

**THE INFLUENCE OF BORON AT DIFFERENT  
CALCIUM LEVELS ON THE GROWTH, YIELD AND  
MINERAL CONTENT OF CANOLA, *Brassica napus* L.**

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**Thesis presented in partial fulfilment of the requirements for  
the degree of Master of Science (Agricultural Sciences) at  
the University of Stellenbosch.**



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**December 1999**

## **DECLARATION**

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree

## ABSTRACT

### THE INFLUENCE OF BORON AT DIFFERENT CALCIUM LEVELS ON THE GROWTH, YIELD AND MINERAL CONTENT OF CANOLA, *Brassica napus* L.

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Oilseed rape plants were grown in pots in two glasshouse trials during 1992 and 1993. Plants received 2 calcium (Ca) rates and 4 boron (B) rates in a factorial design. During the first experiment B rates were 0.2, 0.5, 0.8 and 1.1 and 0.1, 0.5, 0.8 and 1.1 ppm during the second experiment. Ca rates were 117.4 and 182.1 during the first experiment and 56.7 and 182.1 ppm during the second experiment.

A study of the vegetative growth showed that, Ca had no consistent effect on growth or the parameters measured, nor did it show any interaction with B. In general B application rates during the first experiment had little effect on vegetative growth. During the second experiment low B (0.1ppm) had a significant influence on most of the variants measured. Leaf-, stem-, and root growth as well as total plant dry matter were detrimentally affected at the later stages of plant development.

Analysis of the reproductive growth showed that, Ca had no significant effect on the parameters measured, nor did it show any interaction with B. B application rates during the first experiment had no significant effect on the amount of pods, pod mass, seeds per pod, thousand kernel mass or dry mass of crop residue, but did affect the amount and mass of seeds produced per plant. During the second experiment low B (0.1ppm) had a significant effect on the formation of pods and the production of seeds. The amount of pods, pod mass, seeds per pod, seeds per plant, seed mass per plant, dry mass of crop residue and harvest index (HI) were all negatively affected. High B (1.1ppm) had a positive effect on the thousand kernel mass (TKW).

Leaf, stem and pods from the second experiment (1993) were analyzed at different sampling dates to determine the influence of Ca and B application on the accumulation of elements in different plant organs. The data confirmed that levels of all elements vary between plant tissues and with their physiological age. Ca, Mg, Mn and B tend to build up in the leaf tissue of the plant while N, P, K, Na, Cu, Zn and Fe were diluted at rates that depended on the growth of the specific plant part analyzed. The effect of applied Ca on plant Ca content was small and Ca effects on the concentrations of most elements were very small or negligible and unclear. Some effects on K and Mg were observed and can be explained by differences in the concentrations applied due to cation corrections. Low B (0.1ppm) resulted in elevated levels of N, P, K, Ca and Mg in the main- and side stem tissue which was probably caused by a reduction in growth of these plant parts induced by B deficiency. The only consistent effect of B was a negative effect on the Mn content of all of the tissue analyzed. B appeared to accumulate in the leaf, but not in the stem as the plants aged, making the latter more suitable for analysis when physiological age of tissue cannot be accounted for. Low B (0.1 ppm) caused low B values in stem tissue but increasing B levels did not increase the B concentrations in tissue to follow linearly. This could give a false indication of availability of B as higher B applications were not reflected in tissue levels. As B tend to accumulate in leaf tissue the physiological age of leaf tissue is therefore critical when used for analysis. B content in leaf tissue followed the application rates more closely than that of other tissue analyzed and gave a better indication of availability of B, but was dependent on the physiological age of the tissue.

**Keywords:** boron, calcium, canola, vegetative growth, reproductive growth, mineral-content

## UITTREKSEL

# DIE INVLOED VAN BOOR BY VERSKILLENDE KALSIVLAKKE OP DIE GROEI, OPBRENGS EN MINERALE INHOUD VAN CANOLA, *Brassica napus* L.

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Olieryke raapsaad (canola) is gedurende 1992 en 1993 in twee glashuis potproewe verbou. Twee kalsium (Ca) vlakke en 4 boor (B) vlakke is as behandelings in 'n faktoriaal proefontwerp toegedien. B toedieningsvlakke gedurende die eerste eksperiment was 0.2, 0.5, 0.8, en 1.1 dpm en 0.1, 0.2, 0.8, 1.1 dpm gedurende die tweede eksperiment. Ca-toedieningsvlakke was 117.4 en 182.1 dpm gedurende die eerste eksperiment en 56.7 en 182.1 dpm gedurende die tweede eksperiment.

'n Ondersoek na die vegetatiewe groei het getoon dat Ca geen konstante effek gehad het op die die parameters wat gemeet is nie asook geen interaksie met B nie. Oor die algemeen het B-toedieningsvlakke gedurende die eerste eksperiment weinig effek op die vegetatiewe groei gehad. Gedurende die tweede eksperiment het die lae B vlak (0.1 dpm) 'n betekenisvolle invloed op die meeste van die parameters wat gemeet is, gehad. Blaar-, stingel- en wortelgroei, sowel as totale plant droëmateriaal is nadelig beïnvloed by die gevorderde stadiums van plantontwikkeling.

Analise van die reprodktiewe groei het getoon dat Ca geen betekenisvolle invloed op die parameters gemeet, gehad het nie en het ook geen interaksie met B gelewer nie. B-toedieningsvlakke gedurende die eerste eksperiment het geen betekenisvolle verskille op die aantal peule gevorm, peul massa, sade per peul, duisendkorrelmassa of droëmassa van oesreste nie gehad nie, maar het wel die aantal en massa saad geproduseer per plant, beïnvloed. Gedurende die tweede eksperiment het lae B-toedieningsvlakke (0.1 dpm) 'n betekenisvolle effek op die vorming van peule asook saadset gehad. Die aantal peule en peulmassa per plant, sade per peul, sade per plant, saadmassa per plant, droë massa van oesreste en oesindeks (OI) is almal negatief beïnvloed. Hoë B-toediengsvlakke (1.1 dpm) het 'n positiewe effek op die OI gehad.

Plantmateriaal van die tweede eksperiment is in 'n afsonderlike studie geanaliseer ten einde die invloed van behandelings op die minerale inhoud te bepaal. Blaar, stam en peulweefsel is op verskillende tye gemonster en ontleed om die invloed van Ca en B toedieningsvlakke op die akkumulاسie van verskillende elemente in die verskillende plantorgane te bepaal. Die data het bevestig dat vlakke van elemente tussen verskillende plantweefsel wissel asook met die fisiologiese ouderdom van die weefsel. Ca, Mg, Mn en B het geneig om in die blaarweefsel te akkumuleer terwyl N, P, K, Na, Cu, Zn en Fe 'n verdunningseffek ondergaan het, wat gewissel het na gelang van die groeipatroon van die spesifieke plantweefsel. Die invloed van toegediende Ca op die Ca-plantinhoud was gering of onduidelik. 'n Mate van reaksie op K en Mg is waargeneem, maar is toegeskryf aan toedieningsvlakke van die elemente weens kation korreksie. Lae B vlakke (0.1 dpm) het verhoogde N, P, K, Ca, en Mg vlakke in die stamweefsel tot gevolg gehad en is waarskynlik deur 'n verminderde groei van hierdie weefsel, as gevolg van 'n B tekort, teweeg gebring. Die enigste konstante reaksie van B was 'n negatiewe effek op die Mn-inhoud van al die weefsel wat ontleed is. B het geneig om in die blaarweefsel te akkumuleer oor tyd, maar nie in die stamweefsel nie wat laasgenoemde meer geskik maak vir analise wanneer die fisiologiese ouderdom van plantweefsel onbekend is. Lae B toedieningsvlakke het lae B waardes in die stamweefsel gelewer, maar verhoging van die B-toedieningsvlak het nie 'n ooreenstemmende verhoging in die stamweefsel meegebring nie. Dit kan 'n verkeerde aanduiding gee van beskikbare B aangesien die hoër B-toedieningsvlakke nie 'n verhoging in B-inhoud van stamweefsel veroorsaak het nie. Alhoewel die B-vlakke in die blaarweefsel deur die fisiologiese ouderdom van die weefsel beïnvloed is, was die verband tussen B-toediening en die B-inhoud van blaarweefsel beter en het dit 'n beter aanduiding van die beskikbaarheid van B gegee.

**Sleutelwoorde:** boor, kalsium, vegetatiewe groei, reprodktiewe groei, minerale inhoud



**DEDICATED TO MY PARENTS**

# ACKNOWLEDGEMENTS

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DR. N.J.J. COMBRINK, Department Agronomy and Pastures, University of Stellenbosch, for his excellent guidance during the project.

DR. D.B. ARKCOLL, Crop production section, Elsenburg Agricultural Development Institute for his assistance and support of the project.

MR. F. PETRIE, for his technical assistance during the glasshouse trials.

MR. F.J. TITUS, for his excellent assistance throughout the project.

MRS. M.A VISAGIE, for doing the plant analyses.

MISS. E.C.M. MOSTERD, for doing the nitrogen analyses.

THE ELSENBURG AGRICULTURAL DEVELOPMENT INSTITUTE, for the use of the facilities.

THE DEPARTMENT OF AGRICULTURE, WESTERN CAPE, for making this study possible.

My parents, KNOX and MAUREEN HANEKOM, for their support over the years.

My wife, IRMA, for her excellent editing of the final manuscript, her love and support.

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## INTRODUCTION

### THE INFLUENCE OF BORON AT DIFFERENT CALCIUM LEVELS ON THE GROWTH, YIELD AND MINERAL CONTENT OF CANOLA, *Brassica napus* L.

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#### OVERVIEW

The winter rainfall region is predominantly a wheat producing area with between 600 -700 thousand tons of wheat produced annually. Of this approximately 50% has to be transported to the north of the country which has to be paid by the farmers. The region also has to import large amounts of protein for animal feeds from either abroad or from the northern parts of the country.

A search for profitable alternative crops to reduce imports and rotate with wheat, has identified canola (double zero oil seed rape) as the most suitable option (Arkcoll, personal communication, 1995). Canola has rapidly become the third most important source of oil and second most important source of protein in the world because of a combination of the premium quality of it's products and excellent agronomic characteristics.

Commercial production is at an early stage with about 1000 ha planted during 1993 and over 4000 ha in 1994. This has grown to about 25 000 ha over the last few years and is expected to rise rapidly in the next few years to satisfy the local demand for well over 100 000 tons.

Local research has concentrated on the adaptation and management of the crop by identifying and solving major practical problems. These include the need for a good seedbed to ensure a shallow sowing depth, sowing early before cereals, large applications of nitrogenous fertilizer, the control of certain weeds, pests and disease and careful timing of harvest.

Some earlier experiments on canola with micro nutrients as well as literature surveys, indicated that boron (B) is important in the nutrition of canola. As some areas of the region sown to wheat have light sandy soil which are usually prone to micro nutrient deficiencies it is of importance to ensure that the needs of the crop for B is met. The role of B in plants, its deficiency- and toxicity symptoms and factors affecting its uptake by plants, have been extensively researched and reviewed (Eaton, 1944; Berger, 1949; Alisson, 1964; Jackson & Chapman, 1975; Adams, 1978; Gupta, 1979; Elrashidi & O'Connor, 1982; Dugger, 1983; Gupta *et al.*, 1985; Shorrocks, 1989). Despite of all these, the critical values of boron for soil and plant analysis for a lot of crops (Reuter & Robinson 1986), as well as literature on oil seed rape, is lacking.

The object of this study is to determine the effect of B on the growth and yield of canola as well as the mineral composition of the plant and how these are affected by different calcium levels.

## **BORON, AN ESSENTIAL PLANT NUTRIENT**

Boron is one of the seven recognised essential micronutrients required for the normal growth and development of most plants (Shorrocks, 1989). In order for any element to be classified as essential for plants it must be shown that:

- (i) in its absence, plants are unable to complete their life cycle
- (ii) the element cannot be substituted by any other element
- (iii) it plays a unique and direct beneficial role in plant metabolism

(Arnon & Stout 1939).

Although many physiologists and chemists claimed, on the bases of plant composition and on the evidence of growth responses to B application, that B was needed by plants, it was the work of Warington that provided sound proof of the essentiality of B (Shorrocks, 1991). Since that time the importance of B as an agricultural chemical has grown rapidly and hundreds of reports dealing with the essentiality of B for a large number of crops in countries from every continent of the world have been published (Shorrocks, 1991).

## THE ROLE OF BORON IN PLANTS

Despite a vast amount of work being done on B there is perhaps less precise information available on the role of B in plants than for any other micronutrient (Shorrocks, 1991). There are several levels of knowledge of nutrient function. In ascending levels of knowledge these are:

- (i) the element is essential
- (ii) it plays a role in a physiological process
- (iii) it activates an enzyme or regulates the rate of an enzyme-mediated process and
- (iv) it is an integral constituent of an essential metabolite, complex or macro-molecular assembly.

(Shorrocks, 1991).

Much of the work done on B demonstrated B deficiency-induced changes in plant growth and development, on mineral element composition, on enzyme activities, on ultra-structure of cells, on oxygen free radicals, on plasma membrane integrity and also on host-pathogen relations as well on mycorrhizal symbiosis. (Shorrocks, 1991; Gupta, 1979).

In spite of all the work done on B the primary role of B in plants has still not been established. There is, however, no doubt that B plays a key role in carbohydrate metabolism and transport of sugars through membranes, cell wall formation



(apoplast), in phenol metabolism, nucleic acid metabolism and tissue development (Jackson & Chapman, 1975; Pollard, Parr & Loughman, 1977; Pilbeam & Kirkby, 1983; Mengel & Kirkby, 1987). It is, however, a problem that confronts research workers to draw conclusions whether these B deficiency-induced changes reflects direct functions of B or whether they are of an indirect nature (Shorrocks, 1992b).

To date the only convincing scientific evidence for the role of B in plants is the function B has in the apoplast in general and at the cell wall-plasma membrane interface in particular. The best established function of B so far in higher plants is its incorporation into the hemi-cellulose fraction and thus, that it has some role as a structural element of cell walls (Shorrocks, 1992b).

It is believed that most of the B in plants is in the cell walls where boric acid combines to form stable di-esters with cis-diol configured compounds such as mannitol, mannan and polymannuronic acid which are constituents of cell wall hemi-cellulose. The major constituents of the cell wall (polygalacturonic acid, cellulose) do not carry any cis-diols. Cis-diols configurations are found in rarer constituents whose abundance may vary significantly. The amount needed for normal crop growth and reproduction is different among various plants. Monocotyledons generally require less B than dicotyledons. This difference is probably a reflection of the higher proportion in dicots of compounds with cis-diol configurations in cell walls, mainly in the hemi-cellulose fractions and in lignin precursors (Shorrocks, 1992b).

Phenol build-up is a common feature with B deficiency and is probably responsible for many of the effects of tissue breakdown. The effects of B on phenol metabolism is well established. Boron supply can affect phenol concentrations and enzyme activities in the pentose-P-pathway, such as polyphenol oxidases. Under conditions of B deficiency, increased accumulation of phenolic substances occurs. Polyphenol oxidases is not a mainline enzyme in the pentose-P-pathway, but is involved in oxidation of NADPH (Nicotinamide adenine dinucleotide phosphate) which is a byproduct of the pentose-P-pathway. These changes are probably related to the formation of B complexes with certain phenolics such as caffeic acid. The result thereof is that not only are metabolic pathways such as lignin synthesis regulated, but production of oxygen free radicals (OFR) is prevented during the oxidation of phenolic compounds (Shorrocks, 1992b).

As B deficiency often affects apical meristems, a lot of attention has been given to auxin (IAA) levels in studies on B. Many but, not all, are in accord with the theory that the symptoms of boron deficiency are due to accumulation of supra-optimal levels of endogenous IAA, probably as a result of reduced activity of IAA oxidase (Shorrocks, 1992b).

In some cases enhanced destruction of IAA in B deficient tissues and corresponding cessation of cell elongation growth occurred. As the basipetal transport of IAA at least contain an apoplastic component, these effects could be explained by the role of B in phenol metabolism. Whether certain plant species, such as the *Brassicaceae* has a different pathway of IAA biosynthesis which leads

to excessive build-up of IAA in B deficient tissue, remains uncertain (Shorrocks, 1992b).

The particular role that B plays in the integrity of the plasma membrane, as indicated by the efflux of solutes or net H<sup>+</sup> extrusion, has been convincingly demonstrated in root cell cultures as well as in germinating pollen and pollen tubes. Whether these effects of B are indirect effects, namely the protection of the plasma membrane from toxic OFR's formed in the cell walls during phenol oxidation, or whether they are indications that B is an essential element for bio-membranes in general and the plasma membrane in particular and thus a direct function, remains uncertain (Shorrocks, 1992b).

It is unlikely that B plays any regulatory role in membrane transport processes similar to that of Ca, due to the necessity of maintaining pH and potential gradients between the cell compartments. The pH gradients between cell wall (pH 5-6), cytosol (pH 7.5) and vacuole (pH 5 ) would cause the cytosol to act as a trap for the weak boric acid leading to excessive accumulation of B in the cytosol and corresponding detrimental effects on cytosolic pH and interference of metabolic pathways by formation of B complexes with various metabolites (Shorrocks, 1992b).

