Technical Note TN671

SRUC

March 2017 • Elec

Management of boron in soils for crops

Summary

- Soils have been mapped as having a “high”, “moderate” or “low” predicted risk for boron (B) deficiency in crops.
- Light sandy soils contain less adsorbed B than heavier textured soils, but the sea is the main source for B in coastal areas.
- Visual assessment, soil extraction and plant tissue tests for diagnosis of B deficiency in crops are described.
- SAC Consultancy interpretative scales for extractable soil B concentrations in topsoil are tabulated.
- Soil and foliar B treatment options are described.

1. Introduction

Boron (B) is of interest in crop production because of potentially adverse effects arising both from deficiency and toxicity. Boron deficiency during early growth adversely affects germination and seedling growth. Boron is required for nodulation and N-fixation in legumes. Boron availability varies seasonally; availability is lower in a dry summer following a cool, wet spring. Boron is also toxic to some plants at levels only a little above those required for optimum growth. Thus care must be taken to ensure that excessive amounts of B applied to correct potential deficiency in one crop do not present a potential toxicity risk to a following crop, particularly where this may be cereals or potatoes.

Soil texture and geological parent material can be used to aid prediction of deficiency of B in crops. Maps of low, moderate or high risk of B deficiency are included in this note. Soils at risk of B deficiency can also be tested in order to establish the actual status in individual fields. The status in individual fields may have been altered my lime and fertiliser application or amendment by bulky organic fertilisers.

2. Predicted risk of B deficiency

Boron availability in soils is affected by several factors including texture, pH, organic matter content, nature of clay minerals, and soil parent material; and environmental conditions like moderate to heavy rainfall and dry weather. Knowledge of these factors affecting B uptake is essential for the assessment of B deficiency and toxicity under different conditions.

Boron adsorbed on clay particles is probably the main source for plant uptake and the amount will vary with the clay content of the soil. Light sandy soils contain less adsorbed B and are more readily leached than from heavier textured soils. Boron availability decreases as soil pH increases. There is evidence of a strong association between B and soil organic matter, with B availability reducing with increasing organic matter.

Parent material is considered a dominant factor affecting supply of B from the soil. Soils derived from igneous rocks have much lower B concentrations than soils derived from marine sedimentary rocks. High B concentrations are usually found in the soils that have been formed from marine shale enriched parent material. Soils derived from acid granite and other igneous rocks, fresh-water sedimentary deposits, and in coarse textured soils low in organic matter have low B concentrations. Soils derived from sandstone, slate or crystalline limestones have low B concentrations. Boron bioavailability is also reduced in soils derived from volcanic ash and in soils rich in iron and aluminum hydroxides. Soils along the sea shore as well as those derived from mudstone are usually B enriched.

Boron is carried by the wind and supplied to land areas near the coast. The deposition diminishes with the distance from the sea and it is greater in the summertime than in the winter. During stormy years the coastal areas receive several hundred grams per hectare. The concentration of B in seaweed is relatively high and soils which have received applications of seaweed often have high soil B status.

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The distribution of the predicted risk of B deficiency is mapped in Figure 1. Soils are not mapped from Land Capability for Agriculture Classes 6 and 7 where agriculture is unsuited to improvement by mechanical means (http://sifss.hutton.ac.uk/SSKIB_Stats.php). The mapped area is c41000 km^2 which is about 52% of the total area of Scotland." SAC Consultancy area office boundaries are mapped as an overlay in Figure 1.

Soil associations are listed in Table 1 in order of the most common association mapping units for each risk level, along with the area that they cover (as % of the mapped soils area). Some associations can appear in more than one risk class. While the texture of soils is heavily influenced by parent material and, as soil associations are based on parent material, it follows that associations may be broadly similar in texture, but local variability in terms of drainage, land form or other soil forming factors may lead to differences. For example, while the majority of Ettrick association soils are sandy loams of moderate risk of B deficiency, areas of low risk, heavier textured clay loams exist, particularly around Galashiels and Lockerbie; and upland areas may contain areas of peat where B is bound strongly to the organic matter, and thus are at a high risk of deficiency.

High risk soils include drifts derived from acid schists, granulites and granitic rocks (e.g. Arkaig and Countesswells); and fluvioglacial sands and gravels (e.g. Corby); and organic soils.

