

Boron toxicity and bud development in apple trees

Overmål af bor og knopudvikling hos æbletræer

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Summary

Nutrient solutions with different concentrations of boron and magnesium were applied to young apple trees, cv. 'Cox's Orange Pippin', grown in pots with sand and peralite. Trees without boron supply contained around 20 ppm of boron in the leaf dry matter. When the boron supply was increased, the boron concentration of the leaves increased and bud break and bloom were delayed. The delay was already marked following preceding leaf values of 40–50 ppm boron. At 60–70 ppm leaf boron, the blossom density the following year was reduced or buds failed to develop properly this resulted in bare wood. Premature leaf drop on extension shoots was not affected by boron, but some curling of leaf edges and purple colouration appeared at the higher boron levels. Extension growth was reduced only at a very high boron level.

Magnesium supply increased extension growth and reduced premature leaf drop, but bud development was not affected.

Key words: Apple, boron, magnesium, toxicity, bud development, bloom, growth, symptoms.

Resumé

Næringsopløsninger med forskellige koncentrationer af bor og magnesium blev tilført til unge 'Cox's Orange' træer, som var plantet i kar med sand + peralite. Bladene hos træer uden bortilførsel indeholdt ca. 20 ppm bor i tørstoffet. Indholdet steg med stigende bor-tilførsel, samtidig blev løvspring og blomstring forsinket. Denne forsinkelse var tydelig, når bladene året før indeholdt 40–50 ppm bor eller mere. Ved 60–70 ppm bor var blomstermængden næste år reduceret og knopperne udvikledes dårligt, så at der blev bare stykker på grenene. Krøllede bladrande og purpurfarvede blade optrådte også ved de højere bor-niveauer, derimod var bladfald i løbet af sommeren ikke påvirket. Længdetilvæksten blev kun reduceret ved meget stor bor-tilførsel.

Magnesium-tilførsel øgede længdetilvæksten og reducerede det tidlige bladfald, derimod var knopudviklingen ikke påvirket.

Nøgleord: Æble, bor, magnesium, toksicitet, knopudvikling, blomstring, vækst, symptomer.

Introduction

In a previous experiment on the apple cultivar 'Cox's Orange Pippin' boron deficiency reduced extension growth, while summer leaf-fall and the occurrence of necrotic leaf spots were increased (Hansen, 1974). These effects were pronounced when the boron content dropped below 20 ppm of leaf dry matter. Premature leaf drop and the occurrence of leaf symptoms are influenced by magnesium nutrition as well (Hansen, 1970, Vang-Petersen, 1974). In an attempt to investigate the interaction between boron and magnesium on leaf development in greater detail, an experiment with these two elements was carried out. However, we did not succeed in developing boron deficiency in this experiment, as leaf contents were not below 20 ppm boron. On the other hand, the toxic effects of boron on bud development were clearly demonstrated at the higher boron levels. Also in the afore-mentioned experiment incipient boron toxicity was indicated as fewer buds and flower clusters developed as well as bloom being delayed when the leaf boron in the preceding summer exceeded 50 ppm. Similar effects have been demonstrated in other fruit crops, such as peach (Cibes *et al.*, 1955, Hernandez & Childers, 1956). Boron may be applied to apple trees not only in cases of real deficiency, but also when we wish to influence storage quality of the fruit. So it seems appropriate to also stress the susceptibility of buds to excess boron.

Material and methods

In the spring of 1972, two-years-old trees of cultivar 'Cox's Orange Pippin'/MM 104 were heavily pruned at the tops and roots and planted in well drained 15 litre plastic pots in acid washed sand and peralite (approx. 1 : 1 by volume). During the growing seasons the pots were watered thoroughly with nutrient solutions, once a week in 1972 and 1973, three times a week in 1974. Additional watering was given with water purified on ion exchangers. During the winters the trees were kept in a cold house.

The treatments consisted of five levels of boron, namely 0, 0.117, 2.92, 8.7 and 35 mg boron (as boric acid) per liter of nutrient solution. 35 mg

boron/l was combined with 5.3 meq. Mg/l, each of the other boron levels were combined with four levels of magnesium, 0.3, 1.3, 5.3 and 13.3 meq. Mg per litre of nutrient solution. Five replicate trees were used per combination. Besides B and Mg all nutrient solutions contained (meq./l) : N and Ca 14–19, K 3–4, P 4–5, together with sodium, sulphate and trace amounts of Cu, Zn, Mo, Fe, and Mn.