## **SYMPTOMS OF BORON DEFICIENCY**

Whatever the primary role of B turns out to be, the secondary effects remain of considerable relevance especially with regards to the actual manifestation of deficiency symptoms.

Boron is closely related to the activity of meristems, especially apical meristems. When B levels in plant tissue reaches a point below that which is needed, normal cell division does not proceed fully to the complete separation of the dividing cells whose longitudinal walls remain short. This results in incomplete and irregular leaf expansion, development of distorted leaves and the lack of elongation of internodes. Eventually shoot and root apical meristems die or become moribund. The sequential loss of apical dominance causes stunted side shoots to develop from auxiliary meristems. Roots become stubby and stunted and are very inefficient in exploiting the soil. The basic cause of these effects on apical meristems is not known and some argue that the disorganisation of the vascular tissue behind the meristem is a cause and not an effect (Shorrocks, 1989).

It has been a known fact for quite some time that an adequate supply of B is essential for proper seed set and for normal fruit development. It has been established that B is required for the growth of the pollen tube, the B being absorbed by the tube as it grows through the stigma tissue. It was found in some cases that the germination of the pollen grain itself was dependant on B being present in adequate amounts in the exudate on the stigma (Shorrocks, 1989).

Apart from the degeneration and disorganisation of tissue around the apical meristems, breakdown of the walls of parenchyma cells commonly occurs with B deficiency (Gupta, 1983). Lignification is reduced which result in the brown or discoloured flecks, the necrotic spots, the water soaked areas and the corky nodule that are frequently observed in B deficient fruits, tubers, roots and pith. Common symptoms are brittle stem and leaf tissue and the appearance of cracks in petioles and stems (Shorrocks, 1989).

According to (Shorrocks, 1992a) the main and basic characteristics of B deficiency as observed on many crop species are:

- (i) Youngest leaves are the first to be affected. They are misshapen, thick, brittle and small, but seldom exhibit any chlorosis and are in fact often dark green. There is normally a clear increase in the severity of the symptoms from old to younger leaves.
- (ii) Stems are short and severely affected plants seem to have a shrunken appearance.
- (iii) The growing points become moribund and die.
- (iv) Auxiliary meristems develop and causes the plant to become bush shaped.
- (v) Necrotic and watery patches develop in storage tissue and in pith.
- (vi) Cracks and splits occur in petioles, stems and sometime fruit bodies.
- (vii) Leaves tend to have a more simple shape.
- (viii) Roots become thick and stubby with little branching. Root growth will be impaired.

## FACTORS AFFECTING BORON REQUIREMENT AND UPTAKE IN PLANTS

### Soil pH and cations

Soil pH is one of the most important factors affecting the availability of B in soil and plants. Generally, B becomes less available to plants with increasing soil pH. This relationship is, however, not consistent and deviations can occur, owing to factors such as crop species (Gupta, 1972). Studies by Gupta and MacLeod (1981) have shown that a negative relationship between soil pH and plant B occurs when soil pH levels are greater than 6.3-6.5. The availability of B to plants decreases sharply at high pH levels, but the relationship between soil pH and plant B at soil pH levels below 6.5 does not show a definite trend.

Plants vary widely in their nutrient requirements. Due to nutritional balance, the uptake of B by plants can be markedly affected by the presence of other nutrients in the soil. The most well known of these is the effects of calcium (Ca). Eck and Campbell (1962) found that liming decreased the B uptake of plants from soils with high B content. They attributed this effect to a high Ca content. Tanaka (1967) reported that in solution culture the B uptake of radish (*Rhaphanus sativus* L.) was reduced when the Ca content of the medium was increased. No distinction was, however, made between the effects of soil pH and levels of Ca and/or Mg on B uptake.

Gupta and MacLeod (1977) did experiments to separate the effects of soil pH and source of Ca and Mg on the availability of B to plants. They noticed that, in the absence of added B, roots and tops from rutabaga (*Brassica napobrassica*) from Ca and Mg carbonate treatments, had more severe brown heart condition than did that of plants from Ca and Mg sulphate treatments. The B concentration in leaf tissue of plants from treatments with no B, were lower at high soil pH values where Ca and/or Mg were applied as carbonates than they were at lower pH where sulphates were used as a source of Ca and/or Mg. In the presence of added B, this trend was not clear. It appeared that the lower B concentration in plants, in no-B treatments with carbonates, is related to soil pH rather than the concentration of Ca and/or Mg in the soil. It was also noted that the effect of application of lime on B uptake was not related to the availability of Ca and/or Mg, since equivalent amounts of Ca and/or Mg were applied as sulphates, compared with those added as carbonates. The concentrations of Ca and Mg was furthermore the same in the plant tissue of the different treatments. Fox (1968) found, whilst observing alfalfa and cotton (*Gossypium hirsutum* L.) that, separately high Ca and high pH had no effect on B uptake, but in combination they reduced B uptake.

Studies by Reeve and Shive (1944) indicated that the K concentration of the substrate has a definite influence on the accumulation of B in tomato and corn plants. They noted that the increased accumulation of B in the tissue caused by high K, was especially pronounced at high B levels. The B toxicity symptoms on these crops increased in severity with the increase in K concentration in the substrate. At low levels of B the deficiency of B was, however, progressively

intensified with increasing concentrations of K in the growth medium. It was concluded that high levels of K accentuate B deficiency and toxicity symptoms, apparently by suppression of Ca activity.

### **Nitrogen and other anions**

Nitrogen is probably the element that affects the uptake and concentration of B in plants the most. According to Gupta (1979), several investigators have found that large applications of N to the growing medium result in decreased uptake of B by crops. It is not clear whether the lower B in plant tissue is the result of some physiological process or because of increased growth and thus a dilution effect caused by higher N application.

Tanaka (1967) found that B uptake in radish increased with an increase in P supply. On the other hand, Stayanov (1971) as quoted by Gupta (1979) found that high P increased the severity of B deficiency in tobacco.

Tanaka (1967) speculated that there might be a slight effect of sulphate ion on the accumulation of B in plant tissues. Gupta (1979) found that various crops behave differently and that the requirement of some crops for higher S in the substrate might play a role.



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## CHAPTER I

# THE INFLUENCE OF BORON AT DIFFERENT CALCIUM LEVELS ON THE GROWTH, YIELD AND MINERAL CONTENT OF CANOLA, *Brassica napus* L. I. VEGETATIVE GROWTH.

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### Abstract

Oilseed rape plants were grown in pots in two green house trials during 1992 and 1993. Plants received 2 calcium (Ca) rates and 4 boron (B) rates in a factorial design. During the first experiment B rates were 0.2, 0.5, 0.8 and 1.1 and 0.1, 0.5, 0.8 and 1.1 ppm during the second experiment. Ca rates were 117.4 and 182.1 during the first experiment and 56.7 and 182.1 ppm during the second experiment. Ca had no consistent effect on growth or the parameters measured, nor did it show any interaction with B. In general B application rates during the first experiment had little effect on vegetative growth. During the second experiment low B (0.1ppm) had a significant influence on most of the variants measured. Leaf-, stem-, and root growth as well as total plant dry matter were detrimentally affected at the later stages of plant development.

**Keywords:** Boron, calcium, canola, vegetative growth

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### INTRODUCTION

There is growing interest in the oilseed rape crop in the winter rainfall region resulting from better prospects of economic returns and its potential as a break crop in intensive cereal systems. As some of the soils in the region are nutritionally poor, trace element imbalances can be expected. Information from the literature cited (Gupta, 1979; Gupta *et al.*, 1985; Shorrocks, 1991) as well as laboratory reports from the Elsenburg soil science laboratory strongly suggests that boron (B) may be a problem, especially on the lighter sandy soils in the region.

It is often found that reduction in yield occurs because of some limiting trace element without any visible symptoms or reduction in the vegetative growth of the plant. Nuttall, Ukrainetz, Steward & Spurr (1987) could find no clearly defined symptoms that could explain the yield responses caused by B application in oil seed rape. Workers in Australia, however, found that by the time that trace element symptoms became visible in lupines, a 30% loss of growth already occurred (Hannam, Davies, Grahamm & Riggs, 1984).

Although the primary role of B in plants is still not clear it has been shown that B is involved in different aspects of plant metabolism at a cellular level. B is known to have some role in the integrity of the plasmalemma, in cell division and expansion, in the translocation of sugars across membranes and in nucleic acid metabolism (Dugger, 1983; Jackson & Chapman, 1975; Pilbeam & Kirkby, 1983; Pollard, Parr & Loughman, 1977; Shorrocks, 1989; Shorrocks, 1992b). However, information on the sensitivity of these primary functions for B deficiency is lacking.

Whatever the primary role of B may be, the secondary effects are of great importance as B is vital if high yields of good quality are to be obtained. B is known to be closely related to the activity of meristems, especially apical meristems (Lovatt, 1985) and has some role in pollination (Garg, Sharma & Kona, 1979). A breakdown of the walls of parenchyma cells which result in brown or discoloured flecks, necrotic spots, water soaked areas and corky nodules found on roots and stems are associated with B deficiency symptoms (Gupta & Cuttcliff, 1975). Stem and leaf tissue tend to be brittle and the appearance of cracks in

petioles and stems are common (Gupta, 1979; Shorrocks, 1992a)

Many factors affect B requirement and uptake by plants (Gupta 1979; Gupta et al. 1985). Of these the best known is probably the effects of calcium (Ca). Eck & Cambell (1962) found that liming decreased the uptake of B from soils with high B content. They attributed this effect to a high Ca content. Tanaka (1967) reported that in solution culture the uptake of B by radish (*Rhaphanus sativus* L.) was reduced when the Ca content of the medium was increased. Gupta & Macleod (1981) found that at equivalent levels of Ca,  $\text{CaCO}_3$  reduced the B concentration in plants more than  $\text{CaSO}_4$ , indicating a pH rather than a Ca effect. Fox (1968) found whilst observing cotton and lucerne that separately high Ca and high pH had no effect, but in combination they reduced the B content.

The object of this study was to determine the physiological basis of the effect of boron at different calcium levels on the vegetative growth and development of oil seed rape and to assess the sensitivity of vegetative growth for B deficiency.

## **MATERIALS AND METHODS**

Experiments 1 and 2 were conducted in a temperature controlled glasshouse having a 25°C day and 16°C night temperature regime. Nine seeds of the cultivar Eureka, treated with insecticide (dimethoate) and fungicide (thiram), were planted in 6 L pots filled with 5.5 kg of acid washed silica sand. After emergence the

plants were thinned out to five per pot. Each pot had one 8mm drainage hole at the bottom. Irrigation was done by an automated watering system. Pots received tap water after planting, followed by application of nutrient solutions. During the second experiment, nutrients were applied through the irrigation system as soon as the cotyledons were visible. Frequency and amounts applied were adapted as the plants progressed through the vegetative cycle. About 20% over irrigation was applied to ensure that no build up of nutrients occurred.

All nutrients were applied with the irrigation water and contained varying K, Ca and Mg ratios (Table 1 and 2) as two Ca treatments and four boron (B) levels ranging from 0.1 to 1.1 ppm (Table 3 and 4). The rest of the essential macro elements, N, P, S were supplied at the concentrations shown in Table 1 and 2. Trace elements (Table 5) were applied at the concentrations prescribed by Steiner (1984).

During the second experiment the difference in the Ca levels applied were increased as data of the first experiment showed no clear response with the Ca levels applied. As no drastic influence of B on the vegetative growth was experienced during the first experiment, the lowest B level was dropped from 0.2 to 0.1 ppm during the second experiment.

Ion concentrations of all ratios were balanced according to the method as described by Steiner (1984). An electric conductivity of  $2.1 \text{ mS cm}^{-1}$  and a pH 6.5 for all treatments, were kept constant in both experiments.



Silica sand of a specific origin (Consol) was used. The sand was washed with 0.1 M HCl to ensure that it did not supply any nutrients. Acid washing was done by adding 1 L of 0.1M HCl to each pot and leaving it over night to react. Pots were then washed three times per day until the pH again reached a satisfactory level (pH 5.6).

Sampling commenced as soon as the fourth leaf (50-60 days after planting) was fully developed and was repeated every fortnight up to the stage where seeds were beginning to form in the pods. Five plants were sampled randomly from pots during the early stages of the season, until one plant per pot remained. Sampling was then done by randomly taking whole pots containing one plant for analysis.

Plants were separated into the different components i.e. leaves, main stems, side stems and roots. Leaf area data was determined using a Li-Cor LI3100 (1mm<sup>2</sup> resolution) area meter. Stems were divided into main- and side stems and the length of each determined. After air drying at 60°C for 48 hours dry weight of all samples were measured. Root dry weight was measured by washing the roots in water to remove all sand particles and weighing samples after drying at 60°C for 48 hours.

The experiments were laid out in a factorial design with 8 treatments ( 4B x 2Ca) and 4 replications. An experimental unit consisted of 5 plants. Data was subjected to statistical analysis using the Genstat 2.2 software application. Mean values were compared using the least significant difference (LSD) at the 5%

probability level by means of the student T test.

Table 1 Cation ratios of Experiment 1

CATION RATIO 1.1 (Ca1)						
	$K^+$	$Ca^{2+}$	$Mg^{2+}$	$NO_3^-$	$H_2PO_4^-$	$SO_4^{2-}$
Ratio (%)	45	30	25	60	5	35
meq L <sup>-1</sup>	8.8	5.9	4.9	11.5	1.0	6.7
ELEMENT	K	Ca	Mg	N	P	S
ppm	343	117	59	161	30	107
CATION RATIO 1.2 (Ca2)						
	$K^+$	$Ca^{2+}$	$Mg^{2+}$	$NO_3^-$	$H_2PO_4^-$	$SO_4^{2-}$
Ratio (%)	35	45	20	60	5	35
meq L <sup>-1</sup>	7.1	9.1	4.0	11.9	1.0	6.9
ELEMENT	K	Ca	Mg	N	P	S
ppm	276	182	49	166	31	111

Table 2 Cation ratios of Experiment 2

CATION RATIO 2.1 (Ca1)						
	K <sup>+</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	NO <sub>3</sub> <sup>-</sup>	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>
Ratio (%)	55	15	30	60	5	35
meq L <sup>-1</sup>	10.4	2.8	5.7	11.1	0.9	6.5
ELEMENT	K	Ca	Mg	N	P	S
ppm	406	57	68	156	29	104
CATION RATIO 2.2 (Ca2)						
	K <sup>+</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	NO <sub>3</sub> <sup>-</sup>	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>
Ratio (%)	35	45	20	60	5	35
meq L <sup>-1</sup>	7.1	9.1	4.0	11.9	1.0	6.9
ELEMENT	K	Ca	Mg	N	P	S
ppm	276	182	49	166	31	111

Table 3 Rates of boron (ppm) applied as  $H_3BO_3$  (Experiment 1)

Treatment	B1	B2	B3	B4
B application rates	0.1	0.4	0.7	1.0
Irrigation water	0.1	0.1	0.1	0.1
Total B ppm	0.2	0.5	0.8	1.1

Table 4 Rates of boron (ppm) applied as  $H_3BO_3$  (Experiment 2)

Treatment	B1	B2	B3	B4
B application rates	0	0.4	0.7	1.0
Irrigation water	0.1	0.1	0.1	0.1
Total (ppm)	0.1	0.5	0.8	1.1

Table 5 Micro-element composition of nutrient solutions

COMPOUND	ELEMENT	ppm
FeNaEDTA(13%Fe)	Fe	1.33
MnSO <sub>4</sub> .H <sub>2</sub> O	Mn	0.62
ZnSO <sub>4</sub> .7H <sub>2</sub> O	Zn	0.11
CuSO <sub>4</sub> 5H <sub>2</sub> O	Cu	0.02
Na <sub>2</sub> MoO <sub>4</sub> 2H <sub>2</sub> O	Mo	0.05

## RESULTS AND DISCUSSIONS

### Leaf area

Although it is a known fact that interaction is common in the uptake of B and Ca, no interaction between B and Ca was found with leaf area data at any of the sampling dates during both experiments (Figure 1.1 & 1.2).



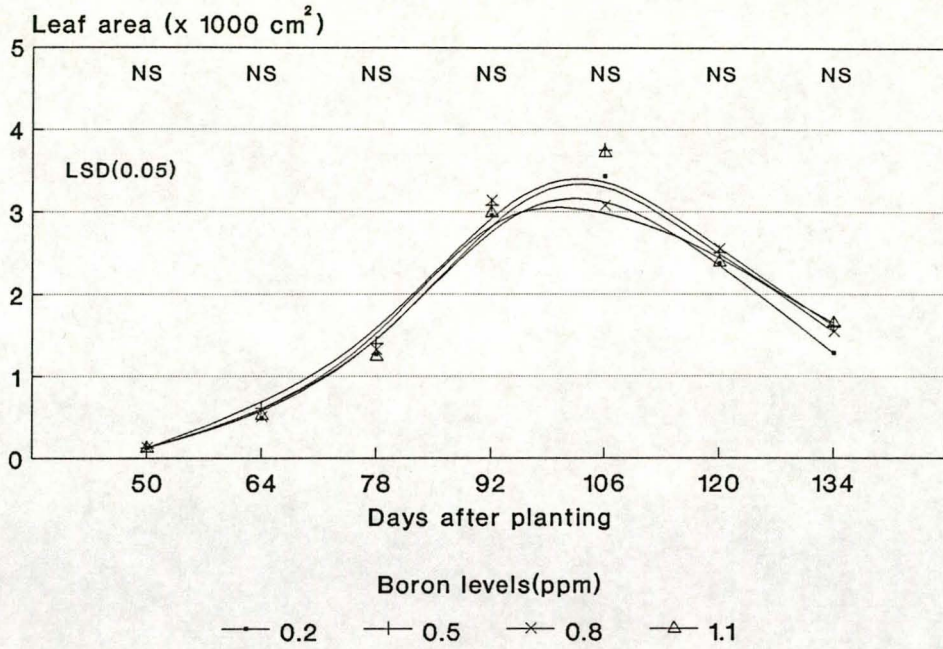


Figure 1.1 Leaf area as affected by B levels during experiment 1.