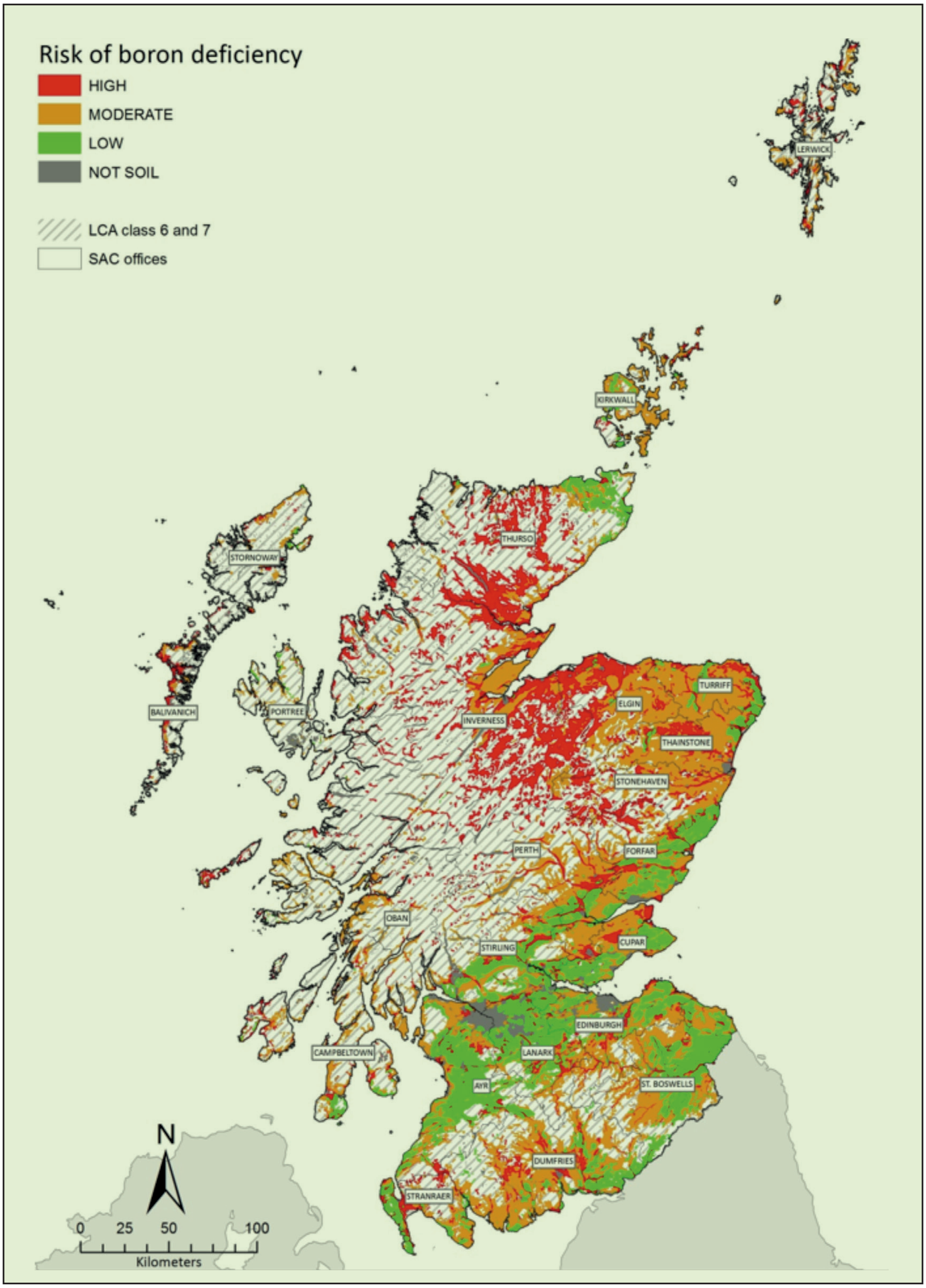

Figure 1. The risk of boron deficiency in crops (high, moderate and low) by soil association in land with the potential to grow crops.

Table 1. Soil associations with high, moderate or low risk of B deficiency and areas (%) in mapped soils with the potential to grow crops.

