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Important functions of boron in crop production and how to manage it

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Abstract

Boron is a crucial non-metal micronutrient with specific physiological and metabolic features; as a consequence, it is essential for optimum crop growth and development. Next to zinc, boron is the trace element that's most widely distributed in India. Due to a small distinction between boron shortages and toxicity, managing boron deficits in agriculture is a significant concern. By applying boron fertilizers at the right rate, time, source, and method and balancing them with other minerals in the soil, attention should be paid to boron nutrition for crops to overcome deficiencies. In alkaline and calcareous soils, boron interacts with other nutrients and goes to adsorption in the soil, which affects the availability of boron for crop growth. Therefore, the foliar application of boron is better than soil application for these soils.

Introduction

Boron is the nutrient element that naturally occurs in soil solution as the non-ionized (H_3BO_3) molecule and plants require in trace amounts (Marschner, 1995) and plays many roles in plants like cell wall formation and stabilization, lignification, xylem differentiation, imparting drought tolerance, RNA metabolism, pollen germination and pollen tube growth and facilitating transport of potassium (K) in guard cells and stomatal opening. Boron is the second most important micronutrient in Indian soils after zinc (Zn) (Sillanpaa, 1990; Alloway, 2008, Shukla et al. 2014, Behera et al. 2016). The difficulty of boron being readily transported and demobilized by crops, except for a few species of fruit and vegetables, is another important characteristic. B should always be accessible in the soil for root uptake in these crops, especially throughout the reproductive growth stage, when boron demands are at their highest.

Major functions of boron in plant growth and development:

Cell wall structure: Boron takes part with calcium (Ca) in the structure of the cell wall. Boron takes part in the movement of Ca in the plant and the normal nutrition of Ca in plants and animals. Bone development in animals and cell wall development in plants are similar. For example, a "hollow heart" in peanuts can occur when a shortage of B limits Ca movement, normal cell wall development and cell division. Ca/B ratio: 1200:1.

Cell division: Boron is essential in active growing regions of plants, such as root tips, and in the development of new leaves and buds. This involves the meristematic tissues (growing) in plants or cells that multiply quickly, allowing the growth of plants to occur.

Sugar transport: Boron increases the rate of transport of sugars (which are produced by photosynthesis in the leaves of mature plants) to regions in active growth and also in the development of fruits.

Flowering and fruiting: The B requirement is much higher for reproductive growth compared to vegetative growth in most plant species. Boron increases flower production and retention, elongation and germination of pollen tubes, and seed and fruit development. B deficiency can cause incomplete pollination of corn or prevent maximum pod growth in soybeans.

Plant hormone regulation: Plant hormones, like animal hormones, regulate many growth and reproduction functions. Flower initiation, fruit development, cell wall and tissue formation, and root elongation are all influenced by hormones. Boron plays an important role in regulating hormone levels in plants.

- ✓ Plays a pivotal role in pollen germination and pollen tube growth in cereals and oilseeds.
- ✓ Essential for cell division & protein synthesis.

