Historical information

Boron (B) is one of the eight essential micronutrients, also called trace elements, required for the normal growth of most plants. It is the only nonmetal among the plant micronutrients. In 1923, it was first time reported that B is essential for cell structure of plants. The importance of boron as an agricultural chemical has grown very rapidly. Its requirement differs markedly within the plant kingdom. It is essential for the normal growth of monocots, dicots, conifers, and ferns, but not for fungi and most algae. Some members of Gramineae, for example, wheat (*Triticum aestivum* L.) and oats (*Avena sativa* L.) have a much lower requirement for boron than do dicots and other monocots, for example, corn. Of the known micronutrient deficiencies, boron deficiency in crops is most widespread. In the last 80 years, more than hundreds of reports have dealt with the essentiality of boron for a variety of agricultural crops in countries from every continent of the world. In soils, concentration of total B is reported to be in the range of 20 to 200 mg Boron kg^{-1}, while the amount available for absorption ranges from 1 to 5 mg kg^{-1} in the soil solution. The accepted range of B is narrow. A deficiency occurs when a hot water extract contains less than 1 mg kg^{-1}. Toxicity occurs at levels above 5 mg kg^{-1}. Boron availability is also influenced by soil water pH; the optimum range for maximum availability lies between 5.5 to 7.0.

Boron in plants

Boron (B) is probably taken up by plants as the undissociated boric acid (H_3BO_3). It appears that much of the B uptake mainly follows water flow through roots. B in a plant is like the mortar in a brick wall, the bricks being the cells of growing parts such as tips (meristems). Key roles of B relate to: (i) membrane integrity and cell-wall development, which affect permeability, cell division and extension; and (ii) pollen tube growth, which affects seed/fruit set and, hence, yield. B is relatively immobile in plants and, frequently, the B content increases from the lower to the upper parts of plants.

Deficiency

Boron deficiency in crops is more widespread than deficiency of any other micronutrient. This phenomenon is the chief reason why numerous reports are available on boron deficiency symptoms in plants. Because of its immobility in plants, boron deficiency symptoms generally appear first on the younger leaves at the top of the plants. This occurrence is also true of the other micronutrients except molybdenum, which is readily translocated. B deficiency usually appears on the growing points of roots, shoots and youngest leaves. Young leaves are deformed and arranged in the form of a rosette. There may be cracking and cork formation in the stalks, stem and fruits; thickening of stem and leaves; shortened internodes, withering or dying of growing points and reduced bud, flower and seed production. Other symptoms are: premature seed drop or fruit drop; crown and heart rot in sugar beet; hen- and chicken-type bunches in grapes; barren cobs in maize; hollow heart in groundnut; unsatisfactory pollination; and poor translocation of assimilates. Death of the growing tip leads to sprouting of auxiliary meristem and a bushy broom-type growth. Roots become thick, slimy and have brownish necrotic spots. Deficiency is often induced by intensive crop production and irrigation, both common features of cotton culture. Boron is not mobile, and thus is needed.

Boron levels in plants

Often when one talks about deficient, sufficient, and toxic levels of nutrients in crops, there is a range in values rather than one definite number that could be considered as critical. Therefore, the term *critical level* in crops is somewhat misleading. A nutrient content value considered critical by workers in one area may not be considered critical in another area. Likewise, the term *optimum level* of a nutrient, as used in the literature by some researchers to express a relationship to maximum crop yield, is sometimes not clear. Theoretically, such a level for a given nutrient should be sufficient to produce the best possible growth of a crop. A range of values would be more appropriate to describe the nutrient status of the crop; therefore, the term sufficiency will be used, rather than critical or optimum.

Boron requirement of some field and horticultural crops

High	Medium	Low
Alfaalfa	Asparagus	Barley
Apple	Carrot	Beans
Broccoli	Corn (sweet)	Blueberry
Brussels sprouts	Cotton	Cereals
Cabbage	Cherry	Citrus
Cauliflower	Lettuce	Corn
Celery	Onion	Cucumber
Clowers	Parnsnip	Flax
Mustard	Peach	Grasses
Peanuts	Pear	Oat
Rape	Potato (sweet)	Peas
Red beet	Radish	Pepper
Rutabaga	Spinach	Potato (White)
Sugar beet	Tobacco	Raspberry
Sunflower	Tomato	Rye
Turnip		Sorghum
		Strawberry
		Wheat