High risk	% area	Moderate risk	% area	Low risk	% area
Arkaig	7.77%	Ettrick	9.64%	Rowanhill	5.05%
Corby	5.32%	Strichen	4.58%	Balrownie	3.08%
Alluvial soils	3.13%	Foudland	3.66%	Thurso	1.31%
Organic soils	3.05%	Countesswells	3.18%	Ettrick	1.27%
Countesswells	1.67%	Tarves	2.75%	Sorn	1.17%
Yarrow	1.19%	Darleith	2.66%	Hobkirk	1.10%
Ettrick	0.71%	Sourhope	2.05%	Stirling	0.96%
Insch	0.67%	Thurso	1.21%	Kilmarnock	0.87%
Torridon	0.60%	Rowanhill	1.19%	Whitsome	0.85%
Lochinver	0.53%	Forfar	0.98%	Darleith	0.77%
Fraserburgh	0.49%	Darvel	0.96%	Rhins	0.70%
Strichen	0.44%	Gourdie	0.89%	Canonbie	0.53%
Nigg	0.43%	Kintyre	0.87%	Glenalmond	0.48%
Dulsie	0.39%	Canisby	0.79%	Stonehaven	0.47%
Links	0.39%	Arkaig	0.74%	Lauder	0.41%

The Soil Information for Scottish Soils (SIFSS) website (http://sifss.hutton.ac.uk/SSKIB_Stats.php) enables the user to select a soil 'map unit' by zooming in on a particular area e.g. a field. This can be done by specifying a postcode, grid reference, or simply by zooming in using the interactive map. The user can then select a soil association within this map unit.

3. Diagnostic methods

3.1 Visual assessment.

Symptoms in the growing crop provide a valuable, but not infallible guide to B deficiency. Some root crops, especially turnips, swedes, carrots, fodder beet and beetroot are particularly prone to B deficiency, especially where soil pH values are high, and/or on light sandy soils. Boron availability varies seasonally; deficiency is observed more frequently in a dry summer following a cool, wet spring, especially if growing conditions improve rapidly after a dry period. Cauliflowers and other brassicas can also be affected, although care must be taken to determine the true cause of symptoms, which can be caused by other factors such as bacterial disease, or uneven water supply. The susceptibility of oilseed rape to B deficiency is less clear. Annual atmospheric (total wet and dry) deposition may typically range from 50 to 250 g/ha B with the highest in coastal sites. These amounts from atmospheric deposition are generally greater than the estimated oilseed rape crop offtakes for B of 60 to 80g per tonne.

Boron deficiency in turnips and swedes is generally known as raan in Scotland and brown heart in England but there are often no external signs of B deficiency. Brown water-soaked areas are found at irregular intervals usually more pronounced in the lower half of the root and extend upwards beyond the shoulder to the neck only in severe cases (Figure 2). In severe cases the central tissue may break down and the root becomes hollow. The roots are tough, fibrous and bitter and their feeding value is impaired. Severely affected roots may be distorted and have a rough, corky and leathery skin. The leaves and growing point do not seem to be affected, although in turnips the development of yellow and purple areas on the leaves may be associated with B deficiency.

Boron deficiency in carrots causes a superficial pinhead sized discolouration just under the skin; the greyish irregularly shaped areas are seen after steam peeling of the carrots and are usually removed by normal domestic peeling. Severely affected tap roots may split and are often brittle.

Boron deficiency in fodder beet causes the death of the growing point and the development of a black heart rot. The crown may become hollow and rot. The stem of cauliflower is frequently hollow and discoloured internally (Figure 3). If the plant is in bud the individual buds turn brown giving a discoloured curd which is unsuitable for marketing.

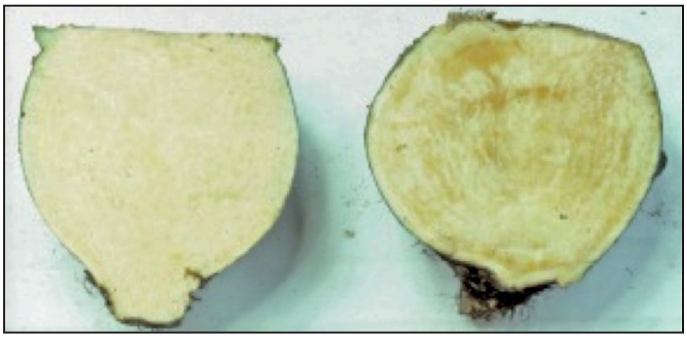

Figure 2. Symptoms of B deficiency in turnips/swedes.

Figure 3. Symptoms of B deficiency in cauliflower.

Oilseed rape leaves are usually paler in colour with reddish discolouration of the youngest leaves. The edges of young leaves are unrolled and as B deficiency accelerates new leaves are deformed. A "raan" like symptom is often seen in the root just below ground level, but this browning does not necessarily indicate B deficiency. It is thought that slight browning relates to low spring soil temperatures which produce poor root growth which may aggravate the possibility for phosphorus deficiency in soils with a low P status.