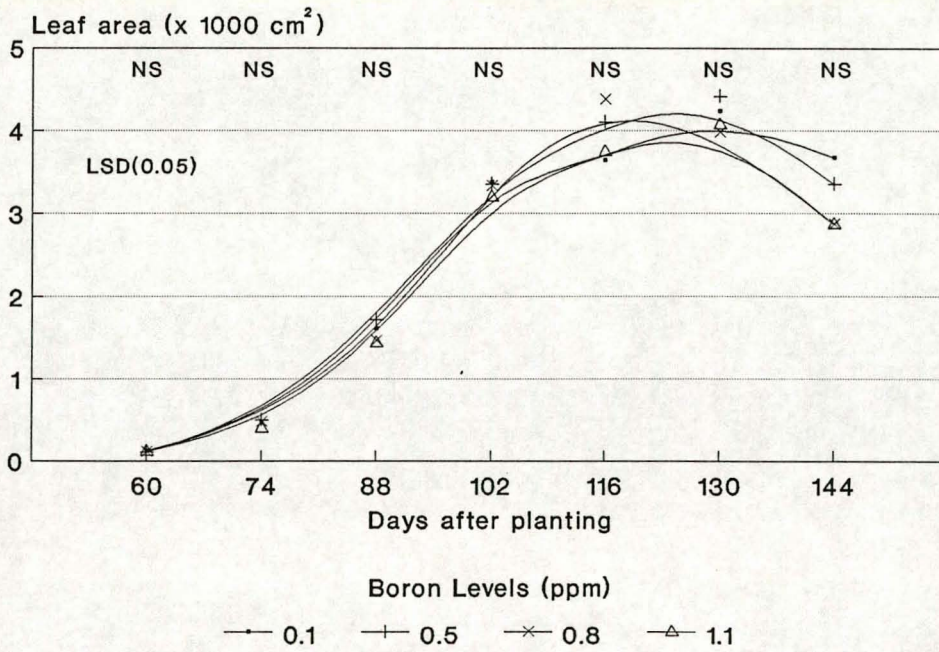


Figure 1.2 Leaf area as affected by B levels during experiment 2.

The different calcium ratios applied did not affect leaf area, except for the last two samplings during the second experiment. The results were inconsistent (results not shown), as Ca caused values to increase 130 days after planting (DAP) but had a negative effect 144 DAP.

B application had no apparent effect on the initiation and growth of leaves of canola during both experiments (Figure 1.1 & 1.2). Leaf area increase showed a typical sigmoid curve. During experiment 1 leaf area increased considerably and fairly consistently with time up to about 100 DAP, whereafter a steady decline occurred. During experiment 2 it peaked at about 116 to 130 DAP.

The increment in leaf area (leaf area increase as % ) during this period ranged from 232% to 430% per fortnight during the first experiment and 225% to 402% during the second experiment. The decline in the rate of leaf area increase after approximately 100 DAP was probably due to further leaf development out of nodes on the lateral branches and not from those on the main stem. These leaves were smaller in size than those on the main stem. New meristems also developed with the creation and elongation of lateral branches.

After approximately 100 DAP (exp.1) to 130 DAP (exp.2) a gradual decline in leaf area was noted as leaves began to age. It was observed that the lower applications of B (0.1 and 0.5 ppm) during the second experiment caused some delay in the decline of leaf area after 130 DAP. These differences were however not significant.

Many studies have shown that B is closely related to the activity of meristems, especially apical meristems (Lovatt, 1985). The observed build up of sugars in the leaves of B deficient plants is furthermore known to be the direct result of a reduction in the utilisation of sugars in the meristems and in the regulation by the plasmalemma of the transport of sugars out of the leaves (Shorrocks, 1989). As most of the nutrients in the leaves are retranslocated to active meristems that develop during the reproductive stage, the development and activity of these meristems could influence the rate of senescence of the leaves.

### **Leaf dry mass**

Data on the leaf dry mass (LDM) showed no Ca X B interaction, nor did Ca have any clear effect on the leaf dry mass.

Except for one sampling date (106 DAP), B levels caused no significant differences in the LDM during experiment 1 (Figure 2.1). However, B application rates of experiment 2 caused values to differ quite significantly towards the end of the growth cycle with the 0.1ppm B application rate having significantly higher values (Figure 2.2). This was probably caused by the accumulation of carbohydrates as well as leaves being thicker or having a higher density. It is common for leaves of B deficient plants to have thick and brittle leaves, a direct result of the need of adequate B for cell division and elongation (Shorrocks, 1989; Shorrocks 1992a).



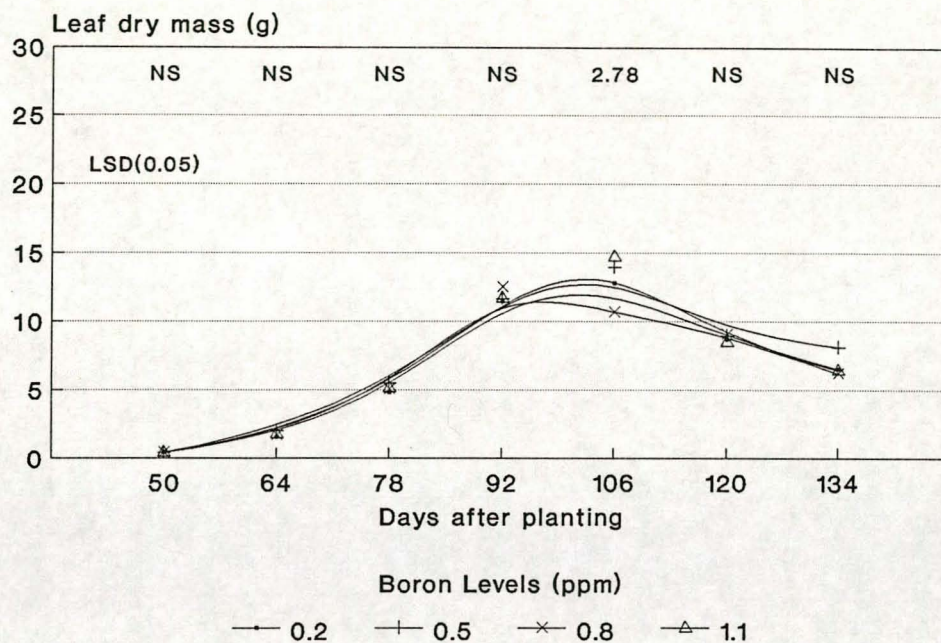


Figure 2.1 Leaf dry mass as affected by B levels during experiment 1.

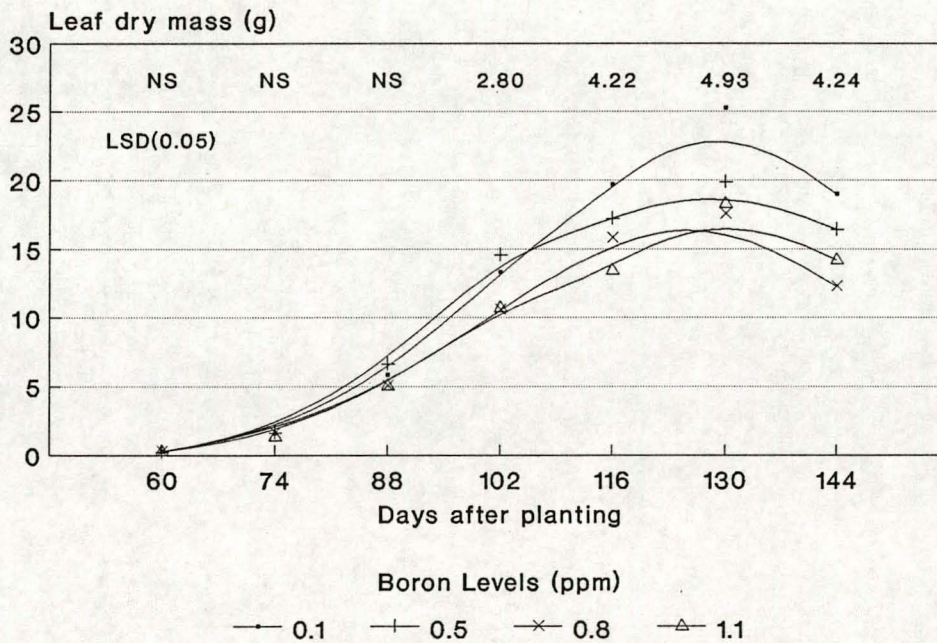


Figure 2.2 Leaf dry mass as affected by B levels during experiment 2.



## Main stem length

Growth of the main stem is shown in Figure 3.1 and 3.2. Initial stem growth is characterised by a rosette stage (80 DAP) in which internodes develop as the leaves are formed. According to Sylvester-Bradley, Makepeace & Broad (1984) no real increase in the length of stems occur during this stage. Lengthening of internodes does not take place and growth is only represented by initiation of leaves out of newly developed nodes. After the rosette stage (80 DAP), a rapid increase in the length of the main stem takes place, as was seen in both experiments. Growth mainly consisted of a lengthening of the internodes rather than the initiation of new nodes (Figure 3.1 & 3.2).

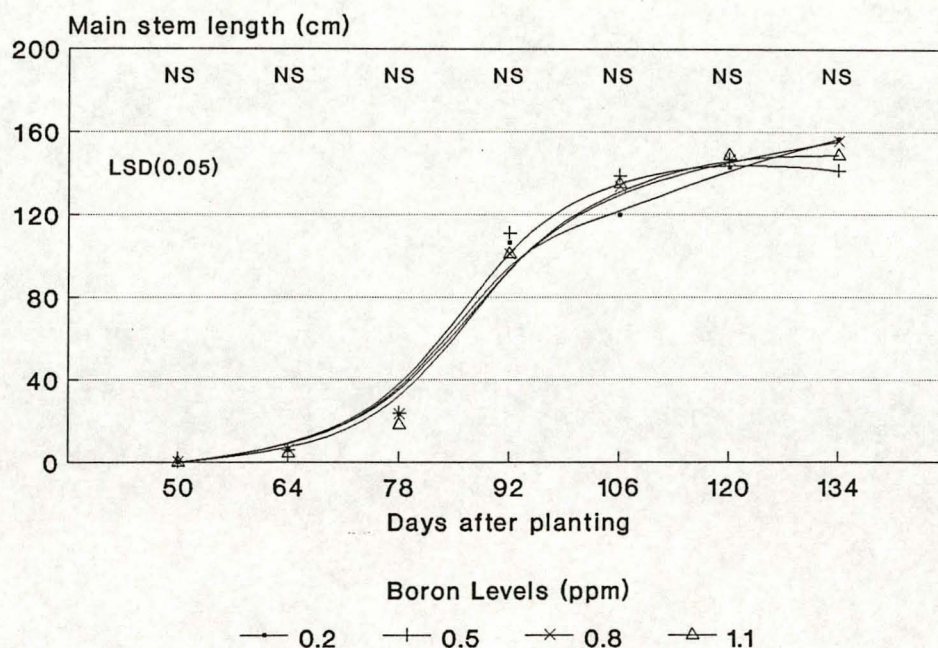


Figure 3.1 Main stem length as affected by B levels during experiment 1.



Main stems increased in length during both experiments until approximately 120 to 130 DAP whereafter no significant increases occurred. No consistent Ca X B interaction or Ca effect on growth of the main stem was found during either experiments. B applications did not affect main stem length in the first experiment (Figure 3.1). This was probably because the lowest B level (0.2 ppm) was adequate for growth. However, statistical significant differences between means of B treatments occurred in experiment 2 as the growing season progressed (Figure 3.2). At each of the sampling dates done after the rosette stage, the lowest B rate (0.1 ppm) produced plants that had consistently shorter main stems. The main meristems could have been detrimentally affected at their very active stage which led to a reduction in internode length.

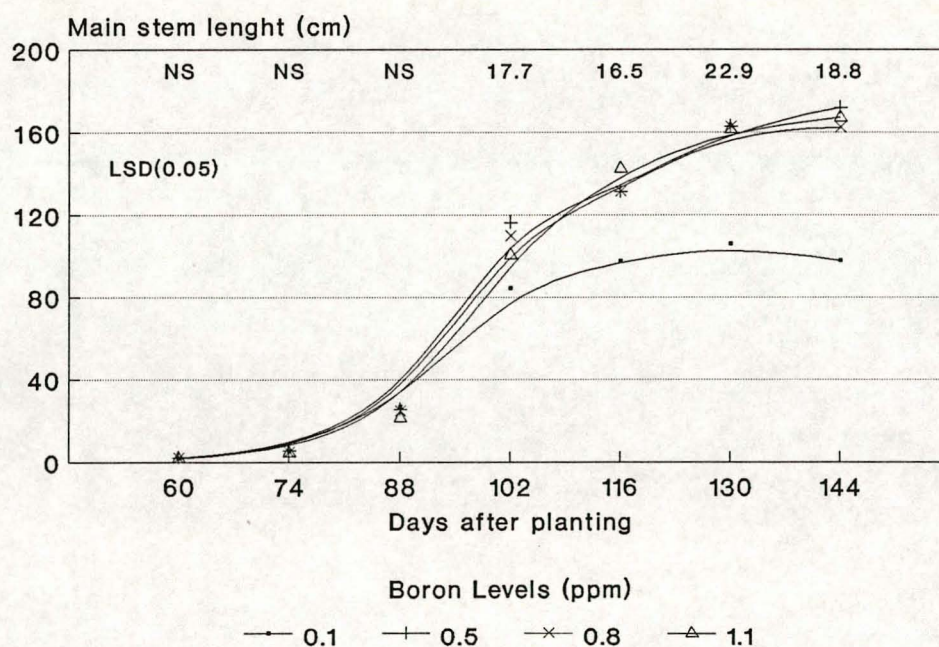


Figure 3.2 Main stem length as affected by B levels during experiment 2.



### Main stem dry mass

No consistent interaction between Ca and B was found during both experiments, nor did Ca show any clear effect on main stem dry mass (MSDM). During the first experiment mean B treatment values for MSDM showed the same trend as was found with stem length (Figure 4.1).

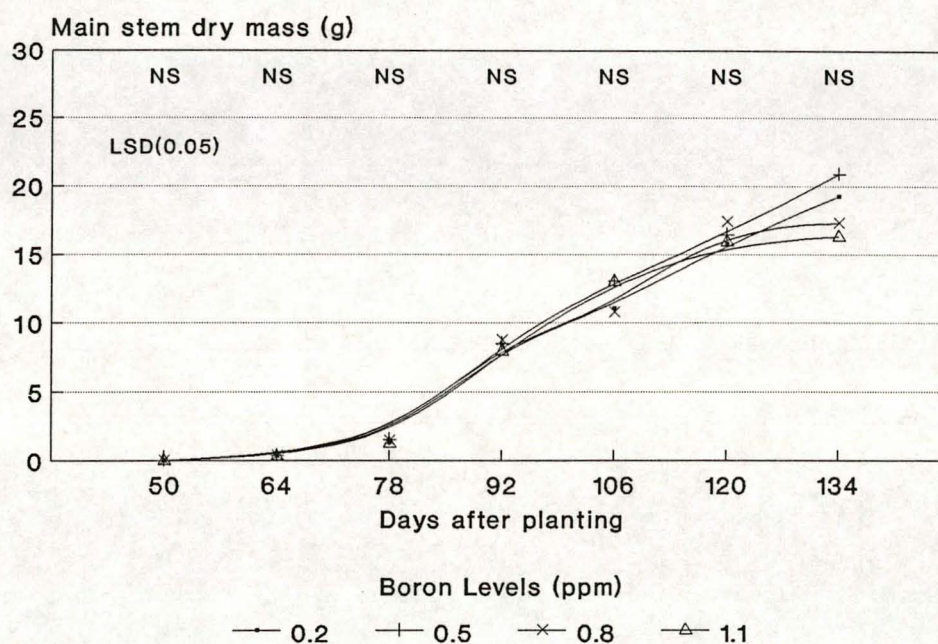


Figure 4.1 Main stem dry mass as affected by B levels during experiment 1.

The pattern of dry matter increase, during experiment 2, was more or less similar to results of the first experiment, except for the 0.1 ppm B treatment which led to significantly lower values of MSDM towards the end of the growth cycle (Figure 4.2). The difference between the 0.1 ppm B application and higher applications



were, however, not of the same order as those of the main stem length data (Figure 3.2 & 4.2). Plants given only 0.1 ppm B had shorter stems, but the mass of these stems were close to those of other treatments, indicating that these stems were thicker.