Problem soils

Boron deficiency is likely to occur in:

- Soils derived from parent material low in B such as acid igneous rocks or fresh Water sediments
- Sandy soils from which boron has been leached
- Alkaline soils, especially those containing free lime
- Soils low in organic matter
- Acid peat and muck soils

Factors affecting plant accumulation of boron

Soil reaction or soil pH is an important factor affecting availability of boron in soils. Generally, boron becomes less available to plants with increasing soil pH. Several workers have observed negative correlations between plant boron accumulation and soil pH. The availability of boron to plants decreases sharply at higher pH levels, but the relationship between soil pH and plant boron at soil pH values below 6.5 does not show a definite trend.

Liming of soil decreased the plant boron accumulation when soil boron reserves were high. They attributed this effect to a high calcium content. Among the macronutrients, nitrogen is of utmost importance in affecting boron accumulation by plants. The authors reported that boron concentrations decreased with increasing rates of nitrogen. Additions of nitrogen decreased the severity of boron toxicity symptoms. The form of nitrogen can affect plant boron accumulation.

Correcting deficiency

Boron deficiency can be corrected by soil applications or foliar sprays of boron fertilizers. Soil applications are more effective if broadcast and mixed into the soil some months before sowing. Borax, boric acid, and chelated B compounds are suitable soil applications but only boric acid or chelated B compounds are suitable as foliar sprays. Foliar sprays should be applied about 5 to 6 weeks after seedling emergence or as soon as symptoms appear. While soil applications often remain effective for many years, foliar sprays have little residual value and must be applied to every crop. Soil tests can be used to estimate the amount of available B in a soil and predict whether fertilizer is needed. The best prediction can be obtained by seeking advice on fertilizer practices used on similar soils in the region.

Methods and rates of application

The boron requirement of crops varies considerably, so recommendations must take these differences into account. Although plant species having high boron requirements are more likely to become boron deficient under boron-limiting conditions in the soil, their recommended boron rates may vary according to other conditions such as differences in root systems, effects of other soil parameters, and available soil calcium. Therefore, generalized boron recommendations must take all such factors into account.

Application of boron fertilizers at the recommended rate for a high-boron-requiring crop may provide excessive available boron for another crop. Tolerance to higher levels of available boron varies considerably, and species with high boron requirements do not necessarily have high tolerance and vice versa. For example, alfalfa and cabbage (*Brassica oleracea* var. *capitata* L.) have high boron requirements but are only semitolerant to high boron levels.

Recommended rates of boron application generally range from 0.25 to 3 kg ha^{-1}, depending on crop requirements and methods of application. Higher rates of boron generally are required for broadcast soil applications than for banded soil application or foliar sprays. Rates are usually similar for all boron sources, except for higher rates with slowly soluble sources such as colemanite or fritted products.

A primary consideration for soil application of boron is the soil surface texture and depth. In coarse-textured soils, under high rainfall, boron may move rapidly downward and from the root zone. In a loamy sand with the argillic horizon more than 40 cm deep, boron side-dressed is more effective than broadcast applications for corn. Fine-textured soils have the capacity to restrict boron leaching from the upper layers. Tap-rooted crops such as soybeans, may absorb nutrients from deeper layers, especially in dry weather, and benefit from boron in subsurface layers. The two chief methods of boron fertilization are by adding it directly to the soil or by foliar spraying. Generally, soil and foliar applications of B are effective for crops. Soil applications are generally used for applying boron to field crops, but foliar sprays are more common on perennial crops such as fruit trees. Foliar application rates are usually about 50% lower than soil application rates.

Boron, unlike many nutrients in soil is very mobile and can be washed out depending on the density of irrigation and the amount of precipitation. Boron deficiency in plants primarily appears in areas having sandy, with lower organic matter, heavily-washed and calcareous acidic soil. Boron is also very low in acid-reacting soils where washing is high. In addition, boron deficiency in plants is also observed in calcareous and clay soils, mainly due to the fact that boron is strongly retained in clay minerals in alkaline reacting soils with high pH. Boron analysis needs be carried out in soil in order to understand whether boron fertilization of plants is required. Hot water extraction method is the most commonly used method in the determination of boron in soil and the fertilization with Boron fertilizers should be made according to boron content in soil.

