 157-160 Kluwer Acad. Publ. Dordrecht.

Katyal, J.C. and Vtek, P.L.G. (1985). Micronutrient problem in tropical Asia. Fertilizer Research, 7: 69–94, https://doi.org/10.1007/BF01048996

Mani, P. K. and Haldar, M. (1996). Effect of dolomite on boron transformation in acid soil in relation to nutrition green gram. Journal of the Indian Society of Soil Science, 44(3): 458-461.

Marchner, H. (1995). Mineral nutrition of higher plants. 2nd ed. Acad. Press. London 889p.

Masood, S., Zhao, X.Q. and Shen, R.F. (2019). Bacillus pumilus increases boron uptake and inhibits rapseed growth under boron supply irrespective of phosphorus fertilization. Aod PLANTS, 11 (4): 1-10, https://doi.org/10.1093/aodpl/plz036

Moond, C.S. and Bandopadhyay, P., Alipatra, A. and Banerjee, H. (2012). Performance of summer mungbean [Vigna radiata (L.) Wilczek] under different irrigation regimes and boron levels. Journal of Food Legumes, 25(1): 37-40.

Mumru, S., Saha, S., Saha, B. and Hazra G.C. (2014). Influences of Zn and B on the yield and nutrition of two widely grown potato cultivars (Solanum tuberosum L.). Annals of Biology, 30: 37-41

Naik, K.G.A., Manure, G.R. and Badiger, M.K. (1993). Yield of castor by fertilizing with phosphorus, sulphur and boron. Journal of the Indian Society of Soil Science, 41(4): 686-688.

Oertli, J.J. (1993). The Mobility of Boron in Plants. Plant and Soil 155/156. 301-304, https://www.jstor.org/stable/42939520

Oertli, J.J. (1994). Non-homogeneity of boron distribution in plants and consequences for foliar diagnosis. Communication in Soil Science and Plant Analysis, 25: 1133-1147.

O'Neill, M.A., Ishi, T., Albersheim, P. and Darvill, A.G. (2004). Rhamnogalacturonan II: Structure and functions of a borate cross-linked cell wall pectic saccharide. Annual Review of Plant Biology, 55: 109-139, https://www.annualreviews.org/doi/10.1146/annurev.arplant.55.031903.141750

Patrick, H.B. and Shelp, B.J. (1997). Boron mobility in plants. Plant and Soil, 193: 85-101.

Pollard, A.S., Parr, A.J. and Loughman, B.C. (1977). Boron in relation to membrane function in higher plants. Journal of Experimental Botany, 28: 831-841.

Prasad, R., Kumar, D., Shrivay, Y.S. and Rana, D.S. (2014). Boron in Indian agriculture-A review. Indian Journal of Agronomy, 59 (4): 511-517.

Rattan, R.K. and Goswami, N.N. (2002). Essential nutrient and their uptake by plants. In: Fundamentals of soil science. Ed: Shekhan, et al. pp 319. Indian
Society of Social Science, New Delhi.

Rawson, H.M. (1996). Hypothesis for why sterility occurs in wheat in Asia. In: Rawson, H.M. and Subedi, K.D. (eds.). Sterility in wheat in sub-tropical Asia: Extent, causes and solutions. pp 132-134. ACIAR Proc. No. 72. Canberra.

Rerkasem, B. and Jamalj, S. (1997). Genotypic variation in plant response to low boron and implications for plant breeding. Plant Soil, 193:169-180.

Saha, R., Mondal, D. and Bisen, J.S. (1995). Tea soils of Darjeeling. Sci. Mono. Series No. 1. Tea Board India, pp 10.

Sakal, R. and Singh, A.P. (1995). Boron research and agricultural production. In: Tondon, H.L.S. (ed.). Micronutrient Research and Agricultural production. FDC, New Delhi 1-31.

Sarkar, S., Banerjee, H., Ray, K. and Ghosh, D. (2018). Boron fertilization effects in processing grade potato on an Inceptisol of West Bengal, India. Journal of Plant Nutrition, 41(11), 1456-1470, https://doi.org/10.1080/01904167.2018.1457685

Sathy, S., Pitchai, G.J. and Indirani, R. (2009). Boron nutrition of crops in relation to yield and quality-a review. Agricultural Reviews, 30 (2): 139-44, https://arccjournals.com/journal/agricultural-reviews/ARCC2097

Shekhawat, K. and Shivay, Y.S. (2008). Effect of nitrogen sources, sulphur and boron levels on productivity, nutrient uptake and quality of sunflower (Helianthus annuus). Indian Journal of Agronomy, 53 (2): 129-34.

Shorrockes, V.M. (1997). The occurrence and correction of boron deficiency. Plant Soil, 193: 121-148, https://link.springer.com/article/10.1023/A:1004216126069

Singh, A.K., Bisen, J.S., Bora, D.K., Kumar, R. and Bera, B. (2011). Comparative study of organic, inorganic and integrated plant nutrient supply on the yield of Darjeeling tea and soil health. Two and a Bud, 58: 58-61.

Singh, A.K., Chauhan, R.K. and Bisen, J.S. (2014). Role of soil organic matter in soil health sustainability. International Journal on Agricultural Sciences, 5 (II): 219-227, https://scholar.google.co.in/citations?user=NHMBv6QAAAAJ&hl=en

Singh, A.P. (1986). Effect of soil nutrients and varietal reactions to the population buildup of brown wheat mite (Pretobius latens Muller) on wheat. Entomon, 11: 115-120.

Singh, M.V. (2012). Spread of micro-nutrient deficiencies specially boron in India and response of field crops. "Brain storming workshop on soil test-based nutrients including boron and other micro nutrients" Organized by ICRISAT - Agriculture Directorate, Karnataka -Rio Tinto India at Bangalore, India.

Singh, M.V. and Gowsami, V. (2013). Efficiency of boron fortified NPK fertilizer in correcting boron deficiency in some cereal and oilseeds crops in India. 17th International Plant Nutrient Colloquium 17-18 August, Istanbul, Turkey.

Singh, S.K., Dey, P., Singh, S., Sharma, P.K., Singh, Y.V., Latare, A.M., Singh, C.M., Kumar, D., Kumar, O., Yadav, S.N. and Verma, S.S. (2015). Emergence of boron and sulphur deficiency in soils of Chandouli, Mirzapur, Sant Ravidas Nagar and Varanasi districts of eastern UP. Journal of the Indian Society of Soil Science, 63 (2): 200-208, https://doi.org/10.3958/0974-0228.2015.00026.2

Singh, V.K. (2007). CISH Lucknow. Data from Farming outlook, 5(3).

Sinha, R.B., Sakal, R., Singh, A.P. and Bhogal, N.S. (1991). Response of some field crops to boron application in calcareous soils. Journal of the Indian Society of Soil Science, 39(1): 118-122, https://scholar.google.co.in/citations?user=xmTxn1cAAAAJ&hl=en

Smithson, J.B. and Herthcote, R.G. (1976). A new recommendation for application of boronated superphosphate to cotton in northeastern Beune plateau soils. Samanau Agricultural Newsletter, 18: 59–63.

Warington, K. (1923). The effect of boric acid and borax on broad bean and certain other plants. Annals of Botany, 37: 629-672, https://doi.org/10.1093/oxfordjournals.aob.a089871

Yermiyahu, U., Keren, R. and Chen, Y. (2001). Effect of composted organic matter on boron uptake by plants. Soil Science Society of America Journal, 65: 1436-1441, https://dx.doi.org/10.2136/sssaj2001.1436