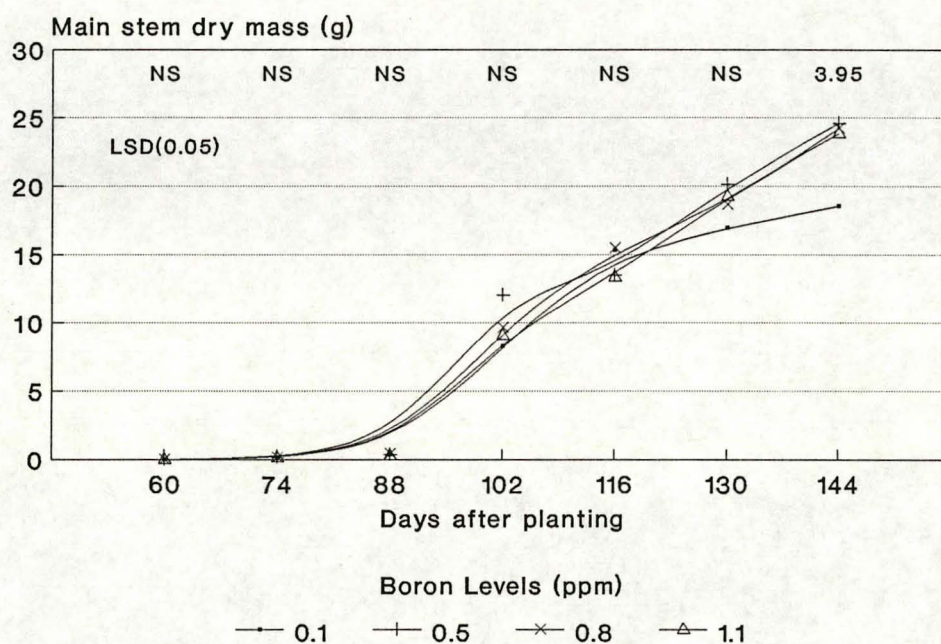


Figure 4.2 Main stem dry mass as affected by B levels during experiment 2.

### Flower bud development

Although it can be argued that the development of the primary raceme and that of auxiliary axes is part of the reproductive growth, the development thereof up to the



completion of flowering will be discussed here, as it is primarily responsible for photosynthesis during grain filling and greatly contributes to the total dry mass (TDM) of plants (Brar & Thies, 1977).

Development of lateral shoots is shown in Figures 5.1 and 5.2. Lateral branches are initiated in succession on the main stem after development of the terminal raceme. Further development of lateral branches takes place as main stem elongation nears completion.

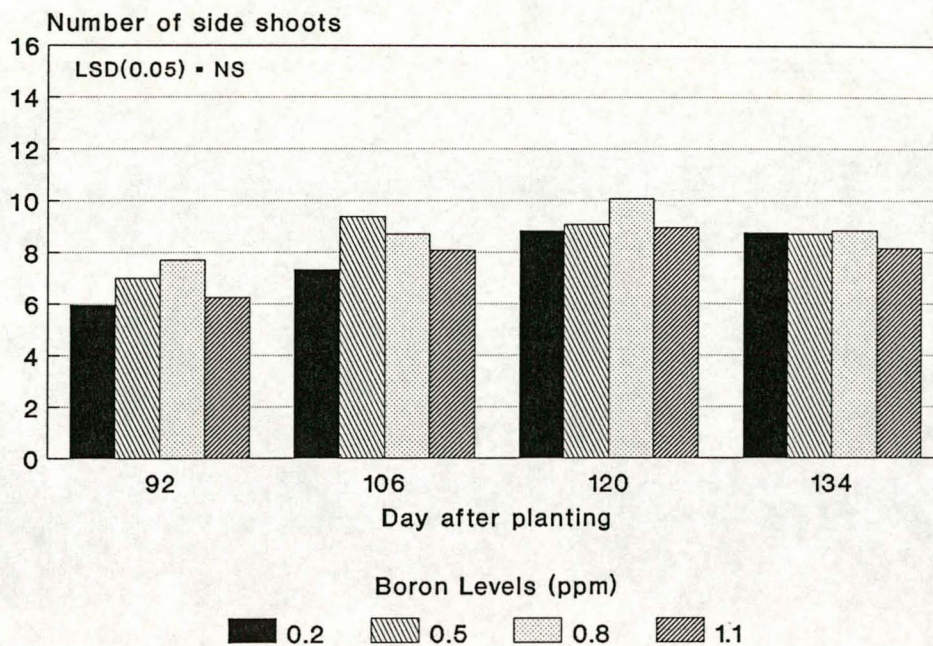


Figure 5.1 Number of side shoots as affected by B levels during experiment 1.



Side shoots were counted from 92 and 102 DAP respectively during the first and second experiment and at each sampling date that followed. The number of side shoots formed was not significantly affected during the first experiment. Decreasing the lowest B rate in the second experiment to 0.1 ppm, almost doubled the number of side shoots formed after 106 DAP (Figure 5.2). As B is closely related to the activity of meristems, especially apical meristems (Jackson, Chapman, 1975), it may be concluded that B supply was insufficient for the apical meristem to function properly. A loss of apical dominance resulted which led to an increased number of side shoots.

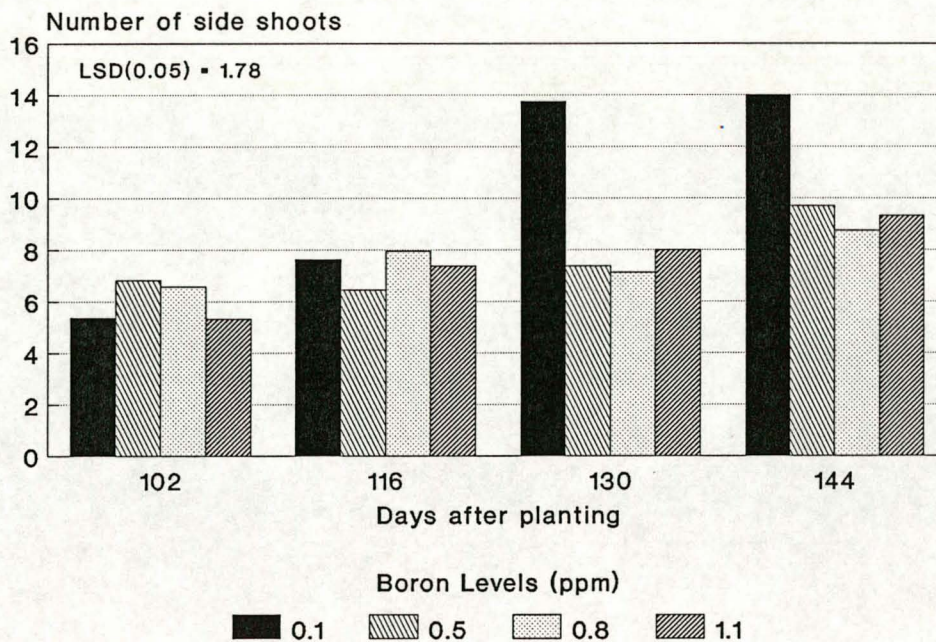


Figure 5.2 Number of side shoots as affected by B levels during experiment 2.



The data on total length of lateral branches show quite significant increases after approximately 90 to 100 DAP in both experiments for all the treatments (Figure 6.1 & 6.2). No consistent Ca X B interaction was found. Statistical analysis of the total length of lateral branches of the first experiment showed meaningful differences between the lower and higher rates of B applied as well as an interaction between Ca and B (data not shown). This interaction was, however, of no importance as it was not found in the results of the second experiment where Ca application rates differed even more.

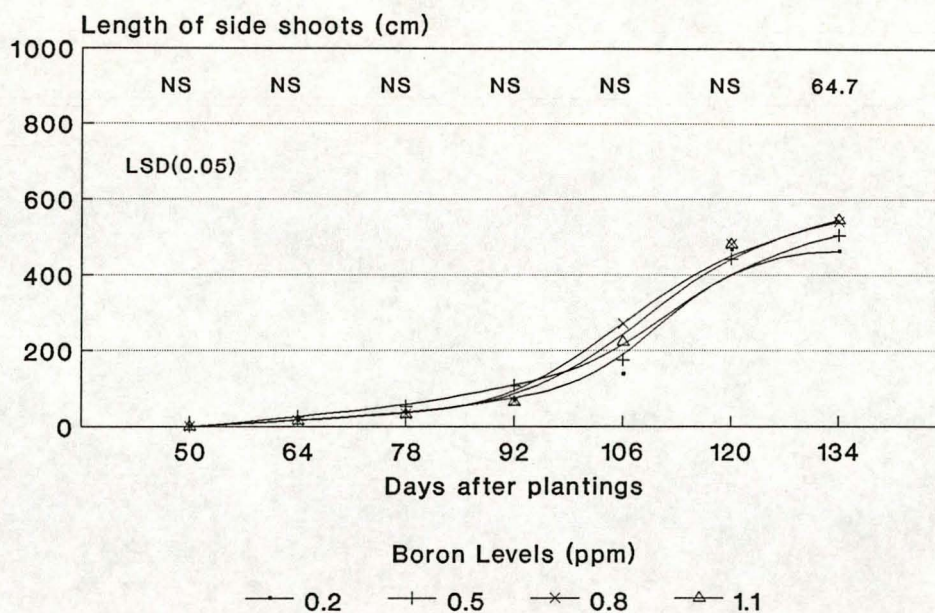


Figure 6.1 Total length of side shoots as affected by B levels during experiment 1.



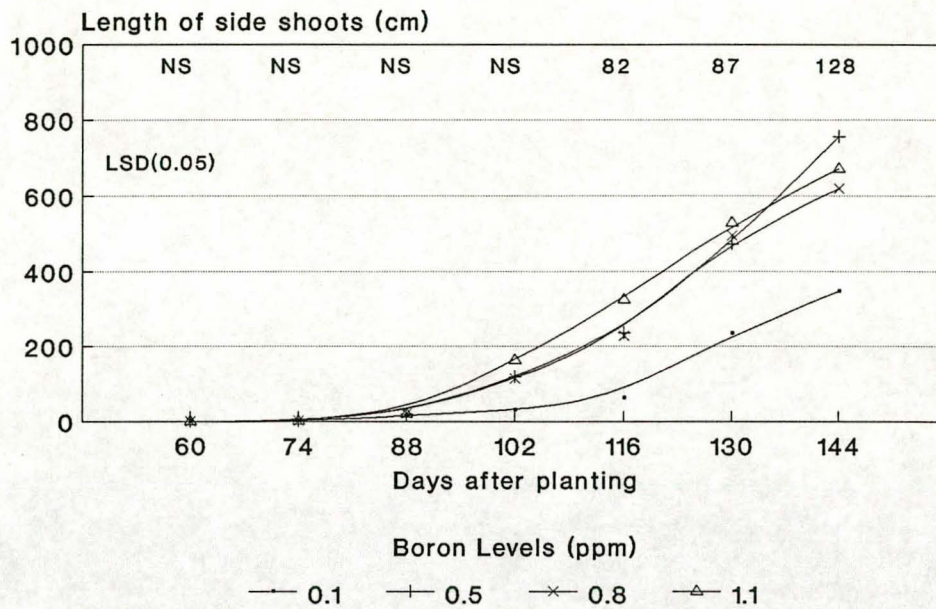


Figure 6.2 Total length of side shoots as affected by B levels during experiment 2.

In the first experiment, side shoot length was significantly reduced by 0.2 ppm B, at a relatively late stage (134 DAP). In the second experiment, 0.1 ppm reduced the total side shoot length at an earlier stage, at 116 DAP (Figure 6.1 & 6.2). This occurred in spite of the fact that more side shoots were formed (Figure 5.2) that would indicate a definite negative affect of low B on the length of individual shoots.



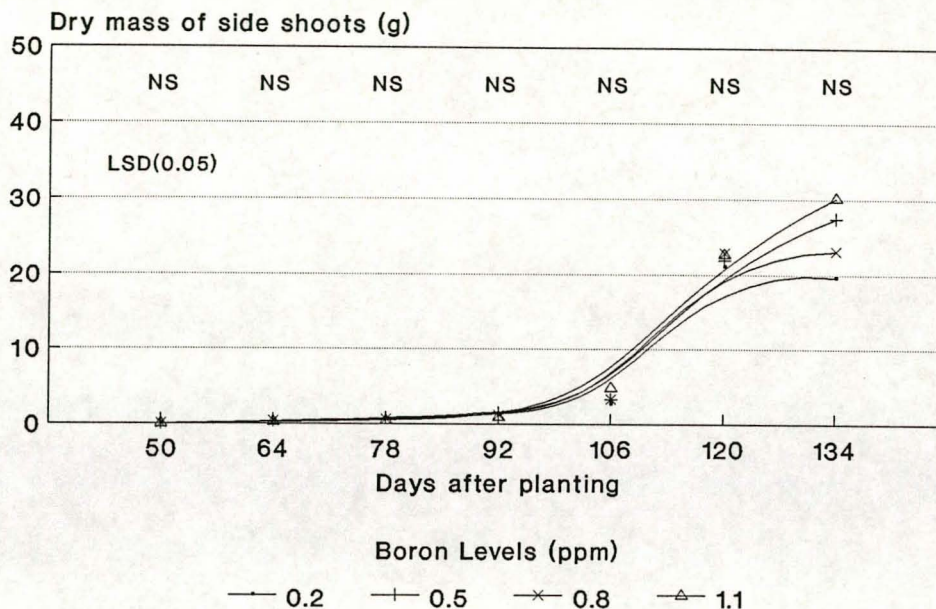


Figure 7.1 Dry mass of side shoots as affected by B levels during experiment 1.

The total dry mass of the lateral branches, as effected by B rates, are shown in Figures 7.1 and 7.2. Total dry mass of lateral branches showed marked increases from 106 and 102 DAP during experiment 1 and 2 respectively. This substantial increase in dry mass was not matched by the increases in length. This was possibly because of the further secondary branching of auxiliary axes observed, as well as some possible thickening of lateral growth as the inflorescence reached maturity.



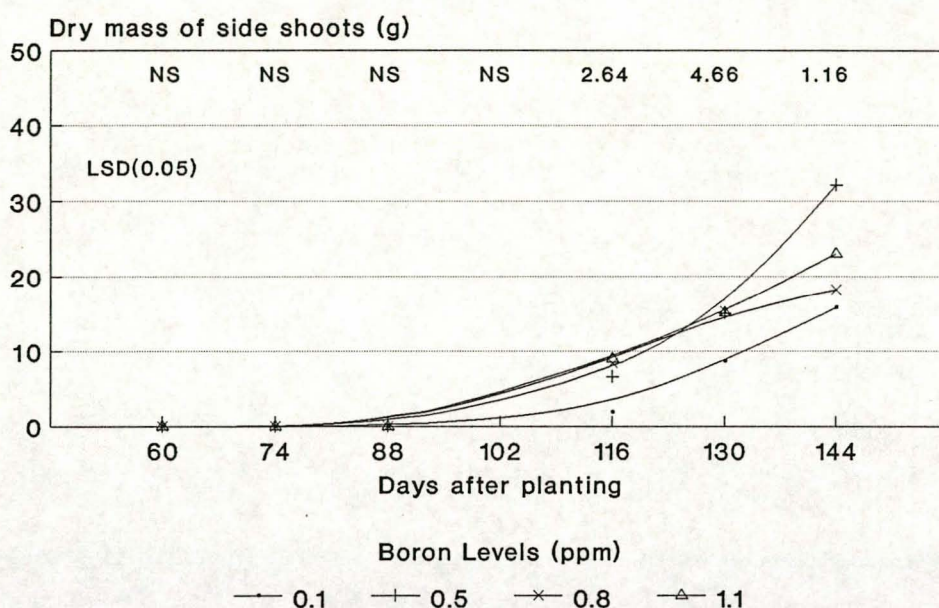


Figure 7.2 Dry mass of side shoots as affected by B levels during experiment 2.

### Root dry mass

Dry matter accumulation in roots was affected by B as shown in Figures 8.1 and 8.2. Dry mass of roots continued to increase right up to the last sampling date during both experiments. As with most of the parameters measured, the low B levels were not limiting during the first experiment, except for a slightly poorer performance at 134 DAP. Lowering of the B1 treatment to 0.1 ppm in the second experiment reduced the growth of roots and caused a reduction of root dry mass towards the end of the growth cycle. This was mainly due to breakdown of the cortex of the primary root with a resulting dieback of lateral roots.



