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Boron deficiency in pastures and field crops

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INTRODUCTION

Boron is one of the six micronutrients or trace elements required by plants. It is known as a trace element because it is required in small quantities compared with elements such as phosphorus and sulfur.

Boron deficiency was first recorded in Australia in the 1930s in apple trees growing in Tasmania and New South Wales. Subsequently the deficiency was found in a wide range of pasture and crop plants. Crops with higher boron requirements such as lucerne, sunflowers, rapeseed, cauliflower and apples are most likely to respond to boron. Pine trees, which are commonly used in tree lots and as windbreaks, also have a high requirement for boron.

WHERE AND WHEN BORON DEFICIENCY OCCURS

Soils

In New South Wales, boron deficiency is most likely to affect pastures and crops of the tablelands and southern slopes, particularly where the soils are derived from granite or sandstone rocks.

Boron is more easily leached from the soil than other trace elements. As a result, sandy or free-draining lightly textured soils in high rainfall areas are more likely to be deficient. Soils developed from basalt, alluvial soils or those with a high clay content are less likely to be deficient than soils formed from granite or sandstone rocks. Some shales, especially those formed in ancient oceans, can have above-average boron contents. Furthermore, soils formed from shales are usually of medium to heavier texture, so they tend to hold boron better than light granite or sandstone soils and are therefore less likely to develop boron deficiency. Soils low in organic matter are more prone to boron deficiency because available boron is released from organic matter as it breaks down.

Seasonal conditions

Boron uptake by plants is influenced by moisture conditions in the soil. Symptoms of the deficiency are more likely during periods of low moisture availability. A period of moisture stress in spring that coincides with flowering can induce a deficiency where boron levels are marginal. This is especially so when a dry period follows a wet winter after much of the available boron has been leached from the root zone. Dry conditions are thought to induce boron deficiency by restricting root activity in the dry surface soils where available boron is usually highest.

Where a deficiency is marginal and induced by dry weather, the plants may recover following good steady

Mature leaves of boron-deficient subterranean clover, showing a range of red and yellow coloured patterns that usually develop towards the outer part of the leaflets. Note the death of parts of the margin of the centre leaf. — Photo: B. Dear.

Sunflower is highly sensitive to boron deficiency, which, when severe, causes the flower head to twist over, become distorted and fail to open, producing no seed.— Photo: B. Dear.

rain. However, boron deficiency can also develop during good growing conditions—in periods of high demand caused by rapid growth, flowering or when foliage is removed during haymaking or heavy grazing.

Liming

While liming has many beneficial effects and increases the availability of molybdenum, it reduces the availability of boron and its uptake by plants. Thus liming soils with marginal boron levels can cause crop and pasture plants to become deficient. Plants should be closely examined if yield reductions occur following liming of the soil. The larger the quantity of lime applied, the greater the likelihood of boron deficiency developing.

Crop susceptibility

Some crop and pasture plants more commonly show boron deficiency symptoms than others (Table 1). Susceptible plants include lucerne, sunflowers and rapeseed. Moderately susceptible plants include red clover, white clover and subterranean clover. Other relatively tolerant plants that rarely show deficiency symptoms include barley, oats, wheat, rice and grasses. Grasses are far less sensitive to boron deficiency than clovers and rarely show deficiency symptoms, even when clover plants in the pasture are affected.

WHY BORON IS NEEDED

Boron is closely associated with cell division and development in the growth regions of the plant, that is, near the tips of shoots and roots. It is also needed for the growth of the pollen tube during flower pollination and is therefore important for good seed set and fruit development. Boron is thought to increase nectar production by flowers, and this attracts pollinating insects. Finally, boron has a role in cell structure. Tissue of boron deficient plants often breaks down prematurely, causing brown flecks, necrotic spots, cracking and corky areas in fruit and tubers.

SYMPTOMS OF BORON DEFICIENCY

The symptoms of boron deficiency reflect the several functions boron fulfills in the plant, but symptoms differ greatly among plant species. The symptoms can often be confused with other deficiencies or disorders (such as virus disease, frost or hormone damage) that cause distorted growth. They also vary depending on the severity of the deficiency.

Boron does not easily move around the plant, and therefore a deficiency is most likely to be seen in the younger tissues first. Because of this poor mobility boron must be continuously taken up by plants

Table 1. Sensitivity of some crop and pasture plants to boron deficiency.