Some trees receiving nutrient solution without boron were sprayed with 0.03 per cent boron (as borax, sodium tetra borate) or higher concentrations three times during the period from June to September.

Leaves for analysis were sampled in August or September, in 1972 from the middle part of the extension shoots, in 1973 and 1974 from the spurs, as leaves from extension shoots in some cases had dropped due to magnesium deficiency. Analysis was carried out as has been done previously (Hansen, 1974).

Leaf drop and symptoms on leaves were evaluated 22–24 August 1973 and i mid September 1974, either by counting or assessment on a scale 0–5 used on individual trees. Bud development in the spring was also assessed on a scale 0–5 (see Tables and Figures).

Results

The development of buds during the spring is distinctly delayed when the boron level is increased, this applies to the buds in general as well as to flower buds (Figures 1a and 2a). In 1973 many buds failed to develop properly at 8.7 mg B/l (corresponding to 65–75 ppm B in the leaves in 1972). This resulted in bare wood on the branches later in Summer 1973 (Figure 1b).

Also in 1974 the amount of leaves on older wood (spurs) was drastically reduced at the higher boron levels (Table 1). Few fruits were harvested at these treatments (Table 1), as a strong negative correlation between blossom density and boron level was established (Figure 2b). No fruits were harvested in 1972 and only a few in 1973, this included all treatments. In contrast to the pronounced effects of boron on resting buds and their following leaf and flower development,

Table 1. Relationships between boron supply, boron content of leaves, extension growth, and leaf and fruit development

mg B/l ppm B	0	0.12	2.9	8.7	35	LSD
1972	21	23	39	68	101	—
1973	24	25	47	84	140	5
1974	20	22	35	50	76	—
dm extension growth/tree						
1972	56	54	60	59	41	3
1973	35	30	38	48	— ¹⁾	8
% fallen leaves, ext. shoots ²⁾						
1973	38	30	33	36	— ¹⁾	5
1974	40	35	28	31	—	8
Leaf symptoms, ext. shoots						
Curling 1973 ³⁾	1.8	1.6	3.3	4.3	— ¹⁾	0.5
Purple 1973 ⁴⁾	1.6	1.3	2.6	3.1	— ¹⁾	0.6
% curling and purple 1974 ²⁾	7	7	10	26	—	8
Foliage density, spurs, 1974 ⁵⁾	3.1	3.6	3.2	1.9	0	0.5
No. fruits/tree, 1974	16	13	21	2	0	6
g branch dry matter/tree, 1974	407	407	393	433	192	—
g root dry matter/tree, 1974	80	108	119	117	48	—

¹⁾ Regrowth 1973.

²⁾ % of all extension shoot leaves developed. Fallen leaves measured as number of buds without leaves.

³⁾ 5 = all extension shoot leaves with curling edges. 0 = none.

⁴⁾ 5 = all extension shoot leaves with purple colour. 0 = none.

⁵⁾ 5 = spurs densely covered with leaves. 0 = no or few leaves on spurs.

the extension growth was only depressed at the very high boron level (Table 1). Curling of leaf edges and purple colouration of the leaves on extension shoots were augmented with increased boron level (Table 1).

Spraying with 0.03 per cent boron three times in the period from June to September where boron in the nutrient solution was omitted, delayed bud development in the spring (values were 3.2 and 1.8 corresponding to Figures 1a and 1b, respectively), whereas the development of buds into leaves or flowers proceeded normally. Severe toxicity symptoms appeared after spraying with 0.06 per cent boron.

In contrast to the reaction to boron, the trees reacted positively to magnesium supply. Here the major effects were on extension shoots, the growth of which was increased, while the premature drop of their leaves was reduced by magnesium supply (Table 2). On the other hand, the bud development in the spring was not affected by magnesium.