Leaf symptoms of B toxicity in barley are characterized by interveinal chlorotic and/or necrotic patches, generally at the margins and tips of older leaves. The most likely case of B toxicity in barley is following placement of a B-containing turnip fertiliser at sowing. Early leaf growth is chlorotic along the entire plant row. The effect is normally transient and leads to no yield penalty (Figure 4). Boron toxicity may occur after a dry winter following B fertilising of the previous crop, but in practice this does not appear to happen in Scottish conditions.

Figure 4. Boron toxicity in barley (right side).

3.2 Soil extraction.
Boron is extracted from air-dry soil by boiling with distilled water under reflux for 10 minutes using a soil: water ratio of 1:2 (w/v). Interpretative scales for extractable B concentrations in soil are shown in Table 2 for mineral soils with up to about 15% organic matter. Where soils contain more than 15% organic matter critical values should be adjusted for the density of the soil, or plant B content determined in addition to soil B.

In field experiments B availability and yield responses to B fertilisation can be influenced by additional site specific factors which soil analysis does not take into account (HGCA Research Review No.78, 2013). For some responsive crops e.g. swedes and turnips, soil tests are ignored and B fertiliser use is standard practice.

Boron concentrations at which deficiency symptoms could appear can vary with soil texture. On heavy clay soils, deficiency is probable at less than 0.8 mg/kg B, on medium texture soils at less than 0.5 mg/kg B and on light sandy soils at less than 0.3 mg/kg B.

3.3 Plant tissue tests.
Critical B limits cannot be easily determined due to the uneven accumulation of B in plant tissues, variation in B uptake at different growth stages and the leaching of B from plant tissue during rainfall. It is generally perceived that plant analyses cannot be carried out in isolation, but in conjunction with soil analyses as an aid to diagnose B problems.
Plant analysis should be carried out early in the growing season when plants are young to allow sufficient time for correction of any arising deficiencies. However, application of ammonium nitrate fertiliser in February/March to winter oilseed rape has an acidifying effect on the soil which makes B more available for the subsequent rapid growth. Carrying out analyses on whole plant samples is not recommended since deficiencies which could be determined from analysis of young tissues can be masked by the incorporation of older tissues. Samples for tissue analysis need to be taken from growing, immature leaves. Analysis of both affected (i.e. showing apparent deficiency symptoms) and, for comparison, unaffected plant samples is often helpful for interpreting the results.

4. Historical advisory extractable B levels in topsoil

SAC Consultancy advisory B data for 3,666 samples from 1996 to 2015 are summarised in Table 3 into B status. The proportion of all samples measured as potentially deficient (VL or L status) was 18.2%. A higher proportion of soils of 28.4% are mapped at high risk of B deficiency in Figure 1. The frequency of B soil analysis prior to vegetables reflects the general susceptibility of brassicas and swedes to B deficiency. Extractable concentrations of B were generally higher after fodder crops and vegetables which reflect B recommendations and retention of available B in the soil. The distribution of B status is shown in Figure 5 for the SAC Consultancy office areas with at least 30 soil samples.

Table 3. Summary of advisory data for B (% of the total number of samples).

	Very low (VL)	Low (L)	Moderate (M)	High (H)	Very high (VH)
Boron (%)	2.3	15.9	64.5	17.2	0.3

Table 2. SAC Consultancy interpretative scales for extractable B concentrations (mg/kg) in mineral soils with up to about 15% organic matter.

	Very low	Low	Moderate	High	Very high
	Deficiency probable	Deficiency possible	No deficiency expected	No risk of deficiency	Crop toxicity may occur
B (mg/kg)	<0.3	0.3 - 0.5	>0.50 – 1.0	>1.0 – 3.5	>3.5