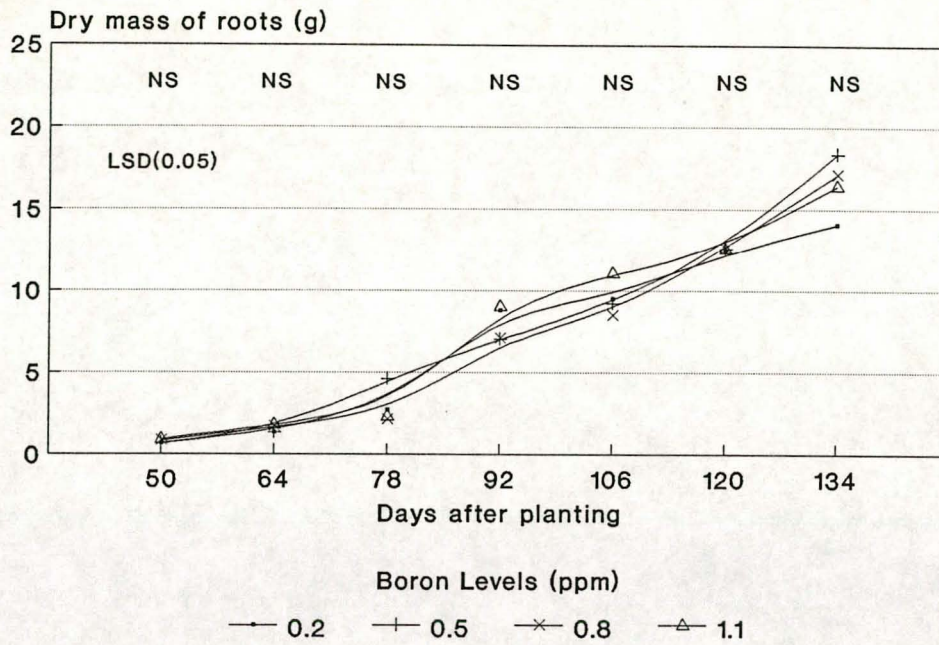


Figure 8.1 Root dry mass as affected by B levels during experiment 1.

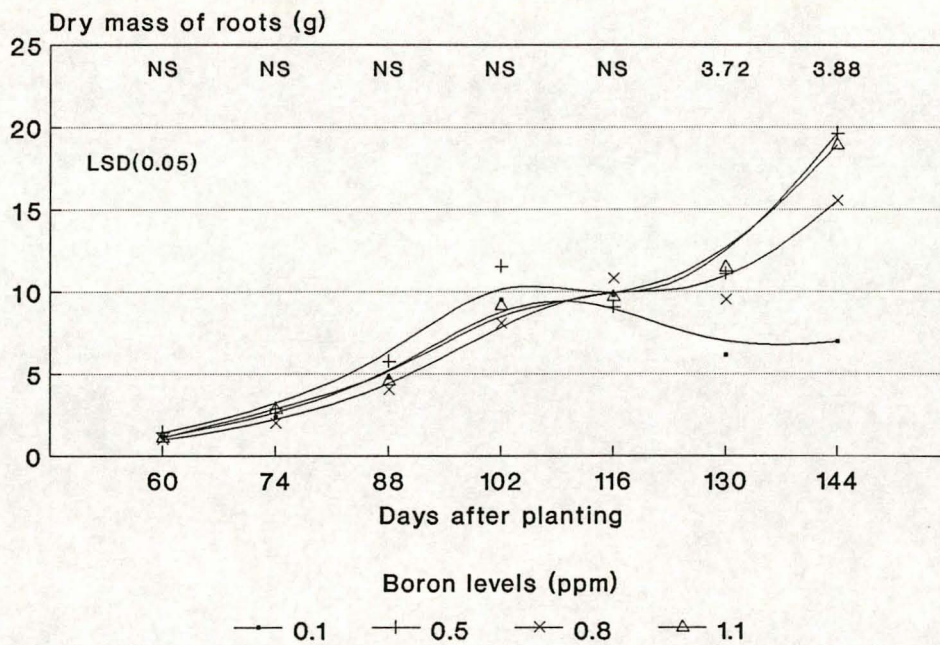


Figure 8.2 Root dry mass as affected by B levels during experiment 2.



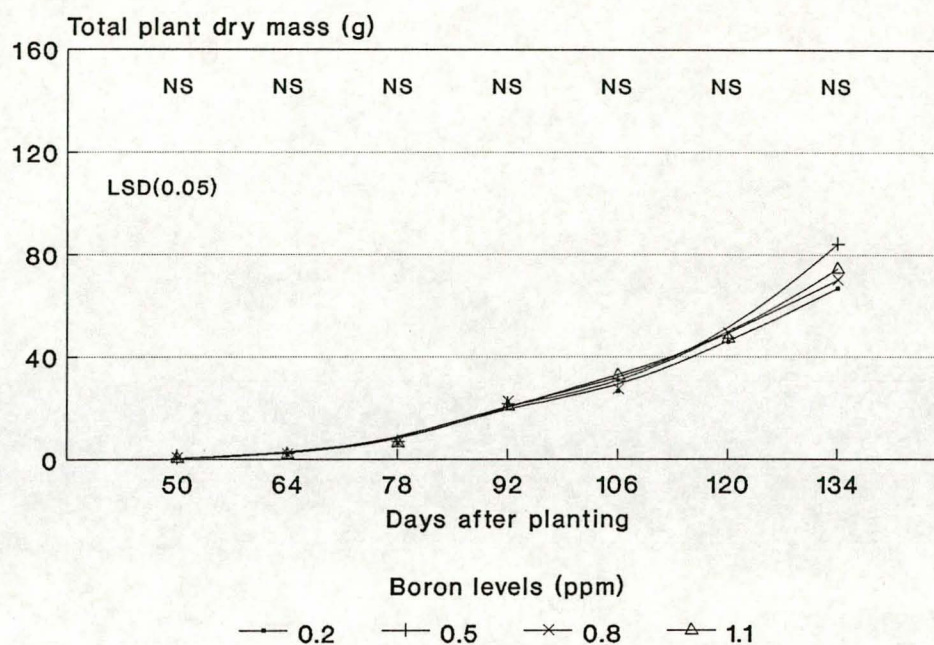


Figure 9.1 Total plant dry mass as affected by B levels during experiment 1.

### Total plant dry mass

Total dry mass (TDM) of plants (above ground) in 1992 is shown in Figure 9.1. No effect of Ca or any interaction with B was shown. No statistical significant differences in TDM of plants among B levels could be found during the first experiment.



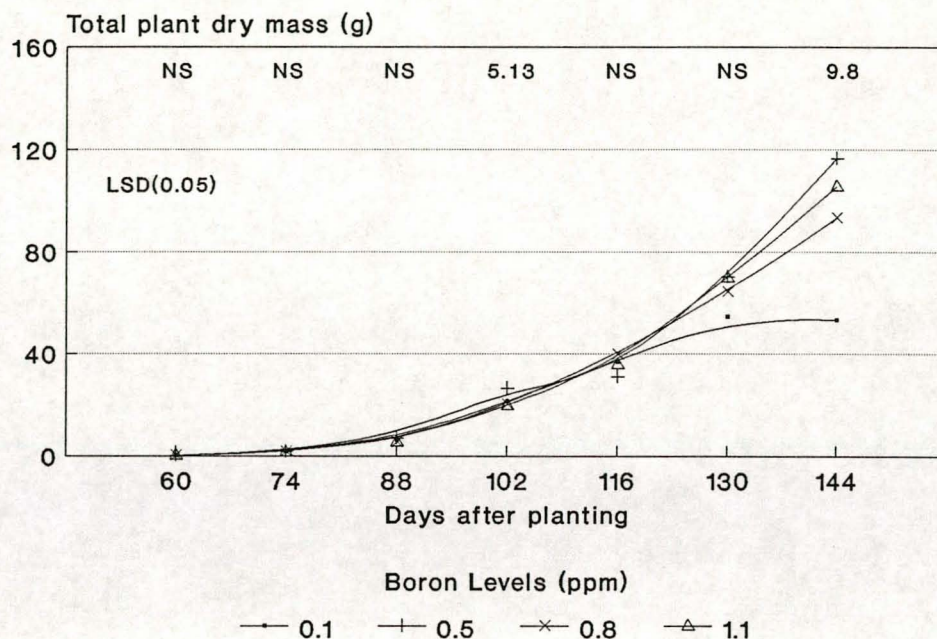


Figure 9.2 Total plant dry mass as affected by B levels during experiment 2.

TDM during 1993 is shown in Figure 9.2. No effect of Ca or interaction with B was shown. TDM continued to increase right up to the last sampling date except for plants receiving the lowest B concentration which failed to match the growth of those receiving higher levels of B. Differences were statistically significant at most of the sampling dates towards the end of the growth period. Apart from the fact that treatments differed between the two experiments, the slight difference in values between years of corresponding sampling dates could be attributed to seasonal effects as well as the fact that nutrient application commenced sooner after planting during the second experiment.

## CONCLUSION

Many previous studies dealing with the effect of B mainly concentrates on yield and yield components. Literature on the effect of B on vegetative growth is scarce.

A well known occurrence in plant nutritional studies, is the interaction between Ca and B in uptake, the one being antagonistic towards the other (Reeve & Shive, 1944; Gupta 1979). Although some interaction was found in this study, no clear pattern was experienced during both trials. It was, however, observed during the second experiment, where Ca application rates differed more, that B deficiency symptoms were more severe at the highest level of Ca than at the lowest level.

It seems to be difficult to induce a Ca-deficiency in canola. Although a relatively low level of Ca was used in experiment 2, no deficiency symptoms developed. This may be due to the fact that nutrients were supplied with the irrigation water on a daily basis, or the ability of canola to tolerate low Ca-levels.

Although the effect of B on growth components was not clear, some variables were affected, especially when less than 0.2 ppm B was applied. During the first experiment, B levels had almost no effect on the variables measured. Most variables were, however, significantly affected by lowering of the lowest B rate during the second experiment.

Contrary to the expected, application of B at 0.2 ppm, which is below the norm for normal growth (Steiner 1984), had almost no effect on vegetative growth of canola. Application of levels below 0.2 ppm did, however, cause a failure of normal vegetative growth. Of the parameters measured, length of main and side stems were the most sensitive with leaf area exhibiting high tolerance to B deficiency. Since leaf area was not significantly reduced by low B levels, yield increases caused by added B, as recorded by other studies (Meyers, Lipsett & Kirchner, 1983; Nuttall *et al.*, 1987; Teuteberg 1978; Zojonc, Borchmann & Rohl 1985) must therefore be due to a requirement of B by canola for reproductive growth and not in increased vegetative growth.

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## CHAPTER II

# THE INFLUENCE OF BORON AT DIFFERENT CALCIUM LEVELS ON THE GROWTH, YIELD AND MINERAL CONTENT OF CANOLA, *Brassica napus* L. II. REPRODUCTIVE GROWTH.

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### Abstract

Oilseed rape were grown in pots in two green house trials during 1992 and 1993. Plants received 2 calcium (Ca) rates and 4 boron (B) rates in a factorial design. During the first experiment B rates were 0.2, 0.5, 0.8 and 1.1 ppm. During the second experiment the lowest B rate was lowered to 0.1 ppm. Ca rates were 117.4 and 182.1 during the first experiment and 56.7 and 182.1 ppm during the second experiment. Ca had no significant effect on the parameters measured, nor did it show any interaction with B. B application rates during the first experiment had no significant effect on the amount of pods, pod weight, seeds per pod, thousand kernel weight or dry weight of crop residue, but did affect the amount and weight of seeds produced per plant. During the second experiment low B(0.1ppm) had a significant effect on the formation of pods and the production of seeds. The amount of pods, pod weight, seeds per pod, seeds per plant, seed weight per plant, dry weight of crop residue and harvest index (HI) were all negatively affected. High B (1.1ppm) had a positive effect on the thousand kernel weight (TKW).

**Keywords:** Boron, calcium, canola, reproductive growth

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## INTRODUCTION

Although the primary role of Boron (B) in plants is still not fully understood a lot of work has illustrated it's effect on plant growth and development (Odhnoff, 1957; Jackson & Chapman, 1975; Cohen & Lepper, 1977; Dear & Lipsett, 1987 ). It is,

however, known that B is required for the germination of the pollen grain and growth of the pollen tube (Garg, Sharma & Kona, 1979) presumably due to the need for B in cell division and expansion (Shorrocks, 1989).

Although numerous papers report on increases in the seed yield of canola with application of B (Teuteberg, 1978; Meyers, Lipsett & Kirchner, 1983; Zajonc, Borchmann & Rohl, 1985; Meng & Zou, 1988; Yang, Xu, Jie & Wang, 1989), an expected vegetative reaction to B during our previous studies with nutrient solutions was poor. It showed that B had no significant effect on the vegetative growth of canola except when extreme low rates of 0.1 ppm B were applied (Chapter I). At this low B rate the main effect was the production of a shorter plant with more lateral branches. The above mentioned increases in seed yield must therefore be the result of an affect of B on the reproductive growth.

Teuteberg (1978), ascribed the positive response in seed yields with applications of B, to an increase in the number of seeds per pod. Nuttall, Ukrainetz, Steward & Spurr (1987) concluded that the explanation for yield responses in the absence of clearly defined symptoms is most likely the requirement of B in pollination and in particular for the growth of the pollen tube.

The object of this study was to determine the influence of B on the reproductive growth and if any, to explain, the reason for yield responses.

## **MATERIALS AND METHODS**

The experiments were conducted in a temperature controlled greenhouse using a sand culture hydroponic system for nutrient application. Other details regarding treatments, nutrient solution, crop culture and experimental design were as described in the previous chapter (Chapter 1).

Pods from different parts of the plant were sampled prior to normal harvesttime, at a stage when pods were fully mature, but not susceptible to shattering. Pod mass and numbers were determined as well as the number of seeds it contained. At harvest seeds were thrashed out, weighed and counted. The amount of crop residue of each plant was determined and used to calculate the harvest index.

Data was subjected to statistical analysis of variance using the Genstat 2.2 software application in order to test significance of treatment effects. Mean values were compared using the least significant difference (LSD) at the 5% probability level by means of the student T test.



## RESULTS AND DISCUSSION

### Pods per plant

Different Ca levels failed to produce significant differences in both experiments. However, in the second experiment, the number of pods per plant tended to decrease when the high Ca level was applied at low B levels (Figure 1). This indication of a Ca X B interaction was, however not significant.

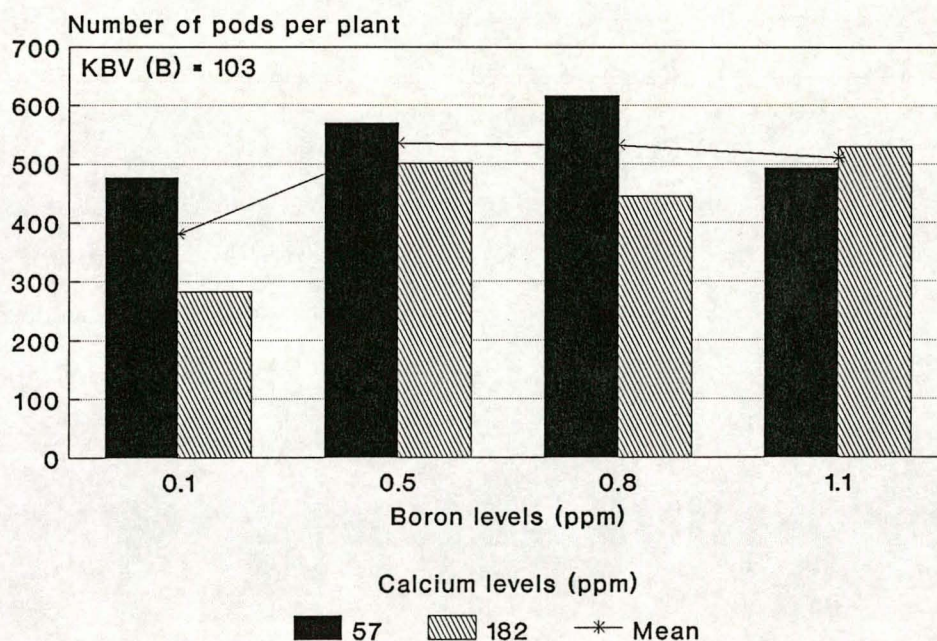


Figure 1. Number of pods as affected by Ca and B levels during experiment 2.



Although the B levels caused no statistical significant differences in the number of pods per plant during the first experiment, a tendency of less pods per plant was visible at the lower application rate of 0.2 ppm B (Table 1). During the first experiment an application of 0.5 ppm B gave the highest number of pods per plant with higher application rates causing a slight decrease (Table 1).

More pods per plant were formed during the second experiment which can be attributed to seasonal differences in light intensity. Temperature was controlled and differences in the number of productive, pod carrying lateral branches between years were minimal. The second experiment showed a significant decrease in the number of pods per plant at the lowest B rate. Although the lowest B rate produced significantly less pods per plant, the differences between higher B applications were insignificant (Table 2). As was the case in the first experiment, the highest number of pods were formed where 0.5 ppm B was applied.

The plants that received the 0.1 ppm B treatment, tended to produce more branches (Chapter 1). These branches did not increase the pod yield since most of the flowers aborted and pods that did form, failed to fill.

Table 1. The effects of calcium (Ca) and boron (B) on the number of pods per plant, pod mass per plant, seeds per pod, seeds per plant, seed mass per plant, thousand kernel mass (TKM), dry mass of crop residue and the harvest index (HI) in the first experiment (1992).