Discussion

Injurious effects of boron on woody plants may include growth reduction and leaf symptoms such as marginal chlorosis or necrosis, tip burn, cupping of leaves, necrotic spots, premature leaf drop and development of anthocyanins (*Francois & Clark, 1979*). Excess boron may be carried to the leaves in the transpirational stream and accumulated in leaf tips and margins. Among fruit trees symptoms of boron toxicity are described for peach in particular, crinkling and necrosis of leaf tips and margins, and yellowing of terminal leaves are included (*Kamali & Childers, 1967, 1970*). Malformed and split fruits may be another index of boron excess (*Hernandez & Childers, 1956*). In the present experiment some curling and purple colouration appeared on the leaves; extension growth, however, was reduced only at the very high boron application. On the other hand, bud development was affected distinctly. Bud break and blossom time were delayed markedly and blossom density was reduced or the buds

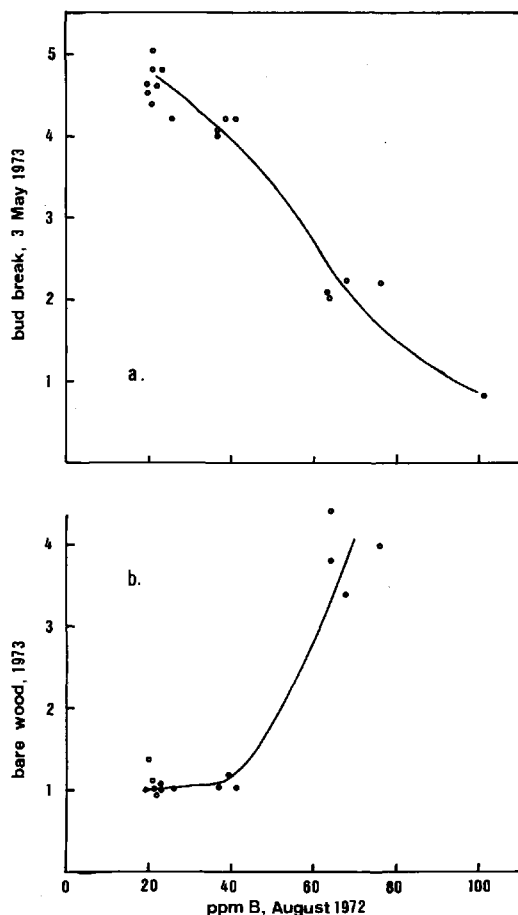


Figure 1. Bud development versus boron in the leaves the preceding year.

Bud break:

5 = all buds with distinctly separated leaves.

0 = no buds opened.

Bare wood:

5 = > 80% of the length of 2nd year's branches without leaves.

1 = < 20% without leaves.

failed to develop properly. Delay and failure of bud opening, drop of buds, scant blossoming and abnormal flowers have been reported from excess boron in peach trees (Cibes *et al.*, 1955; Hernandez & Childers, 1956; Kamali & Childers, 1970). These adverse effects of boron may develop at leaf values around 50 ppm boron.

The question arises as to whether boron really acts toxically on the buds with a direct inhibitory or injurious effect. Boron accumulates in growing regions such as fruits (Hernandez & Childers, 1956). Rapidly growing leaves may accumulate boron even from storage organs such as a tulip bulb (Rasmussen, 1974). The flower buds of pear, apple and cherry accumulate boron during the dormant season, differences in the soil boron level are reflected and enlarged in the boron levels of the buds (Woodbridge *et al.*, 1971). More than 500 ppm B has been detected in pear buds, in this case without toxicity symptoms.

Table 2. Relationships between magnesium supply, magnesium content of leaves, extension growth and leaf and bud development

meq. Mg/l	0.3	1.3	5.3	13.3	LSD
% Mg					
1972	0.24	0.28	0.33	0.40	—
1973	0.12	0.15	0.26	0.40	0.02
dm extension growth/tree					
1972	53	57	60	61	3
1973	27	36	41	47	8
% fallen leaves, ext. shoots					
1973 ¹⁾	48	39	26	33	5
Bud-break, 1973 ²⁾	3.8	3.9	3.8	3.9	n.s.
Bare wood, 1973 ²⁾	1.8	1.8	1.8	1.7	n.s.
Blossom stage, 1974 ³⁾	2.5	2.5	2.6	2.5	n.s.
Blossom density, 1974 ³⁾	4.0	3.9	4.3	4.4	—
Foliage density, spurs, 1974 ¹⁾	1.0	3.4	3.7	3.7	0.5

¹⁾ See Table 1, ²⁾ See Fig. 1, ³⁾ See Fig. 2.