	Susceptible	Moderately susceptible	Tolerant
Pasture and field crops	Lucerne Sunflower Rapeseed Turnip Sugarbeet Cotton Pine trees	Clovers –white –red –subterranean –Persian Townsville stylo *(Stylosanthes humulis)* Tobacco Maize Sweet corn	Barley Oats Wheat Rye Rice Grasses Sorghum Soybean Safflower Sugar cane
Some other crops (indicator plants)	Apple Table beet Swede Cauliflower Carrot Celery Carnation	Cabbage Brussels sprouts Strawberry Potato Pear Citrus Bananas	Bean Pea Asparagus Cucumber Onion Blueberry

These symptoms in maize— broken creamy-yellow streaks on the leaves—are not commonly seen in field-grown crops in New South Wales, because maize is far less sensitive to boron deficiency than sunflowers. — Photo: R. Weir.

throughout the growing season, and this is one reason why deficiency symptoms can develop suddenly. Symptoms rarely occur evenly through a crop, but are usually found in isolated patches. Mild deficiency can go unnoticed, but where the deficiency is more severe the effects can produce dramatic symptoms, which may be summarised as follows:

General. Stunted and distorted growth, death of the growing point leading to multiple branching causing 'multiple crowns' (beet), rosetting or umbrella-shaped growth (lucerne).

Roots. The growth of root tips is the first to be affected but this is usually not noticed in early deficiency. Roots are severely stunted. Storage organs develop brown internal areas (brown heart of turnips) or cracks, which may lead to rotting (heart rot of sugar beet).

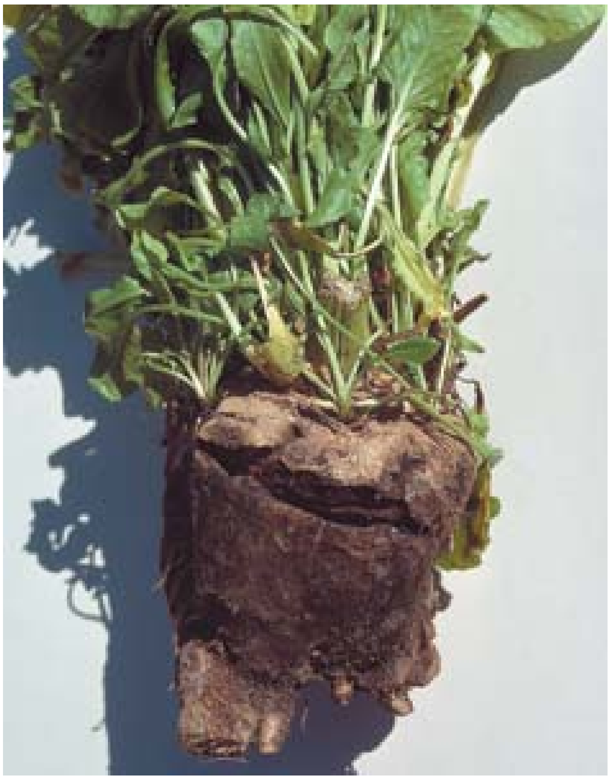
Severe boron deficiency in sunflower, showing its effect on the youngest tissues: death of the growing point surrounded by small, deformed upper leaves. Lower leaves are almost normal in size and shape. Failure of the main growing point has induced secondary shoots, which will also fail. — Photo: R. Weir.

Internal breakdown of tissues (brown heart) and the irregular shape of these turnips was the result of boron deficiency. — Photo: R. Weir.

Leaves. The youngest leaves are the first to show symptoms. Yellow to orange tints (lucerne), red and purple colouration (clover), distorted, thickened or leathery leaves. Corkiness or cracking of the mid-rib (cabbage).

Stems. Shortened, thickened, cracked or showing external corkiness (celery). Internal cavities (cauliflower) leading to breakdown and rotting.

Boron deficiency in sugar beet, showing cracking of the root, which is hollow in its centre, leading to 'heart rot'. The leafy top becomes a proliferation of many small shoots ('multiple crowns') as the main crown fails. Photo: — R. Weir.



Bright reddish-purple, orange and yellow colours develop in the upper leaves of boron deficient lucerne. The top of the shoot fails to lengthen normally. This gives an 'umbrella' shape to the affected shoot. — Photo: R. Weir.