TREATMENT (ppm)	Pods per plant	Pod mass (g/plt)	Seeds per pod	Seeds per plant	Seed mass (g/plt)	TKM	Crop Res.(g/plt)	HI
Ca1 = 117	329	28.67	20.7	6507	24.60	3.760	105.5	19.09
Ca2 = 182	327	26.76	19.4	6239	23.92	3.857	97.2	19.80
LSD(P ≤ 0.05)	NS	NS	NS	NS	NS	NS	NS	NS
B1 = 0.2	286	26.04	15.5	4336	16.17	3.851	101.5	14.37
B2 = 0.5	370	30.85	18.7	6699	25.08	3.744	102.9	19.79
B3 = 0.8	333	26.83	23.3	7529	28.34	3.764	104.5	21.28
B4 = 1.1	324	27.15	22.7	6929	27.45	3.962	96.5	22.35
LSD(P ≤ 0.05)	NS	NS	NS	1261	5.69	NS	NS	4.07

Table 2. The effects of calcium (Ca) and boron (B) on the number of pods per plant, pod mass per plant, seeds per pod, seeds per plant, seed mass per plant, thousand kernel mass (TKM), dry mass of crop residue and the harvest index (HI) in the second experiment (1993).

TREATMENT (ppm)	Pods per plant	Pod mass (g/plt)	Seeds per pod	Seeds per plant	Seed mass (g/plt)	TKM	Crop Res.(g/plt)	HI
Ca1 = 57	420	32.5	9.6	4921	20.8	4.49	70.0	28.2
Ca2 = 182	369	33.2	12.4	5460	23.1	4.53	86.2	24.7
LSD(P ≤ 0.05)	NS	NS	NS	NS	NS	NS	NS	NS
B1 = 0.1	380	6.72	2.6	1037	4.5	3.88	54.4	7.4
B2 = 0.5	535	43.3	14.7	6909	28.3	4.14	92.2	32.1
B3 = 0.8	531	43.7	16.0	7659	31.0	4.07	88.4	35.1
B4 = 1.1	511	44.4	10.6	5159	23.9	5.94	77.4	31.3
LSD(P ≤ 0.05)	103	6.5	6.1	2823	9.86	2.39	23.0	7.8

### Mass of pods per plant

As with the amount of pods formed, B application had no effect on the dry weight of pods per plant during the first experiment (Table 1). No Ca effect or Ca x B interaction could be found. During the second experiment an increase in Ca tended to have a negative effect on the pod mass per plant at the low B rate (Figure 2). No significant interaction with B could, however, be found. At the low B level, a significant reduction in the mass of pods per plant was found with almost no difference between the three higher B rates (Table 2).

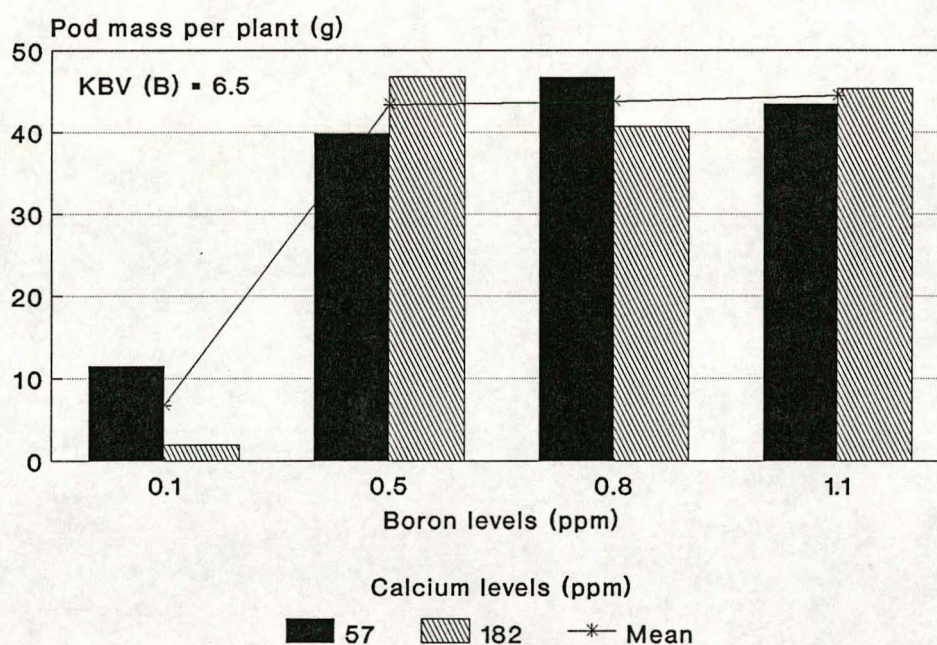


Figure 2. Pod mass as affected by Ca and B levels during experiment 2.

The fact that mass and number of pods per plant were similarly affected by B applications during both experiments, is an indication that B did not affect pod size. At the lowest B rate this statement does however not apply, as it was noted that pods seemed to be larger than those of the high B treatments during the first experiment, but small and shrivelled during the second. Differences between treatment means were only significant during the second experiment where the 0.1 ppm B rate severely lowered the dry weight of pods. This gives reason to believe that as with vegetative growth (Chapter I), only severe deficiency of B, would affect pod initiation which seems to be less sensitive to B deficiency than the formation of seeds.

### **Seeds per pod**

The number of seeds that were produced per pod is shown in Table 1 and Table 2. Seed set was clearly influenced by B rates although differences were only significant during the second experiment. Values of the first experiment show an increase in seed set with higher rates of B applied. The rate of 0.1 ppm B during the second experiment seemed to be insufficient for normal seed set as very little seeds were formed per pod. The maximum number of seeds were produced with the 0.8 ppm B rate. Application of B rates higher than 0.8 ppm seemed to have some detrimental effect on seed set (Table 2).



Data on the influence of Ca on seed set was inconsistent. No significant differences between application rates or interaction with B were present during both of the experiments.

### **Seeds per plant**

The number of seeds produced per plant in both experiments is shown in Table 1 and Table 2. Boron had a clear effect on the amount of seeds produced as differences between treatment means were significant during both experiments. The number of seeds produced increased as the B application increased except in the second experiment where applications higher than 0.8 ppm caused values to drop significantly.

The effect of Ca on the seeds produced was inconsistent. No statistical meaningful differences or interaction with B could be found.

### **Seed mass per plant**

The effect of B on the mass of seed per plant was significant for both experiments. The seed yield reduced dramatically below 0.2 ppm B. Higher levels of B caused plants to produce more seed, except for applications beyond 0.8 ppm in the second experiment. No Ca effect or interaction with B was noted.

### **Thousand kernel mass**

Neither B nor Ca had any influence on the size and mass of individual seeds produced during the first experiment nor were any Ca x B interaction present (Table 1).

During the second experiment the application of 1.1 ppm B did, however, cause the mass of seeds to increase significantly (Table 2). This may indicate some positive effect of high B applications on the processes involved in the development of seeds. No Ca effect or interaction with B was noted.

### **Dry mass of Crop Residue**

The crop residue, an indication of the biomass used to produce seed, is shown in Table 1 and Table 2. During the first experiment, B rates had no significant influence on the vegetative growth (Chapter I) or crop residue mass (Table 1). The vegetative growth (Chapter I) and crop residue (Table 2) were, however, influenced during the second experiment where the lowest B rate of 0.1 ppm failed to produce plants of comparable size.

As most of the crop residue predominantly consist of stalk and relatively little is contributed by the chaf of the pods, it can be reasoned that the size of the plants and had the greatest influence on the amount of crop residue available. To further

motivate this statement, there were no significant differences in the amount of pods carried among higher B rates applied. It can therefore be reasoned that the crop residue is a function of the vegetative growth and that this result confirm the reaction of vegetative growth to B application as was found during the previous study (Chapter I).

### **Harvest index**

The proportion of seeds produced in relation to the crop residue, the harvest index (HI), is shown in Table 1 and Table 2. No Ca effect or Ca x B interaction was found during both experiments. The B applications did however have a marked effect on the HI during both experiments. As B had no significant influence on the crop residue produced in the first experiment, differences in HI (Table 1) can largely be attributed to differences in seed yield rather than differences in the biomass available to produce yield.

### **CONCLUSION**

Many plant nutritional studies report interaction between Ca and B where it was found that B uptake is inhibited by high Ca levels (Kabata-Pendias & Pendias 1991). No difference between Ca application rates or any significant Ca x B interaction was found in any of the parameters measured during both experiments.



It was, however, noted that the detrimental effect of the lowest B level on the number of pods and pod mass per plant was more pronounced at the high Ca level in the second experiment (Figure 1 & 2).

B had a clear effect on the amount of seeds produced per plant. During the first experiment the effect of B on the amount of pods formed, pod weight per plant or the amount of seeds per pod was not clear although some indication of a negative effect at the lowest B rate could be seen. However, the accumulated effect of this resulted in a marked effect of B on the amount of seeds per plant, seed mass per plant and the HI.

Lowering the lowest B rate from 0.2 to 0.1 ppm during the second experiment, did cause plants to have significantly less pods, a lower pod weight per plant, and less seeds per pod. The number of seeds per plant, seed mass per plant and the HI were also detrimentally affected by the low B-level.

Some workers attributed a negative effect of low B on yield to less seeds per pod formed, rather than less pods per plant formed (Nuttall *et al.*, 1987; Zajonc *et al.*, 1985). Whether or not the reduced production of seed at B rates below 0.2 ppm was caused by less pods per plant formed or less seeds per pod could not be seen as B had no effect on either of these parameters during the first experiment. During the second experiment lowering the lowest B rate to 0.1 ppm affected both of these parameters, again making it difficult to conclude the reason for loss of seed production. The findings of Nuttall *et al.* (1987) who ascribed a yield

response to B in the absence of clearly defined symptoms to the requirement for B in pollination, strongly suggest that similar effects were achieved during these experiments.

It is the opinion of the authors that application of B at levels higher than that which would sustain normal vegetative growth, would not affect the amount of pods formed. The effect of low B levels on yield is probably caused by less seeds per pod through the effect of B on pollination. Below a B-level that would sustain normal vegetative growth, the formation of pods would be negatively affected, with the resulting loss of yield.

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ZAJONC, I., BORCHMANN, W. & RÖHL, W., 1985. Effect of timed boron applications on the yield components of spring rape. From abstract in *Field Crop Abstracts* 40(3), 1642.



## CHAPTER III

# THE INFLUENCE OF BORON AT DIFFERENT CALCIUM LEVELS ON THE GROWTH, YIELD AND MINERAL CONTENT OF CANOLA, *Brassica napus* L. III. MINERAL CONTENT.

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### Abstract

Oilseed rape plants were grown in pots in a green house trial during 1993. Plants received 2 calcium (Ca) rates and 4 boron (B) rates in a factorial design. B rates during this experiment were 0.1, 0.5, 0.8 and 1.1 ppm and Ca rates were 56.7 and 182.1 ppm. Leaf, stem and pods were analyzed at different sampling dates to determine the influence of Ca and B application on the accumulation of elements in different plant organs. The data confirmed that levels of all elements vary between plant tissues and with their physiological age. Ca, Mg, Mn and B tend to build up in the leaf tissue of the plant while N, P, K, Na, Cu, Zn and Fe were diluted at rates that depended on the growth of the specific plant part analyzed. The effect of applied Ca on plant Ca content was small and Ca effects on the concentrations of most elements were very small or negligible and unclear. Some effects on K and Mg were observed and can be explained by differences in the concentrations applied due to cation corrections. Low B (0.1 ppm) resulted in elevated levels of N, P, K, Ca and Mg in the main- and side stem tissue which was probably caused by a reduction in growth of these plant parts induced by B deficiency. The only consistent effect of B was a negative effect on the Mn content of all of the tissue analyzed. B appeared to accumulate in the leaf, but not in the stem as the plants aged, making the latter more suitable for analysis when physiological age of tissue cannot be accounted for. Low B (0.1 ppm) caused low B values in stem tissue but increasing B levels did not increase the B concentrations in tissue to follow linearly. This could give a false indication of availability of B as higher B applications were not reflected in tissue levels. As B tend to accumulate in leaf tissue the physiological age of leaf tissue is therefore critical when used for analysis. B content in leaf tissue followed the application rates more closely than that of other tissue analyzed and gave a better indication of availability of B, but was dependant on the physiological age of the tissue.

**Keywords:** Boron, calcium, canola, mineral-content

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## INTRODUCTION

Boron (B) deficiency in several plant species is a common problem so that B is often applied to a variety of commercial crops (Shorrocks, 1992). The B content of plants grown under commercial conditions varies widely with plant species, climate and soil. In general, dicot plants tend to have a higher content of B and thus a higher requirement than monocot plants (Kabata-Pendias & Pendias, 1991).

Being a member of the Cruciferae and in particular the Brassicas, canola is described as a B sensitive crop (Bruchlos & Bergman, 1979). A 4t.ha<sup>-1</sup> seed yield (12-15 ton dry matter) contains a total of approximately 320 g.ha<sup>-1</sup> B of which 25% is removed in the seed (Shorrocks, 1992). Substantial increases in the yield of canola following B application, have been reported and numerous papers have seen the light on the beneficial role of B in seed production of canola (Nuttall *et al.*, 1987; Teuteberg, 1978; Zajonc, Borchmann & Röhl, 1985).

Information regarding the influence of B supply on the availability, concentration and distribution of various other major nutrients in the canola plant is, however, lacking. It is generally believed that increased availability of nutrients in the root medium should have some direct relationship with the concentration of such nutrients in the plant tissue. However, the availability of a given nutrient may interact with the uptake and/or requirement of other nutrients and thus alter the nutritional status of the plant.

Interactions between B and the uptake of other elements are apparently related to changes in membrane permeability and the status of cell colloids (Shorrocks, 1989). The physiological basis of these interactions is still uncertain.

Some cases of interaction of B with Fe, Cu, Mn, Mo and Si have been reported (Kabata-Pendias *et al.*, 1991). Several of these interactions have not yet been confirmed. Some cases of antagonism may indirectly result from increased growth which may increase the demand for other micronutrients.

The B-Ca interaction is probably one of the best known (Kabata-Pendias *et al.*, 1991). For plants to grow well, a certain balance needs to exist between the intake and tissue concentrations of Ca and B (Gupta and Cutcliffe, 1972). Lime-induced B deficiency has frequently been observed in acid soils. Some reports also describe an interaction of B and phosphorus (P) (Tanaka, 1967).

For fertilizer requirements of crops to be determined accurately and be met by nutrient application, there is a need to link fertilizer responses and soil analyses with plant tissue analyses. A sound knowledge of nutrient concentrations in various plant parts at successive stages in plant development may lead to a better understanding of nutritional problems of plants. This paper then studies the effect of B at different Ca levels on the nutrient content on canola plants.

## MATERIALS AND METHODS

The experiment was conducted in a temperature controlled glasshouse having a 25°C day and 16°C night temperature regime. Nine seeds of the cultivar Eureka, treated with insecticide (dimethoate) and fungicide (thiram), were planted in 6 L pots filled with 5.5kg of acid washed silica sand. Silica sand of a specific origin (Consol) was used. The sand was washed with 0.1 M HCl to ensure that it did not supply any nutrients. Acid washing was done by adding 1 L of 0.1M HCl to each pot and leaving it over night to react. Pots were then washed three times per day until the pH again reached a level of pH 5.6.

After emergence the plants were thinned out to five per pot. Each pot had one 8mm drainage hole at the bottom. Irrigation was done by an automated watering system. Pots received tap water after planting, followed by application of nutrient solutions through the irrigation system as soon as the cotyledons were visible. Frequency and amounts applied was adapted as the plants developed. About 20% over irrigation was applied to ensure that no buildup of nutrients occurred.

All nutrients were applied with the irrigation water and contained varying K, Ca and Mg ratios (Table 3) as two Ca treatments and four boron (B) levels ranging from 0.1 to 1.1 ppm (Table 2). The rest of the essential macro elements, N, P, S were supplied at concentrations as shown in Table 3. Trace elements (Table 1) were applied at concentrations as prescribed by Steiner (1984).



Ion concentrations of all ratios were balanced according to the method as described by Steiner (1984). An electric conductivity of  $2.1 \text{ mS cm}^{-1}$  and a pH 6.5 for all treatments, were kept constant in the experiment.

The experiment was laid out in a factorial design with 8 treatments (4B x 2Ca) and 4 replications. An experimental unit consisted of 5 plants. Sampling commenced as soon as the fourth leaf (60 days after planting) was fully developed and was repeated every fortnight up to the stage where seeds were beginning to form in the pods. Five plants were sampled randomly from pots during the early stages of the season, until one plant per pot remained. Sampling was then done by randomly taking 5 whole pots containing one plant for analysis.

Plants were separated into leaves, main stem and lateral branches. Material was sampled up to the end of the growth cycle to study the complete picture of the changes in mineral content of different plant parts throughout the season. Pods were analyzed after separating them into main stem and side stem pods.

Samples were prepared by drying at  $60^\circ\text{C}$  for 48 hours and milling through a 1 mm sieve to a fine powder. After dry ashing at  $480^\circ\text{C}$  and uptake in hydrochloric acid (HCl), P, K, Ca, Mg, Na, Cu, Zn, Mn, Fe, Al and B were determined using a direct current plasma spectrometer (DCP). Nitrogen was determined by the Kjeldahl method using selenium as a catalyst.

Data was subjected to statistical analysis of variance using the Genstat 2.2 software application. Student's least significant difference (LSD) was used at the 1% and 5% probability level to compare treatment means.