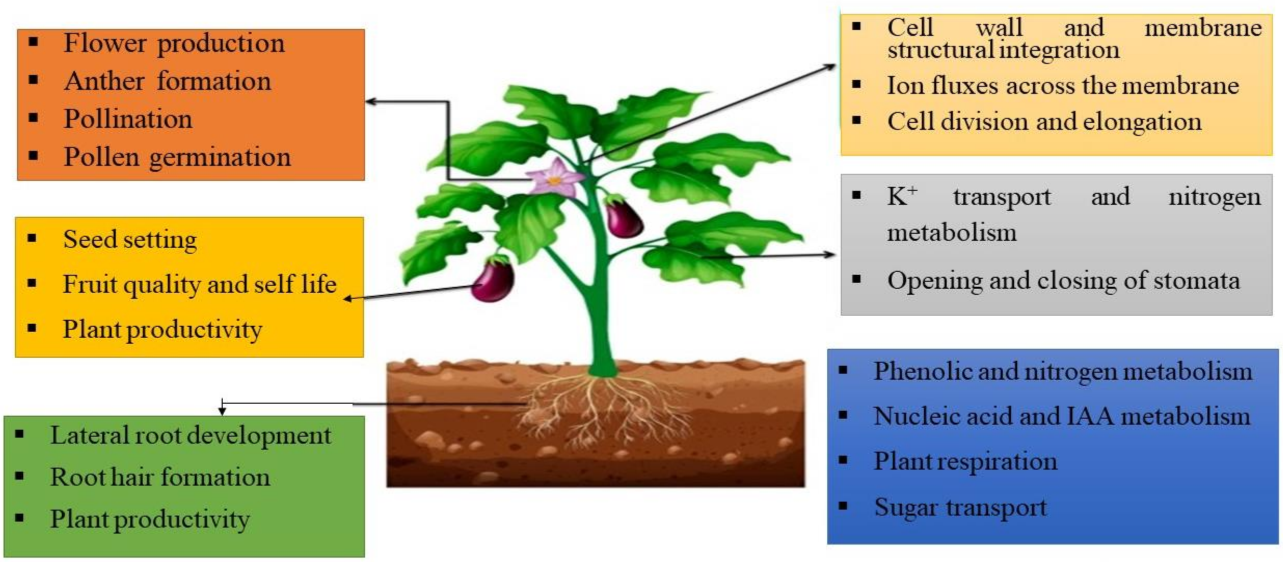

Fig. 1. Functions of Boron in Plants

Source fig. Shireen et al. 2018

Boron uptake

- Boron uptake is mainly by mass flow and is absorbed as boric acid, which is not charged. Unlike other nutrients, most crop species have very little control over the uptake of B when available in the toxicity range (< 0.3 ppm, critical limit). This response is a direct result of the passive intake of B from plant membranes, unlike other nutrients that have specific transporters that regulate uptake. The accumulation of plant B is therefore directly related to transpiration. The range between insufficient availability and toxic availability of boron is very narrow (Reisenauer et al. 1973).
- Boron is primarily mobilized by the flow of water through the xylem from the roots to the leaves. Because deficiency symptoms in field crops are found in the growing tissue, foliar B fertilization, therefore, provides limited value because it is restricted to the sprayed tissues and cannot supply B for later growth.

Boron deficiency symptoms

Symptoms of boron deficiency are related to its main role in plants, cell wall growth and structure. Typical deficiency symptoms include:

- Impaired cell expansion in rapidly growing organs (leaves, roots and pollen tube), impaired growth of the plant meristems in roots and shoots causing malformation and thick and shorter roots, flower abortion, male and female flowers sterility, and reduced seed set due to inhibition of pollen growth. The reproductive organs, which have a high concentration of pectin rich in B, are often the most sensitive to B deficiency because of their high B demand. These organs also have low sweating levels that limit B's movement to these tissues.
- Boron deficiency occurs on young leaves of plants that cannot mobilize. In the case of severe B deficiency, slow growth and death of growing tissues are common. Inhibition of root elongation, the inability of flowers to produce seed and fruit abortion is also common deficiencies. However, these negative effects may occur without any visible symptoms of boron deficiency.
- Brown-head and Hollow stem of cauliflower.
- Breakdown of tissues: Sugar beet, turnip, potatoes
- Fruit cracking: Apple
- Leaf chlorosis (loss of green colour) and necrosis (leaf death) occur only in a few species and rarely as the first symptom. Because some crops make it sensitivity (Table 1.) difficult to visually

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see a boron deficiency, the best strategy for boron is to prevent deficiency with the foliar and soil application of the micronutrient (Chaitanya et al. 2014, Arunkumar et al. 2018).

