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Boron levels in soils of the Western Australian wheatbelt and implications for crop production

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Abstract

Boron (B) is removed from soils when crop products are harvested. However, B has never been used as a fertiliser in broadacre agriculture in WA. A GRDC-funded project was started in 1998 to consider the sustainability of this mining of soil B. The project aims are to (1) map the spatial distribution of B deficiency in canola and lupin; (2) investigate the role of B in soil and plants for grain yield of canola and lupin, and; (3) develop management options for B to take account of soil properties and crop requirements. The present paper reports preliminary results that begin to define the extent of low B soils in the WA wheatbelt and its likely implications for crop production. Young leaves of canola and lupin crops were sampled at 136 sites in the wheatbelt during vegetative growth in 1998. Potentially B deficient crops representing 10-20\% of sites were widely distributed throughout the wheatbelt. In 73 Reference Soils of south-west Australia, extractable soil B was positively correlated with soil pH and clay content. A preliminary study of the response of farmers’ canola crops to a B spray was conducted at 7 sites with sandy to sandy loam texture in the Great Southern Region of WA in 1998. For all sites, a mean increase of 14\% in seed yield was found from the B spray application at flowering. Preliminary pot trial results suggest that responses to B in canola and lupins will occur on a number of low B soils. Our results tend to confirm that the risk of B deficiency warrants further consideration. The key questions now are: where is it most likely to occur, under what crops is it most likely, what seasonal factors bring on B deficiency and what are the management options for dealing with the problem?

Key words
Boron, sandy soils, acid soils, soil analysis, seed set, pod symptoms

Introduction

Boron (B) is removed from soils when crop products are harvested, yet little B is used as a fertiliser in the WA wheatbelt. The continued removal of B from soils by harvesting crops is putting further pressure on soil B reserves. As both the area under non-cereals, and the crop yield increase, the risk of B deficiency becomes more important in WA due to the higher B demands for crop production.
The implications of low and declining reserves of soil B are important as B is essential for flower development, seed set and seed quality. Since assimilated B is not mobile in plants, requirements for reproductive growth must be met by current uptake. The WA Mediterranean climate (wet winters, dry summers) may amplify the problem by releasing B in autumn and exposing it to the risk of loss by leaching prior to flowering in spring. In wet years, excessive vegetative growth early in the season will absorb the remaining B, making it unavailable for pod and seed set. When flowering occurs during periods of extended rainfall and high humidity, B uptake is depressed and this can account for poor pod and seed set (Bell, 1999). By contrast in dry years, low soil water inhibits B uptake. These soil and climatic factors result in seasonal and regional risks of B deficiency, especially for crops with higher B requirements.

Boron is required in higher amounts for reproductive development than for vegetative growth of plants (Dell and Huang 1997). Deficiency of B at critical stages of reproductive development can restrict fertilisation, or cause pod abortion or poor seed set or seed growth. In addition B absorbed by leaves and stems is largely unavailable for re-use to support growth of flowers, pods and seed later in the season.

Soil and tissue analysis tests and glasshouse experiments already show cases of B deficiency in WA (Bell 1999; Bell et al. 1989; Bell and Webb 1995; Salardini and Robson, unpublished data; Wong unpublished data). Until recently, little interest has been shown in exploring the implications of this in crop production in the WA wheatbelt. In 1998, the GRDC agreed to fund a 3 year investigation jointly by the authors on Meeting the Boron Requirements of Legumes and Canola in WA. The aims of this project are (1) to map the spatial distribution of B deficiency in canola and lupin by systematic soil and crop surveys and by B foliar addition (2) to confirm the deficiency; investigate the role of B in soil and plants for germination, pod set, and grain yield of canola and lupin, and; (3) develop management options for B to take account of soil properties and crop requirements. The present paper reports on preliminary results which begin to define the extent of low B soils in the WA wheatbelt and its likely implications for crop production.

Methods

Young leaves of farmers' canola and lupin crops and soil (0-10;10-30 cm) were sampled for B analysis at 136 sites in the wheatbelt, predominantly on sandy soils in 1998. For canola, plants at vegetative growth stage were selected (Growth stages 1,10 to 2,03, after Sylvester-Makepeace 1984). Youngest open leaf (YOL) and youngest mature leaf (YML) samples were collected for this survey. The YOL was normally the 2nd leaf visible from the apex, and was the first leaf with a fully unrolled leaf blade. The YML was normally the second leaf below the YOL. Its maturity is evident from the darker green colour, and the thickening of the midrib and main veins compared to younger leaves. Petioles were excluded from the samples. For lupin, youngest open leaf (YOL) and youngest mature leaf (YML) were collected from plants at pre-flowering stage. Petioles were excluded from the samples. Plant and soil samples in each field were collected from areas where the plants were green and healthy and from areas where the plants were sparse, small and/or pale in colour.
Plant samples were rinsed for 15 -30 sec with gentle agitation in double deionized (DDI) water and stored on ice. Plant samples were dried at 70 °C. The dried plant samples were finely milled and digested in concentrated nitric acid at 130 °C for B determination by inductively coupled plasma atomic emission spectrophotometry (ICP-AES) (Zarcinas et al., 1987).