Table 1 Micro-element composition of nutrient solutions

COMPOUND	ELEMENT	ppm
FeNaEDTA(13%Fe)	Fe	1.33
MnSO <sub>4</sub> .H <sub>2</sub> O	Mn	0.62
ZnSO <sub>4</sub> .7H <sub>2</sub> O	Zn	0.11
CuSO <sub>4</sub> 5H <sub>2</sub> O	Cu	0.02
Na <sub>2</sub> MoO <sub>4</sub> 2H <sub>2</sub> O	Mo	0.05

Table 2 Rates of B (ppm) applied as H<sub>3</sub>BO<sub>3</sub> for B treatments

Treatment	B1	B2	B3	B4
B application rates	0.0	0.4	0.7	1.0
Irrigation water	0.1	0.1	0.1	0.1
Total(ppm)	0.1	0.5	0.8	1.1

Table 3 Cation ratios used as calcium (Ca) treatments.

CATION RATIO 1 (Ca1)						
	K <sup>+</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	NO <sub>3</sub> <sup>-</sup>	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>
Ratio (%)	55	15	30	60	5	35
meq L <sup>-1</sup>	10.4	2.8	5.7	11.1	0.9	6.5
ELEMENT	K	Ca	Mg	N	P	S
ppm	406	57	68	156	29	104
CATION RATIO 2 (Ca2)						
	K <sup>+</sup>	Ca <sup>2+</sup>	Mg <sup>2+</sup>	NO <sub>3</sub> <sup>-</sup>	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>
Ratio (%)	35	45	20	60	5	35
meq L <sup>-1</sup>	7.1	9.1	4.0	11.9	1.0	6.9
ELEMENT	K	Ca	Mg	N	P	S
ppm	276	182	49	166	31	111

## RESULTS AND DISCUSSION

Although sampling was done every 14 days, only leaf data collected at 60, 88, 116, 144 days after planting (DAP); stem data at 102, 116, 130, 144 DAP and pod data at 130 and 144 DAP is presented.

### Nitrogen

Neither Ca nor B had any clear effect on the N content of leaf tissue (LT). The higher Ca level tended to increase the leaf N-content at 88 DAP, but this effect disappeared at the later sampling stages (Table 4). Significant differences between B rates were found at 116 and 144 DAP, but were inconsistent. A dilution effect, due to the accumulation of carbohydrates as the plants developed or possible mobilization and translocation could explain the gradual decline in concentration of leaf-N between 60 and 144 DAP.

The N content of the main stem tissue (MST) showed a noticeable decline towards the end of the growth period, indicating a possible dilution effect caused by growth (Table 5). Ca had a positive effect on N concentration in the MST except at 144 DAP where a slight negative effect can be seen. The low B (0.1ppm) level increased the N in the MST towards the end of the growth period. This was probably caused by deficient levels of B, limiting DM production (Chapter I) and thus less dilution of the N rather than a direct effect of B on N uptake.



Table 4. Mineral content of leaves as affected by calcium (Ca) and boron (B) treatments at different growth stages of canola plants.

TREAT	N %	P %	K %	Ca %	Mg %	Na ppm	Cu ppm	Zn ppm	Mn ppm	Fe ppm	B ppm	Al ppm
<b>60 DAP</b>												
57 ppm Ca	5.746	0.563	7.488	1.822	0.908	1568	10.50	113.7	109.2	341	44.57	62.7
182 ppm Ca	5.821	0.563	7.266	1.876	0.847	1517	11.05	94.1	101.7	373	44.78	49.5
LSD	NS	NS	*	NS	**	NS	NS	**	*	NS	NS	**
0.1 ppm B	5.891	0.558	7.475	1.920	0.901	1619	10.91	98.9	121.9	333	14.89	57.5
0.5 ppm B	5.800	0.562	7.131	2.278	0.721	1389	10.66	102.2	128.8	357	50.81	54.0
0.8 ppm B	5.615	0.578	7.562	1.489	1.011	1640	11.17	102.2	106.9	377	50.94	67.2
1.1 ppm B	5.826	0.555	7.338	1.709	0.878	1523	10.35	112.2	64.2	360	62.06	45.7
LSD	NS	NS	*	**	**	**	NS	**	**	NS	**	**
Ca*B	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	**
<b>88 DAP</b>												
57 ppm Ca	4.620	0.576	9.292	2.614	0.963	1029	5.08	73.16	97.7	116.6	67.78	37.2
182 ppm Ca	4.811	0.580	9.205	2.483	0.881	997	5.27	57.83	91.1	116.4	55.91	25.7
LSD	*	NS	NS	**	**	NS	NS	*	*	NS	**	NS
0.1 ppm B	4.612	0.579	8.490	3.148	0.778	917	4.73	63.50	119.9	118.1	42.65	26.8
0.5 ppm B	4.731	0.596	9.465	2.967	0.929	1023	5.11	64.37	121.2	118.5	62.88	29.8
0.8 ppm B	4.693	0.543	9.775	1.676	1.081	1085	5.56	68.10	77.6	116.2	67.65	51.2
1.1 ppm B	4.825	0.594	9.265	2.401	0.899	1027	5.29	66.00	58.9	113.1	74.20	18.0
LSD	NS	**	**	**	**	**	NS	NS	**	NS	**	**
Ca*B	NS	**	**	**	**	NS	NS	NS	**	NS	**	NS

\*  $P \leq 0.05$

\*\*  $P \leq 0.01$

Table 4. continued

TREAT	N %	P %	K %	Ca %	Mg %	Na ppm	Cu ppm	Zn ppm	Mn ppm	Fe ppm	B ppm	Al ppm
116 DAP												
57 ppm Ca	4.501	0.339	7.122	2.250	1.112	916	4.83	53.1	99.1	147	94.4	47.2
182 ppm Ca	4.549	0.353	6.090	3.044	0.932	872	4.70	39.1	107.9	129	90.1	10.0
LSD	NS	NS	**	**	**	NS	NS	*	NS	NS	NS	*
0.1 ppm B	3.880	0.352	5.880	2.487	0.929	868	4.51	38.4	101.9	90	14.1	32.7
0.5 ppm B	4.911	0.372	6.59	2.777	1.060	899	4.72	51.7	132.2	181	83.3	29.7
0.8 ppm B	4.636	0.334	7.07	2.508	1.069	940	4.47	46.5	114.6	101	117.2	30.3
1.1 ppm B	4.673	0.327	6.885	2.815	1.031	869	5.35	47.9	65.3	180	154.4	21.8
LSD	**	NS	**	**	**	NS	NS	NS	*	NS	*	NS
Ca*B	NS	NS	NS	*	NS	**	NS	NS	NS	NS	NS	NS
144 DAP												
57 ppm Ca	3.415	0.468	6.954	3.311	1.332	835	5.74	57.7	153.3	237	187.4	178.0
182 ppm Ca	3.535	0.412	5.866	3.930	1.079	773	5.54	51.4	134.2	220	199.1	111.1
LSD	NS	*	**	**	**	*	NS	NS	*	NS	NS	*
0.1 ppm B	3.766	0.768	5.587	3.285	1.044	841	5.93	48.3	165.6	347	18.0	136.2
0.5 ppm B	3.376	0.329	6.582	3.779	1.272	836	5.61	55.7	175.9	143	186.7	150.4
0.8 ppm B	3.336	0.336	6.845	3.788	1.282	778	5.80	56.8	159.0	134	253.0	145.7
1.1 ppm B	3.421	0.324	6.625	3.631	1.224	761	5.23	57.4	74.4	290	315.3	145.9
LSD	*	**	**	*	**	NS	NS	NS	**	NS	*	NS
Ca*B	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS

\*  $P \leq 0.05$ \*\*  $P \leq 0.01$

Table 5. Mineral content of main stems as affected by calcium (Ca) and boron (B) treatments at different growth stages of canola plants.

TREAT	N %	P %	K %	Ca %	Mg %	Na ppm	Cu ppm	Zn ppm	Mn ppm	Fe ppm	B ppm	Al ppm
<b>102 DAP</b>												
57 ppm Ca	2.807	0.460	6.635	0.484	0.426	1047	2.30	35.0	31.14	60.7	26.98	14.2
182 ppm Ca	3.159	0.467	6.747	0.732	0.412	1066	3.11	35.6	29.18	49.2	26.21	16.0
LSD	**	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS
0.1 ppm B	3.043	0.493	6.865	0.670	0.449	1061	3.00	38.5	32.85	67.6	10.84	16.2
0.5 ppm B	3.039	0.465	6.600	0.576	0.412	1066	1.95	33.8	33.60	50.1	30.80	11.8
0.8 ppm B	3.024	0.453	6.700	0.586	0.415	1058	2.84	31.8	30.02	52.6	31.87	15.7
1.1 ppm B	2.827	0.443	6.600	0.601	0.401	1042	3.02	37.0	24.16	49.6	32.88	16.6
LSD	NS	NS	NS	NS	*	NS	NS	NS	**	NS	**	NS
Ca*B	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	*	*
<b>116 DAP</b>												
57 ppm Ca	3.095	0.392	5.273	0.454	0.377	1057	2.42	24.97	30.60	44.5	23.46	>10.0
182 ppm Ca	3.243	0.382	5.033	0.606	0.331	1008	2.59	21.01	28.67	31.9	22.48	>10.0
LSD	NS	NS	NS	**	**	**	NS	**	NS	*	NS	NS
0.1 ppm B	3.263	0.401	5.705	0.605	0.391	1124	2.62	22.39	30.47	35.6	8.61	>10.0
0.5 ppm B	3.227	0.392	5.030	0.511	0.337	1031	2.28	23.61	31.72	49.1	25.77	>10.0
0.8 ppm B	3.134	0.382	5.190	0.502	0.360	1046	3.05	23.17	32.17	35.3	27.98	>10.0
1.1 ppm B	3.051	0.374	4.685	0.501	0.328	929	2.07	22.77	24.17	32.6	29.52	>10.0
LSD	NS	NS	**	*	**	*	NS	NS	**	NS	**	NS
Ca*B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

\* P ≤ 0.05

\*\* P ≤ 0.01

Table 5. continued

TREAT	N %	P %	K %	Ca %	Mg %	Na ppm	Cu ppm	Zn ppm	Mn ppm	Fe ppm	B ppm	Al ppm
130 DAP												
57 ppm Ca	2.148	0.250	5.194	0.510	0.313	1070	2.06	19.97	27.90	58.4	19.82	23.1
182 ppm Ca	2.342	0.249	5.040	0.679	0.301	1164	1.78	15.42	24.94	53.9	18.64	40.7
LSD	*	NS	NS	**	NS	**	NS	*	**	NS	NS	**
0.1 ppm B	2.861	0.418	5.458	0.796	0.412	1115	2.26	25.26	32.97	48.3	11.55	27.6
0.5 ppm B	2.065	0.222	4.968	0.561	0.273	1137	1.60	16.52	28.73	61.3	21.75	22.8
0.8 ppm B	2.046	0.192	4.843	0.507	0.273	1085	2.43	16.03	24.77	59.8	21.87	23.7
1.1 ppm B	2.006	0.167	5.200	0.513	0.272	1133	1.39	12.97	19.21	55.4	21.74	53.5
LSD	**	**	*	**	*	NS	NS	*	**	NS	*	**
Ca*B	NS	*	NS	*	NS	NS	NS	NS	NS	NS	NS	**
144 DAP												
57 ppm Ca	2.153	0.191	5.020	0.392	0.248	879	3.05	18.27	21.34	70.0	19.26	104.9
182 ppm Ca	2.105	0.175	4.805	0.529	0.208	1030	2.88	14.09	19.28	56.4	16.54	73.5
LSD	**	NS	NS	**	**	*	NS	*	*	NS	**	**
0.1 ppm B	2.876	0.397	5.517	0.748	0.357	1039	2.18	19.04	27.84	43.3	10.65	81.6
0.5 ppm B	1.830	0.122	4.760	0.360	0.186	925	3.27	13.25	19.11	58.9	18.63	89.1
0.8 ppm B	1.976	0.106	4.837	0.366	0.179	843	3.58	18.97	19.64	94.5	19.84	95.5
1.1 ppm B	1.834	0.108	4.535	0.367	0.188	912	2.84	13.46	14.65	55.9	22.50	90.6
LSD	NS	**	**	**	**	*	NS	NS	**	NS	**	NS
Ca*B	NS	NS	NS	**	NS	NS	NS	NS	**	NS	NS	*

\* P ≤ 0.05

\*\* P ≤ 0.01

Mineral content of side stem tissue (SST) at 130 and 144 DAP is shown in Table 6. Application of Ca had no influence on the N content of SST. Increased B levels did, however, lower the N concentration of the SST. A reason for this could have been the reduction in the dry mass (DM) accumulation of side stems at low B, shown previously in Chapter I. Between 130 to 144 DAP the N content of the side stems decreased, as was also found in other ageing plant parts.

Ca treatment levels caused a significant difference in the N concentration of pods on the main stem sampled at 144 DAP (Table 7). No effect was found at 130 DAP, nor with the analysis of the pods on the side stems (Table 8). The N concentration did not differ much between sampling dates for both the main stem pod tissue (MPT) and side stem pod tissue (SPT). B application rates caused significant differences in N content between SPT (Table 8), but had no effect on the N content of the MPT (Table 7). No trend could be seen as the effect of B varied at different sampling dates.

In general, the N content of plant tissue varied with both type and age of plant tissue analyzed, becoming less as physiologically older tissue was sampled. This is similar to the results found by Habekotté & Smid (1992). Of the different tissue sampled the pods had much less variation in N content than that of the leaf and stem tissue. This can be explained by the fact that the pods do not have the same rapid growth patterns and do not undergo very large changes in DM over time compared to the LT and MST.



Table 6. Mineral content of side stems as affected by calcium (Ca) and boron (B) treatments at different growth stages of canola plants.

TREAT	N %	P %	K %	Ca %	Mg %	Na ppm	Cu ppm	Zn ppm	Mn ppm	Fe ppm	B ppm	Al ppm
<b>130 DAP</b>												
57 ppm Ca	3.392	0.497	4.030	0.453	0.363	725	2.33	25.08	30.99	87	17.56	82.0
182 ppm Ca	3.284	0.453	3.661	0.589	0.307	723	2.36	19.31	26.76	31	16.39	68.1
LSD	NS	*	*	**	**	NS	NS	**	*	NS	NS	**
0.1 ppm B	4.219	0.730	4.635	0.816	0.461	701	3.94	36.85	43.92	45	5.11	90.6
0.5 ppm B	2.990	0.396	3.389	0.411	0.271	698	1.82	16.99	26.61	36	19.00	71.7
0.8 ppm B	3.175	0.405	3.625	0.435	0.313	724	2.25	19.07	25.50	126	21.28	70.8
1.1 ppm B	2.969	0.370	3.733	0.423	0.287	773	1.38	15.87	19.46	29	22.51	67.1
LSD	**	**	**	**	**	NS	**	**	**	NS	*	**
Ca*B	NS	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS
<b>144 DAP</b>												
57 ppm Ca	2.963	0.413	4.469	0.499	0.282	681	5.06	18.8	29.30	67	18.28	35.4
182 ppm Ca	2.850	0.374	3.926	0.583	0.227	728	3.77	14.1	26.63	87	19.63	42.1
LSD	NS	*	**	*	**	NS	NS	NS	NS	NS	NS	NS
0.1 ppm B	3.810	0.749	4.570	0.852	0.387	662	5.53	26.3	40.40	108	5.83	56.0
0.5 ppm B	2.684	0.307	4.022	0.475	0.224	717	3.32	11.1	26.50	46	23.20	61.5
0.8 ppm B	2.573	0.272	4.162	0.427	0.204	725	5.62	18.4	26.65	98	22.83	27.5
1.1 ppm B	2.559	0.245	4.035	0.408	0.203	714	3.20	10.0	18.31	55	23.95	10.0
LSD	**	**	*	**	**	NS	NS	*	**	NS	**	**
Ca*B	NS	NS	**	NS	**	*	NS	NS	*	NS	NS	NS

\* P ≤ 0.05  
 \*\* P ≤ 0.01

Table 7. Mineral content of main stem pods as affected by calcium (Ca) and boron (B) treatments at different growth stages of canola plants.