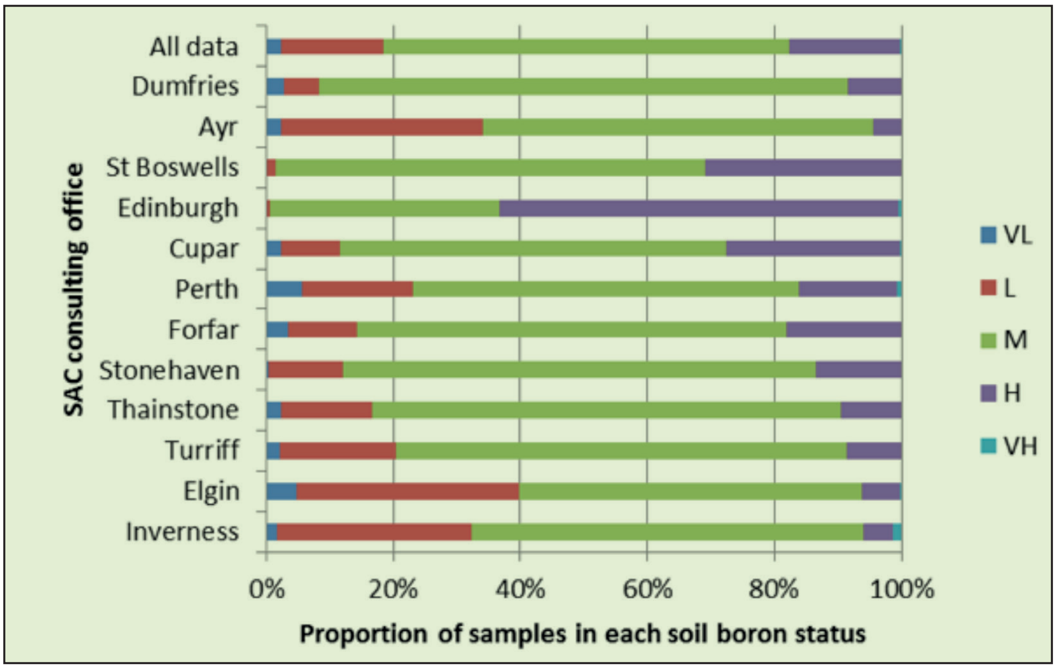

Figure 5. A breakdown of advisory soil data for boron status by SAC Consultancy office and full data set from 1996-2015.

5. Treatments

Boron can be applied either to the soil or to the foliage, together with a fertiliser or alone, as a solid or a solution. The final choice as to the method used for preventing or correcting a B deficiency may be decided as much by considerations of convenience as of crop physiology. Where soil analysis indicates a deficiency, or where susceptible crops are grown, the recommendation is to apply B to the seedbed (2 kg/ha B); or as a foliar spray according to manufacturers recommendations as soon as leaf cover allows. For some responsive crops e.g. swedes and turnips, soil tests are ignored and B fertiliser use is standard practice, often added to the NPK fertiliser.

Boron fertilisers include Borax (11.3% B); Solubor (20.5% B); and sodium-calcium borate (9.3%), a slow-release, granular B source that may be applied directly or in combination with other nutrients. Blended NPK fertilisers typically contain 0.4% B for growing turnips, swedes and brassicas. Liquid fertiliser is available that contains 0.225% w/v of B for soil application; and for foliar application containing 150 g/l of B soluble in water. Suppliers should be consulted for the latest information on application rates and compatibility with spray-applied agricultural chemicals.

Boron compounds used for treating B deficiency in plants are given in Table 4 along with chemical formula and B content.

Boron analysis of livestock manures is rarely undertaken, but seaweed and some bulky organic fertilisers are known to be significant sources of B including composts, biosolids and ash from the combustion of biomass plants. Dried ground seaweed may contain 60 to 80 g/t B which is comparable to a 4 t/ha oilseed rape crop removing approximately 80 g/ha B and more than 200 g/ha B deposited in coastal areas.

Evidence for statistically significant oilseed rape yield responses to applied B is limited and no correlation was found between yield response and soil or tissue B status. Deficiencies in wheat, barley or oats have not been detected in the UK (HGCA Research Review No.78, 2013).

Table 4. Boron compounds used for treating B deficiency in plants.

Compound	Formula	Boron content (%)
Boric acid	H_3BO_3	17.5
Disodium tetraborate decahydrate (Borax)	$Na_2B_4O_7.10H_2O$	11.3
Disodium tetraborate pentahydrate (Borax, Granubor II)	$Na_2B_4O_7.5H_2O$	14.8
Anhydrous sodium tetraborate	$Na_2B_4O_7$	21.5
Sodium pentaborate	$Na_2B_{10}O_{16.}10H_2O$	18.3
Solubor	$Na_2B_8O_{13.}4H_2O$	20.9
Sodium-calcium pentaborate octahydrate	$Na_2O.2CaO.5B_2O_{3.}16H_2O$	9.3

Authors:

Alex Sinclair SAC Consulting Solutions, Ferguson Building, Craibstone Estate, Aberdeen AB21 9YA, tel. 07776486966.
Tony Edwards SRUC, Ferguson Building, Craibstone Estate, Aberdeen, AB21 9YA
Malcolm Coull The James Hutton Institute, Craigiebuckler, Aberdeen, AB15 8QH.

Funded by the Scottish Government as part of its Farm Advisory Service.