Seven sites having sandy to sandy loam soil texture were selected for a preliminary study of the effect of foliar B application on canola seed yield. Sites in the Great Southern Region were as follows: Albany (2); Katanning (2); Narrogin; Williams (2). Boron as B-PC (?) (5% B) was used for foliar spraying. Forty mL of B-PC was mixed in 10 litres of water and sprayed by hand to a 100 m² area (10 x 10 m) at flowering stage of canola (growth stages 4,5 to 4,8 after Sylvester-Bradley and Makepeace 1984). The rate of application was 1000 litres/ha or 4 litres of B-PC/ha, supplying 0.2 kg B/ha. From the 100 m² sprayed area, plant samples were collected at maturity in four replicate quadrats of 1 m² each. Four replications of 1 m² each were also collected from adjacent non-sprayed areas as controls. Two replications were selected from areas of good growth and two from areas of poorer growth in both sprayed and control treatments. Seed yield and 1000 seed weight were recorded (Table 1).

Surface horizons of 73 Reference Soils of SW Australia were analysed for hot CaCl₂ extractable B, and these values were correlated with soil properties (pH, clay, sand) reported for these soils by McArthur (1991).

Results and discussion

Boron concentrations in young leaves below 20 mg B/kg in canola were considered to be potentially B deficient for seed yield (Wei et al. 1998). Boron concentrations in lupin were consistently about 4 mg B/kg lower than in canola on adjacent sites. Tentatively, 16 mg B/kg in lupin was used to identify potentially deficient crops. Potentially boron deficient crops were widely distributed in the wheatbelt at the following locations, mostly on sites selected for sandy surface textures: Geraldton, Badgingarra (2 sites), Carnamah, Mingenew (2 sites), Moora (2 sites), Wannamal, Williams, Corrigin, Dumbleyung (2 sites), Lake Grace (2 sites), and Esperance (2 sites). Levels of B in young leaves of canola and lupin crops in 1998 and in soil samples suggested that 10-20 % of sites were potentially B deficient (Fig. 1). These sites were widely distributed throughout the wheatbelt. On these same sites, 18 out of 68 had soil B levels in the 0-30 cm layer < 0.5 mg/kg, the tentative critical level for canola (Bell, 1999).

In 1998, a preliminary study in the Great Southern Region of WA of the response of canola crops to boron (B) spraying was conducted at 7 sites identified in the above survey with sandy to sandy loam texture. At 2 sites, an increase in seed yield by 33-50 % was obtained from a B spray application at early flowering. At all sites, an average increase of 14 % was found (Table 1). In addition, seed size was increased from 2.8 to 3.3 g/1000 seed at the Narrogin site.

In Reference Soils of southwest Australia, extractable soil B was positively correlated with clay content (Fig. 2) and pH (Fig. 3), negatively with sand content but not with organic matter levels. Low boron soils (< 0.5 mg B/kg soil - Bell 1997, 1999) were generally acid (pH CaCl₂ < 5.5) and contained < 10 % clay in the A1 horizon.
Figure 1. Frequency distribution of leaf B concentrations in canola and lupin in farmers’ crops in 1998. Values from 136 sites, sampled during vegetative growth.

Figure 2. Relationship between extractable B and pH (CaCl₂) in 73 Reference Soils from the WA wheatbelt. Soils sampled from the A1 horizon. pH values taken from McArthur (1991).

Table 1. Effect of boron (B) spray (supplying 0.2 kg B/ha) at flowering stage on canola seed yield (total seed weight in g/m²) at 7 sites in the Great Southern Region, 1998. Values are means of four replicates.

<table>
<thead>
<tr>
<th>Sites</th>
<th>Unsprayed</th>
<th>B Spray</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albany 1</td>
<td>179a</td>
<td>194a</td>
<td>ns</td>
</tr>
<tr>
<td>Albany 2</td>
<td>144ab</td>
<td>158ab</td>
<td>ns</td>
</tr>
<tr>
<td>Katanning 1</td>
<td>106b</td>
<td>117c</td>
<td>**</td>
</tr>
<tr>
<td>Katanning 3</td>
<td>107b</td>
<td>159ab</td>
<td>**</td>
</tr>
<tr>
<td>Narrogin 1</td>
<td>113b</td>
<td>150bc</td>
<td>*</td>
</tr>
<tr>
<td>Williams 1</td>
<td>132b</td>
<td>117c</td>
<td>ns</td>
</tr>
<tr>
<td>Williams 2</td>
<td>146ab</td>
<td>165ab</td>
<td>ns</td>
</tr>
<tr>
<td>Mean</td>
<td>132</td>
<td>151</td>
<td>**</td>
</tr>
</tbody>
</table>

* = Significant at $p \leq 0.05$; ** = Significant at $p < 0.01$; ns = not significant

Means in a column followed by a common letter were not significantly different at $p \leq 0.05$.

In a recent pot experiment, B fertiliser increased growth and seed set in canola on four low B soils from the northern sandplains (unpublished data). These soils are acid sandy soils and were formed on sandstone rather than granitic parent rocks. In lupins, B increased pod set only on the MRA 5 soil from east of Dandaragan (McArthur 1991). However, on all 8 soils, pods developed symptoms late in their maturation when grown without B. Symptoms included: exudation of sticky droplets on the pod wall, blotchy patches on pod walls which
later developed into discoloured lesions. In extreme cases, leaves remained green or resumed growth due to impaired pod and seed development.

Our results tend to confirm that the risk of B deficiency warrants further consideration and the key questions are: where is it most likely to occur, under what crops is it most likely and what seasonal factors bring on B deficiency? Preliminary results suggest that the acid sandy soils developed on sandstones on the Dandaragan plateau warrant more detailed investigation.

It is still too early to give definite advice about B for WA agriculture. However, for the time being farmers could look out for symptoms especially on sensitive crops (canola, lupin, lucerne, chickpea) or use soil and plant tests for a more positive diagnosis (Bell 1997, 1999).

Acknowledgments

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References