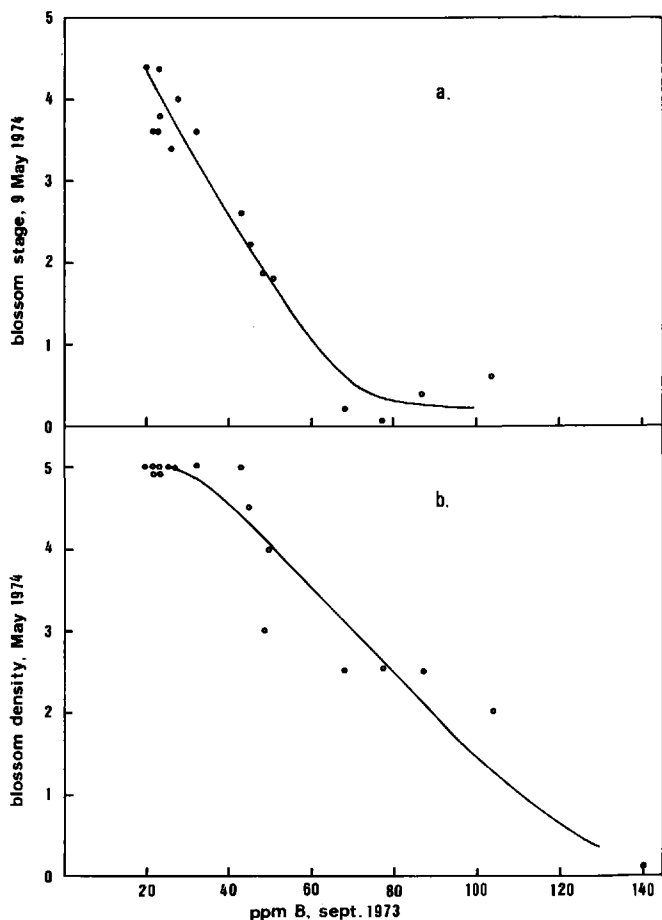


Figure 2. Blossom development versus boron in the leaves the preceding year.

Blossom stage:

5 = all flowers full bloom.

3 = balloon.

1 = flower buds still green.

0 = buds very small.

Blossom density:

5 = all spurs with flowers.

0 = no spurs with flowers.

Another possibility is that buds are affected through a mechanism, which is influenced not only by boron, but also by other factors. For example, 1) a negative correlation exists between terminal shoot growth and flower bud initiation (Luckwill & Silva, 1979; Hansen & Grauslund, 1980). This cannot be the mediating mechanism in

this case, however, as boron affects bud development, but not shoot growth, while the reverse is true for magnesium. Still, other conditions may have effects similar to excess boron such as, 2) application of gibberellic acid may result in extension shoots getting bare wood at their lower parts next spring with small and underdeveloped

flowers in their upper sections (Hansen & Grauslund, 1980). Similarities between boron and gibberellic acid have been proposed as they both retard senescence of leaf discs (Parmar & Hammond, 1971). 3) In pecan, excess boron may influence bud break in a way similar to the way that other sorts of injury influence bud break (Sparks & Payne, 1976). 4) A disorder in the apple cultivar 'Cox's Orange Pippin', the so-called »Cox-disease«, exhibits symptoms very similar to those of boron excess, except that severe leaf fall may occur as well (Hansen, 1974). This disorder is related to the accumulation of assimilates and function and death of the roots, the latter probably caused by unfortunate aeration in the soil (Boekel & van der Boon, 1978; van der Boon, 1978). The purple colouration of leaves with increased boron level indicates accumulation of assimilates. On the other hand, root dry weight do not provide evidence that boron has a negative effect on the roots except at a very high level of boron (Table 1). So, in some cases the responses of buds to excess boron correspond to responses caused by other factors; in other cases this is not so. A thorough understanding of the mechanisms underlying bud development has not yet been achieved.

Conclusion

The parts of apple trees the most sensitive to excess boron are probably the buds. Already at leaf values of 40–50 ppm boron, bud break and bloom may be delayed the following spring. At 60–70 ppm leaf boron the blossom density next year may be reduced or the buds may fail to develop properly resulting in bare sections of wood.

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