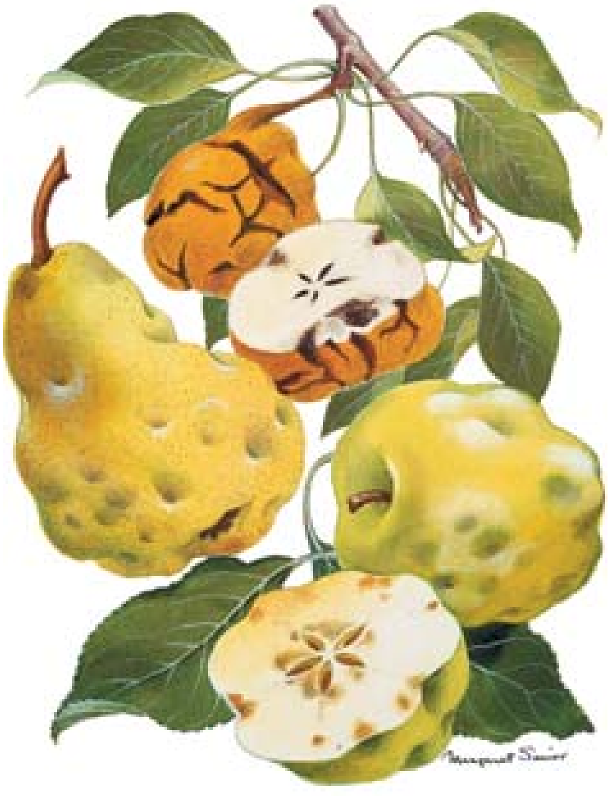
When boron deficiency is milder or comes late in the season, the only symptom of the deficiency to be seen in lucerne (and other crops) may be a failure of the flowers to set seed. — Photo: M. H. Walker.

Flowers and seed. Reduced number of flowers, low pollen production, failure to set seed (clovers, lucerne, rapeseed), barren florets, collapse of flower stem (sunflower).

Fruit. External cracking or corkiness. Mis-shapen fruit. Internal brown, corky or gum areas within fruit.

Symptoms are most noticeable in sensitive crops or pasture species with a higher boron requirement.

Boron deficiency causes characteristic symptoms in apples and pears, consisting of brown corky areas scattered through the flesh. Sometimes the fruit develop irregular depressions or cracks in the skin and flesh and become misshapen. Illustration: Margaret Senior.



Commonly observed deficiency symptoms for some important species are described in Table 2.

RECOGNISING BORON DEFICIENCY IN PASTURES AND MILDLY AFFECTED CROPS

Severe deficiency symptoms are less common in pastures and in some crops than the milder forms of boron deficiency, which are more difficult to detect. The deficiency may merely reduce seed yields. Pastures or crops could therefore be suffering without a problem being recognised. Lower than expected yields might be the only sign that boron is deficient in a crop, while in a pasture, reduced seed production of legumes (white clover, subterranean clover and lucerne) is likely to occur with no other deficiency symptoms. The reason for poor regeneration may not be recognised. Seed producers should also be observant for non-foliar symptoms of boron deficiency—namely low seed yields and fewer flowers per head or seeds per flower.

Detecting a mild boron deficiency is not easy, because it tends to show up during certain seasonal conditions and then temporarily disappear. Furthermore, the roots are the first area to be affected, becoming stunted with little lateral growth. Such effects are not usually noticed until top growth, in turn, is affected.

DIAGNOSING THE NEED FOR BORON

Because plants with only slight boron deficiency may not show obvious symptoms nor marked reductions in herbage production, it may be difficult to know whether there is a need to apply boron.

Indicator plants. If symptoms have been observed in sensitive crops grown on similar soils within the district, the possibility of boron deficiency being important in other species is more likely. Useful indicator plants that are both sensitive to boron deficiency and display characteristic symptoms include sunflowers, cauliflowers and apples (see Tables 1 and 2). However, less sensitive crops may not necessarily respond to boron and not in all seasons.

Test strips. The surest test is to apply a strip of boron across the suspected paddock using a boom spray and watch for any change in the growth, vigour or seed production between the treated and untreated areas.

Soil analysis. This has not proven to be a reliable method for routinely detecting boron deficiency, although it will indicate the general boron level of the soil.

Leaf analysis. This will give a guide to a plant's boron status. Samples should be taken from the youngest recently matured leaves, which are the most likely to be deficient. Typical boron levels in leaf tissue are shown in Table 3. These values should be used as a guide only. When boron leaf contents approach those indicated for deficient plants, other factors such as moisture stress can determine whether or not a deficiency is observed. When boron levels are marginal, a precautionary dressing is probably warranted for sensitive crops or for crops grown for seed production in areas subject to boron deficiency.