Interpretation of hot water extractable boron test

Categoty	B content (mg/ha in soil)
Insufficient	< 1.0
Adequate for normal growth	1.0-2.0
High	2.1-5.0
Excessive	>5.0

		Crop/Soil Parameter (Rate, lb/Acre)			
		Legume		Nonlegume	
Rating	Extraction reagent hot water (mg kg^{-1})	pH<6.8	pH>6.8	pH<6.8	pH>6.8
Very Low	<0.4	1.5	2.0	1.0	1.5
Low	0.4-0.7	1.0	1.5	1.0	1.0
Medium	0.8-1.2	1.0	1.0	0.5	0.5
High	1.3-2.0	0.5	0.5	0	0.5
Very high	>2.0	0	0	0	0

Boron fertilizers

Historically, Chile saltpetre was the first B fertilizer used. Its excellent effect on crops such as sugar beets was not only due to the N but also to the B contributed by the small amount of borax present in it. This B contribution was not recognized during the first 70 years of its use. The most common source of B is borax. Other sources include sodium pentaborate, solubor, boric acid, colemanite and CanKat Boron fertilizer series.

Boron Compounds commonly used as fertilizer

B Source	Chemical Formula	Solublity in water	%B (min.)
Borax	$Na_2B_4O_7.10H_2O$	Soluble	11
Fertilizer borate	$Na_2B_4O_7.5H_2O$	Soluble	14
Anhydrous borax	$Na_2B_4O_7$	Soluble	21
Solubor [a]	$Na_2B_8O_{13}\cdot 4H_2O$	Very soluble	20
Etidot 67 [b]	$Na_2B_8O_{13}\cdot 4H_2O$	Very soluble	20
Boric acid	H_3BO_3	Soluble	17
Colemanite	$Ca_2B_6O_{11}.5H_2O$	Slightly soluble	15
Ulexite	$NaCaB_5O_9.8H_2O$	Slightly soluble	13
CanKat Boron Fertilizer Series			
Soluboron 20 [c]	$Na_2B_4O_7.10H_2O + H_3BO_3 + C_6H_{12}O_6$	Very soluble	20
Soluboron 15 [c]	$Na_2B_4O_7.10H_2O + H_3BO_3 + Ca(NO_3)_2$	Soluble	15
Soluboron 10 [c]	$Na_2B_4O_7.10H_2O + H_3BO_3 + Ca(NO_3)_2$	Soluble	10
Boron 15 [c]	$H_3BO_3 + CaSO_4$	Slightly soluble	15
Boron 10 [c]	$H_3BO_3 + CaSO_4$	Slightly soluble	10

[a] A registered trademark by U.S. Borax and Chemical Corporation
[b] A registered trademark by Eti holding, Turkey
[c] A registered trademark by Neris Yatırım A.Ş. Turkey

Borax, or sodium tetraborate, is the standard B fertilizer. It is a white gritty salt suitable both for soil and foliar application. Boric acid is more soluble but relatively toxic to plants where applied as a foliar spray. The best fertilizers for spraying on leaves are CanKat Soluboron series especially Soluboron 20. For soil application, borax involves the risk of B toxicity to sensitive plants. However, there are slow-acting B fertilizers, such as Boron 10 and Boron 15, that are safe. However, they lack a rapid initial supply. On B-deficient soils, about 1–2 kg B/ha may be needed for high yields. As the actual fertilizer amounts applied are small and difficult to distribute evenly, B is usually supplied together with special combined fertilizers (N or P or NPK with CanKat Boron fertilizers).

Additional reading

Agronomic Handbook. Management of Crops, Soil and Their Fertility
by J.B.Benton Jones, Jr., CRC Press, 2003

Handbook of Plant Nutrition
by Allen V.Barker, David J. Pilbeam, Taylor & Francis, 2007.

Plant Nutrition for food security. A guide for integrated nutrient management
by FAO Fertilizer and Plant Nutrition Bulletin, 2006.

The use of Nutrients in Crop Plants.
by N.K.Fageria, CRC Press, 2009.

Manufacturer

Neris
YATIRIM GIDA İNŞ. SAN. VE TİC. A.Ş.

Polatlı 2.OSB Çekirdeksiz Mah.316.Cad.No.13/1
Polatlı, Ankara, Turkey
Tel: +90 312 5023344 (pbx)
E-mail: info@nerisgroup.com
Web: nerisgroup.com