Table 1. Relative sensitivity of selected crops to B deficiency

High sensitivity		Moderate sensitivity		Low sensitivity	
Alfalfa	Sugar beet	Apple	Cotton	Barley	Pea
Cauliflower	Turnip	Broccoli	Lettuce	Bean	Potato
Celery		Cabbage	Radish	Cucumber	Sorghum
Rapeseed		Carrot	Spinach	Corn	Soybean
Peanut		Clovers	Tomato	Grasses	Sudan grass

Causes of Boron Deficiency in Soil:

Boron deficiency is particularly prevalent in acidic, light-textured, highly leached soils, calcareous soils, very clayey soils, and soils with low organic matter content. Adoption of high-yielding cultivars, intensive cultivation with increased use of B-free high-analysis fertilizers, and drought condition also promotes B deficiency.

Factors affecting boron availability in soils:

- Parent material
- Nature of clay minerals
- Liming
- Sources of irrigation,
- Soil texture
- pH
- Organic matter content
- Environmental conditions like moderate to heavy rainfall

Method of Application and Sources of Boron Fertilizer:

The requirement to include boron in the fertilizer recommendation relates to sources of boron fertilizer:

Sources of boron Fertilizer: The boron requirement for various crops has proved to be a natural prerequisite for the efficient and rational use of boron manure. Several compounds have been recommended as a source of B for soil and foliage application. Several manures containing boron are listed below.

Table 2. Boron-containing fertilizers:

S. No.	Boron Fertilizer	B content (%)
1.	Borax	11
2.	Sodium tetraborate (Fertilizer Borate-48, Agribol)	14-15
3.	Fertilizer Borate-68	21
4.	Boric acid	17
5.	Solubor	20-21
6.	Colemanite (Portabor)	10-16
7.	Boron frits	2-6

Rate of application:

The narrow concentration range between boron deficiency and toxicity requires special care in the application of boron fertilizers. The generally recommended dose of boron for soil application is 0.50 to 2 kg ha^{-1} with or without mixing with major nutrients or as a foliar spray at 0.2 to 0.5% (W: V). Generally, the recommended dose for Borax is 10-15 kg ha^{-1}, for boric acid 5-7 and soluble is 7-9 kg ha^{-}

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[1] on the ground or applied by foliar spraying. Foliar spray is more prominent than the soil application due to the following reasons:

- Uniform spread over the crop canopy
- Require a lower rate than soil application
- Crops respond immediately for rapid recovery.

Soil amelioration: To correct the B deficiency issue, it is sometimes useful to apply lime and organic matter to increase the availability of B in acidic soils. The beneficial effects of organic farming have been realized for sustainable agriculture production, restoration of soil fertility, production of quality foods, and avoidance of pollution of soil, water and air including low-cost technology. The main sources of micronutrients used at the farmer's level are organic matter available in farmhouses.

• Green Manure	20.0 B mg kg^{-1}	• Sewage sludge	9.0 B mg kg^{-1}
• City compost	15.0 B mg kg^{-1}	• FYM	4.6 B mg kg^{-1}
• Rural compost	10.0 B mg kg^{-1}	• Poultry Manure	5.0 B mg kg^{-1}

Precautions

- Boron-containing fertilizers should not come into contact with the seed at planting time.
- Borax and fertilizer borates are not suitable for compounding with $(NH_4)_2SO_4$ as their alkaline reaction may cause the liberation of NH_3.

Conclusion

Boron deficiency decreases crop growth and yield, hence the importance of boron nutrition for optimum growth and yield. The source, rate, duration and method of applying boron fertilizer and the appropriate balancing of other nutrients in the soil affect the yield on boron-deficient soils. Foliar application of boron at the right time of crop growth shows better performance than the soil application especially in zinc-deficient soil to avoid boron toxicity in crops and in alkaline, calcareous soil to avoid interaction and adsorption in soil, which affects growth and yield of the crop. The soil and foliar application methods of B are effective in improving crop yield, product quality, boron concentration and absorption, and economic yields.

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