CORRECTING A DEFICIENCY

Boron may be applied to the soil as a straight boron material such as borax, or it may be purchased mixed

Table 2. Boron deficiency symptoms for some important species.

Plant	Mild deficiency	Severe deficiency
Lucerne	Flowers form but seed set reduced. Young leaves at top of plant develop a yellow-orange colour, at first on the underside and near the edge, but then over the whole leaf.	Flowers fail to develop or fall prematurely. Upper leaves bright yellow-red. Stems shortened. Growing point becomes dormant, numerous side branches give plant an umbrella-shape. Most obvious during periods of moisture stress.
Sub clover	Reduced seed set. Small seed size. Leaves usually normal.	Seed set greatly restricted. Older leaves develop bright red colouration long outer margin Light brown dead patches may form within this red tissue. Younger leaves pale, stunted and distorted with short petioles.
White clover	Young leaves slow to open. Mature leaves turn yellow-red on margin and underneath.	Young leaves narrow at tip. Short stems, mass of stunted shoots. Older sleaves turn yellow then red.
Persian and Balansa clovers	Similar to lucerne.	
Sunflower	Plants may grow normally until flower buds begin to develop. Young leaves are affected, remain small and become mottled silvery yellow, first near their base, then curl downward, becoming crinkled, distorted and hardened. Flower stalk brittle, heads snap off easily or bend over. Seed set is uneven or segments of head may produce no seeds at all.	Dead areas develop at base of upper leaves, while lower leaves are normal. Growing point may die and multiple heads form. Shortened inter-nodes at top of plant give a compressed appearance with thickening of upper stem. Flower head may not form at all or dead tissue develops at its basis as scaly patch, causing twisting, collapse and death of flower head.
Rapeseed	Seed yield is reduced before stunting or leaf symptoms become obvious. Decreased flower numbers. Pod abortion.	Seed yield greatly reduced, stunting of plants. Brown areas in pith of stem. Leaves yellow-orange and may be deformed with cracking and bending of leaf stalk.
Pine trees	Short yellow needles at tip of leading shoot.	Orange-red colouration of needles. Severe dieback during periods of moisture stress. Development of multiple leaders.

Yellowing of leaves with some orange colours developing in boron-deficient rape plants. Reduced flowering with very little seed formation usually occurs before leaf colouration is seen. —Photo: B. Dear.

with a fertiliser. Alternatively it can be dissolved in water and sprayed on to the crop or the soil. It can also be fed into the irrigation water.

Boron mixed with fertilisers

Uniform spreading of the very small quantity of boron needed can be a problem. Boron compounds can be mixed with most fertilisers to facilitate spreading. A granulated boron material will be blended in appropriate proportions by fertiliser companies on request. The boron particle size used for mixtures with fertilisers should be similar to that of the fertiliser particles to avoid settling in the bag.

Seed pod abortion due to boron deficiency in rapeseed. This could have been avoided if foliar sprays had been applied before flowering. — Photo: B. Dear.

Red leaf colour in boron-deficient Persian clover plants. —Photo: B. Dear.

Where the boron added to a fertilizer is in a large granular form, such as illexite, it may be difficult to achieve an even distribution. In such cases application of lower rates over several years may be necessary to achieve an even spread, taking care not to exceed the recommended total application rate of boron.

Orders should be placed well in advance of requirements.

Boron sprayed on the soil

Applying boron by boom spray to the soil is a convenient way of achieving an even spread. Higher concentrations (up to 2.5% w/v) can be used than are safe for foliage application. Suggested rates of application are given in Table 4. Boron can be spread in some herbicide solutions provided they are compatible.

Foliar application

Cauliflower is a very good indicator of boron deficiency in an area. It is sensitive to this deficiency and also shows distinctive symptoms, including hollow cavities in the stem and often bronzing of the curd. — Photo: R. Weir.

Table 3. Typical boron contents of young leaves (ppm B)

Crop or pasture species	Deficient plants	Normal plants
Lucerne	< 17-20	30-80
Red clover	< 15-18	20-40
White clover	< 13-16	15-40
Subterranean clover	< 15-18	22-40
Sunflower	< 15-20	35-200
Turnip	< 15	40-120
Wheat	< 5	5-20
Pine trees	< 10	12-20

When the deficiency occurs during a critical stage such as flowering, foliar sprays will give immediate correction. Applying boron as a spray is convenient and efficient. It offers a quick method of getting boron into a growing crop at a critical stage of its growth or when deficiency symptoms develop after the crop is planted. In rapidly growing crops, more than one spray may be needed during the growing season because of boron's poor ability to move into new tissues as they grow.

Spraying is also appropriate for a seed crop if a problem of seed setting due to boron deficiency is anticipated. Split foliar applications not exceeding 0.5 kg of boron per hectare can be applied at strategic times, such as just before flowering (Table 4). The concentration of boron in sprays applied to the plant must be kept at a level that will not injure leaves, flowers or other tissues. For example, the concentration of Solubor® should not usually exceed 0.2-0.5% w/ v (Table 4).

The strategy for field crops is, then, to apply boron to the soil at or before sowing if a deficiency is expected, but to use foliar sprays for emergency correction if an unexpected deficiency develops during growth.

Irrigation

Boron can be applied dissolved in irrigation water. This enables split applications, which provide a regular supply throughout the growing season. This is particularly suited to sandy soils where boron is quickly leached.

Seed dressings

The application of boron to seed before sowing has not proved to be effective, and in the case of inoculated legume seed it could be detrimental.

Products available

For boron products available see Table 5. Solubor is very soluble and the most convenient form for foliar sprays. Borax or boric acid can also be used for sprays if well agitated during solution; this is further aided by using warm water.

Table 4. Suggested rates of boron application.

Crop	Boron (B) kg/ha	Soil application borax[1] kg/ha	Foliar application Solubor®	
			kg/ha	Maximum concentration % w/v
Lucerne	1-3	10-30	5-10	0.5
Clover	1-1.5	10-15	5-10	0.5
Sunflower	1-3[2]	10-25	5-15	0.25
Rapeseed	1-2	10-20	5-12	1.6[3]
Linseed	0.5-1	5-10	2-5	0.25
Cotton	0.5-1	5-15	2-10	0.5
Turnip	1-3	10-25	5-10	0.5
Sugar beet	1-3	10-25	5-15	2.5[3]
Maize (and sweet corn)	0.5-1	5-10	2.5	0.5
Pine trees	1-5	10-40	5-25	2.5[3]

®Registered trade name

1 If using Solubor® for soil application halve rates given for borax.

2 Use the lower rate if applying borated fertiliser in a band.

3 These maximum concentrations apply to low volume sprays only. Concentrations for high volume sprays should not exceed 0.25-0.5%w/v

Table 5. Boron products available

Product	Boron content %B	Amount required (kg) to supply 1kg Boron	Comments
Mixed with fertilisers*	0.8-8.0	Variable	Blended granular products
Boric acid	17.5	5.7	Granular or powder
Borax	11.3	8.8	Granular or powder
Solubor®	20.5	4.9	Very soluble powder

® Registered trade name
* Boron may be purchased mixed with fertilisers such as superphosphate, on request. Orders should be placed at least 8 weeks before needed.

Residual effects

Foliar sprays have no long-term effect, and usually need to be repeated for each crop, sometimes several times during the season. Soil applications at the rates given in Table 4 usually will not need to be repeated annually and may last from 2 to 5 years, but no firm rules can be given. Sandy and free-draining soils, or those with a very low clay and organic matter content, are likely to require more frequent applications. Care is necessary, however, as excessive use of boron can be very damaging.

BORON TOXICITY

Boron is only required in small amounts and the range between deficiency and toxicity for this trace element is very narrow.

Exceeding the recommended application rate or applying boron too frequently can result in toxic concentrations of boron in soils and plants. Levels of boron in plant tissue should be monitored to determine the effectiveness of boron application strategies and the change in soil boron availablity.

Boron toxicity is usually seen as a yellowing or burning of the leaf margins. Some soils, such as those derived from marine sediment rocks, have high levels of boron, but naturally occuring boron toxic soils are not common in New South Wales. Sometimes irrigation water can have a high enough boron content to cause toxicity. This occurs primarily in inland areas, particularly where bore water is used for irrigation, but sometimes water from creeks, billabongs and rivers in these areas may also cause toxicity to irrigated crops. Rising water tables as a result of irrigation can also cause boron levels to increase in the surface soils and cause toxicity. Plants with a low requirement for boron, such as barley, wheat or beans, are more likely to show toxicity symptoms than plants with a high requirement.

Boron-deficient pine trees, stunted and round in shape due to successive die-back of growing points. Dead terminal shoots develop a bright orange-red colour. Trees in the background show forking from the main stem, another effect of death of the apical shoot.—Photo: M. Lambert.

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