TREAT	N %	P %	K %	Ca %	Mg %	Na ppm	Cu ppm	Zn ppm	Mn ppm	Fe ppm	B ppm	Al ppm
<b>130 DAP</b>												
57 ppm Ca	3.817	0.604	2.619	0.527	0.466	502.7	2.68	32.2	43.06	43.3	36.39	88.3
182 ppm Ca	3.739	0.570	2.387	0.676	0.392	473.4	3.06	33.8	43.62	43.7	37.23	63.5
LSD	NS	NS	*	**	**	NS	NS	NS	NS	NS	NS	**
0.1 ppm B	3.788	0.629	1.883	0.684	0.450	379.4	3.28	34.6	52.07	47.2	7.43	66.9
0.5 ppm B	3.879	0.607	2.600	0.592	0.423	503.5	2.90	36.0	49.85	46.7	36.92	85.0
0.8 ppm B	3.686	0.565	2.758	0.574	0.423	544.0	2.35	31.4	40.60	38.5	45.70	76.2
1.1 ppm B	3.760	0.547	2.773	0.556	0.420	525.2	2.93	29.9	30.85	41.6	57.17	75.7
LSD	NS	**	**	NS	NS	*	NS	NS	**	NS	**	NS
Ca*B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
<b>144 DAP</b>												
57 ppm Ca	3.657	0.475	2.836	0.540	0.401	575	3.34	26.4	49.4	48.8	45.31	84.0
182 ppm Ca	3.488	0.413	2.680	0.676	0.352	545	6.33	29.9	42.6	50.8	46.49	25.2
LSD	*	**	NS	**	**	NS	*	NS	*	NS	NS	**
0.1 ppm B	3.572	0.444	2.758	0.608	0.377	560	4.84	28.1	46.0	49.8	8.40	54.6
0.5 ppm B	3.535	0.4654	2.830	0.670	0.391	580	7.29	29.3	56.9	53.1	48.40	23.6
0.8 ppm B	3.480	0.406	2.652	0.577	0.356	557	3.97	25.1	46.8	51.0	58.50	80.5
1.1 ppm B	3.703	0.462	2.792	0.577	0.383	544	3.25	30.1	34.2	45.3	68.30	59.7
LSD	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	**	**
Ca*B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**

\* P ≤ 0.05  
\*\* P ≤ 0.01

Table 8. Mineral content of side stem pods as affected by calcium (Ca) and boron (B) treatments at different growth stages of canola plants.

TREAT	N %	P %	K %	Ca %	Mg %	Na ppm	Cu ppm	Zn ppm	Mn ppm	Fe ppm	B ppm	Al ppm
130 DAP												
57 ppm Ca	3.976	0.604	2.385	0.534	0.450	492.1	2.58	33.27	46.07	205	33.72	147.3
182 ppm Ca	3.922	0.568	2.076	0.693	0.367	476.4	3.09	35.42	46.86	289	36.22	125.8
LSD	NS	*	**	**	*	NS	NS	NS	NS	NS	NS	**
0.1 ppm B	3.384	0.551	1.698	0.689	0.407	414.4	3.49	40.87	60.55	704	7.67	443.0
0.5 ppm B	4.199	0.637	2.393	0.598	0.409	497.7	3.11	35.80	50.55	200	36.47	56.6
0.8 ppm B	4.246	0.600	2.450	0.598	0.417	509.5	2.78	32.38	43.10	54	42.95	27.8
1.1 ppm B	3.966	0.557	2.383	0.570	0.402	515.5	1.95	28.35	31.67	30	52.80	18.7
LSD	*	**	**	*	NS	*	NS	**	**	**	**	**
Ca*B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
144 DAP												
57 ppm Ca	3.707	0.438	2.715	0.513	0.390	467.2	5.06	18.8	29.30	67	18.28	35.4
182 ppm Ca	3.674	0.430	2.629	0.654	0.362	466.7	3.77	14.1	26.63	87	19.63	42.1
LSD	NS	NS	NS	**	*	NS	NS	NS	NS	NS	*	NS
0.1 ppm B	3.691	0.434	2.672	0.583	0.376	466.9	5.53	26.3	40.40	108	5.83	56.0
0.5 ppm B	3.604	0.427	2.392	0.621	0.370	448.5	3.32	11.1	26.50	46	23.20	61.5
0.8 ppm B	3.579	0.398	2.890	0.567	0.371	478.0	5.62	18.4	26.65	98	22.83	27.5
1.1 ppm B	3.890	0.477	2.732	0.562	0.388	474.3	3.20	10.0	18.31	55	23.95	10.0
LSD	*	**	NS	NS	NS	NS	NS	NS	**	NS	**	NS
Ca*B	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

\* P ≤ 0.05

\*\* P ≤ 0.01

## Phosphorus

The P concentrations of LT were little affected by either Ca or B application rates (Table 4). Some significant differences, but no trends were found between B rates at some sampling dates. Although a Ca x B interaction was found at 88 DAP, it was inconsistent. The concentration of P in leaves declined as plants developed, possibly due to a dilution effect or mobilization and translocation as was seen with N. The relatively high leaf-P found at the lowest B level at 144 DAP, may be due to a lack of growth caused by the B-deficiency. These results are in contrast with the findings of Pollard, Parr & Loughman (1977) as quoted by Gupta (1979) who suggested that B deficiency symptoms of corn and broadbeans could be caused by reduced uptake of P. Robertson & Loughman (1974) also found that B deficiency reduced the absorption of P in whole plants and root segments of *Vicia faba*.

P-content of MST reacted in almost the same way as N with low B resulting in high P concentrations in MST at the last two sampling dates. Ca had no influence on the P levels in the MST (Table 5). Levels of P in the MST at the end were low compared to other tissue.

The concentration of P in SST was influenced by both Ca and B. Ca had a negative effect on P uptake. Of interest is a slight drop in P content from 130 to 144 DAP. Low B (0.1ppm) again raised P considerably at both of the sampling dates, again indicating less plant growth.

The P concentration in pods was influenced by both Ca and B treatments (Table 7 & 8). The effect of Ca on P content of pods varied a lot between sampling dates with no apparent trend. Both the MPT and SPT showed a reduction in P content, which was probably not caused by an increase of pod size as levels of other elements demonstrated little dilution effects. B treatment had a negative effect on the P content of the MPT at 130 DAP but no effect at 144 DAP. The P content of the SPT varied significantly at both sampling dates, but no pattern could be seen.

#### **Potassium, calcium, magnesium and sodium**

As cation ratio's were varied with the two Ca treatments (Steiner 1984), levels of K and Mg applied differed, making it difficult to interpret any effect that Ca application might have on either the K or Mg content of leaves (Table 4). K-, Ca- and Mg content of leaves were not consistently affected by Ca x B interactions. Calcium application had little effect on the Ca content of LT during the early stages of growth, but did show an increase in Ca concentration in ageing leaves. B rates caused highly significant changes in K, Ca as well as Mg content of LT at most of the sampling dates. At the later sampling stages (116 - 144 DAP) it seemed as if the concentrations of these cations peaked at a B-level of 0.8 ppm. According to Jackson & Chapman (1975) and Cohen & Lepper (1977) the earliest symptoms of B deficiency is a slowdown or cessation of root growth. Whether the increase in levels of these cations was due to a positive effect of B on root growth as found





by Gupta & Cutcliffe (1971), is not known. Sodium levels in LT were generally not affected by Ca application levels. B had some effect at 60 and 88 DAP but differences at 116 and 144 DAP were insignificant (Table 4).

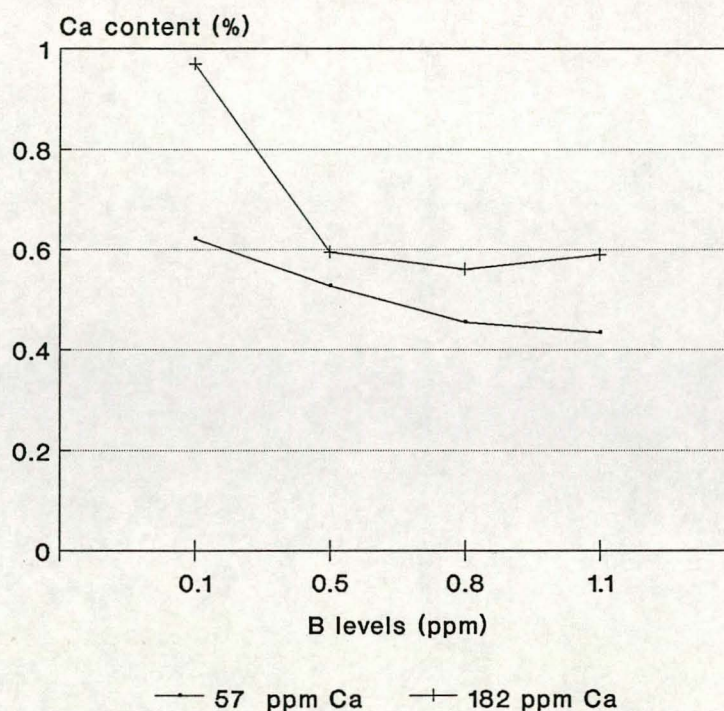


Figure 1.1 Ca content (%) of MST as affected by Ca X B interaction at 130 DAP.

Contrary to Ca levels in LT, levels of the MST changed according to the application levels and were significantly lowered by increasing B rates at 116 DAP. A significant Ca x B interaction was present at 130 DAP (Figure 1.1) and 144 DAP (Figure 1.2), indicating that an accumulation of Ca from high Ca-levels occurred only at the low B-level of 0.1 ppm. Apart from a possible concentration effect, due to a low DW at the low B-level, poor translocation of Ca as suggested by Marsh and Shive (1941), could also have been a contributing factor.



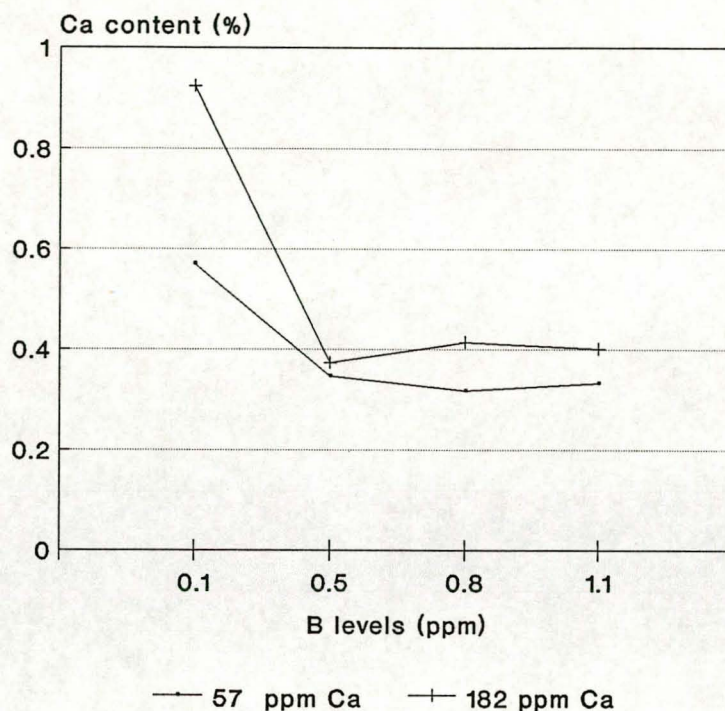


Figure 1.2 Ca content (%) of MST as affected by Ca X B interaction at 144 DAP.

K concentrations in MST showed no response to Ca applications. B application levels caused significant differences in K content, but these varied a lot and no real trend could be identified. The lower Mg concentrations experienced at the high Ca application level was probably caused by the associated lower input of Mg as the cation ratio varied. Mg concentration was high at low B values probably due to less DM accumulation. The Na concentrations in MST were inconsistently influenced by Ca at different growth stages. B rates had a negative effect at 116 DAP, but no effect was found at 130 DAP. At 144 DAP, low B (0.1 ppm) raised the Na content of the MST, once again probably due to reduced growth.

Levels of K, Ca and Mg in the SST correlated with the cation ratios applied according to Steiner's calculation method (Steiner 1984). The low B level of 0.1 ppm caused significantly higher levels of K, Ca and Mg in the SST as was found with N and P. The Na concentration in the SST were not effected by either Ca or B application rates.

K, Ca and Mg were significantly influenced by the different Ca rate in both MPT and SPT at both sampling dates (Table 7 & 8). Values seem to follow the application ratios of the different elements. B application tended to increase the K content of both the MPT and SPT only at 130 DAP. The Ca content of pods was only influenced by B in the tissue of the SPT at 130 DAP. No effect of B on Mg concentration was found. The Na content of pod tissue was not influenced by Ca treatment. B had a negative effect on the Na content of the MPT and SPT but, this effect was, as with the K content, only significant at 130 DAP( Table 7 & 8). Values of pod tissue were low when compared with the Na content of stem and especially leaves.

A comparison of the different tissues analyzed showed that levels of K in the MST and SST were slightly lower than in the LT, but were significantly less in the MPT and SPT. Similarly the Ca and Mg content of LT were also higher than in the stems and pods.

### **Copper, zinc, manganese and iron**

Of the trace elements analyzed, Cu- and Fe content of leaves showed no response to either Ca or B applications. Zn was negatively influenced by the high Ca level at most of the sampling dates except at 144 DAP, but was not influenced by B levels. The Mn levels of LT reacted to both Ca and B application rates, both having a negative effect. Similar results was reported by Reinbott, Blevins & Schon (1997), who found that B foliar application decreased the Mn content of soybean leaves.

The Cu- and Fe content of MST were not affected by either Ca or B. Ca had a negative effect on Zn uptake which was more pronounced towards the end (Table 5). Low B caused Zn values to be slightly higher and differences were significant only at 130 DAP. This again was probably caused by reduced growth and thus, less dilution. Cu and Zn content of the MST was also noticeably lower that of the LT. The main stem Mn concentration was lowered by the high Ca rate, but this effect only became significant towards the end. Highly significant differences in Mn content occurred between B rates with higher B application rates having an antagonistic effect on Mn, as was the case in the LT (Table 5).

The Cu concentration of the SST was hardly affected by Ca nor did the B application rates have any influence on the Cu concentration of the SST. The Zn concentration was lowered by the high Ca-level at 130 DAP, but differences were insignificant at 144 DAP. Low B (0.1 ppm) raised the Zn content significantly at



both sampling dates, probably due to the lack of a dilution effect as was found with extra growth at the higher B rates. The Mn content of the SST was lowered by increasing the Ca rate, but this was not significant at 144 DAP. Low B produced quite a marked increase in Mn content. The lower Mn content at high B-levels found at both sampling dates was also found in the analysis of other parts of the plants. Stem tissue also had a much lower Mn content than LT. The Fe content of the SST again showed no reaction to either Ca or B application rates.

Of the trace elements analyzed in the main stem pods only Mn was significantly lowered by the higher B applications (Table 7). The Cu-, Zn- and Fe-content showed very little reaction to either Ca or B treatments. With the analyses of the side stem pods, Zn, Mn and Fe concentrations decreased as the B-levels increased (Table 8).

### **Boron**

The B levels of LT is shown in Table 4. The well documented influence that Ca has on the uptake of B (Kabata-Pendias *et al.*, 1991), was only seen at 88 DAP due to a significant Ca x B interaction. Ca had a negative effect on the B concentration in the LT, but only at the lowest B-level (Figure 2). This is in agreement with the results reported by Reeve and Shive (1944); Tanaka (1967) and, Hill and Morrel (1975). The lack of any significant interaction at other sampling dates could be explained by the fact that Ca application had little effect

on the Ca content of LT. Concentrations of B increased in LT with higher B applications and accumulated in the LT towards the end of the growth period as can be seen in Table 4).

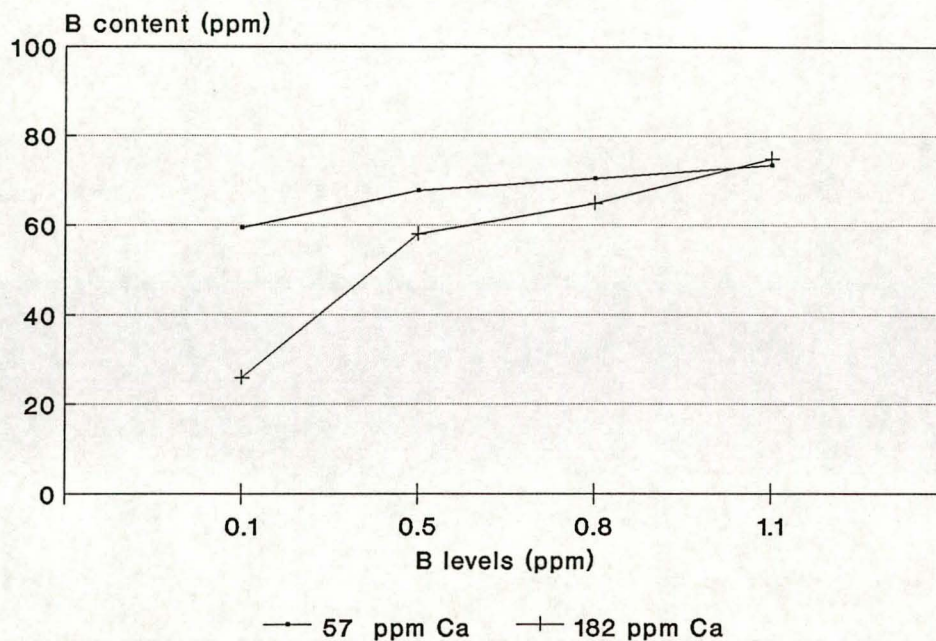


Figure 2. B content (ppm) of LT as affected by Ca X B interaction at 144 DAP.

Contrary to the accumulation of B, found in leaves (Table 4), B content of MST did not increase and even dropped towards the end of the growth period (Table 5). This could be caused by either a dilution effect or rapid translocation to other plant tissue. Differences between the high B application levels were insignificant but a significant difference between 0.1 ppm B and the higher levels was found. This may imply that the MST B-content can be used as indication of B deficiency, but would be less effective as indication of excesses in the plant.

Ca application had no effect on the B content of SST. Low B (0.1 ppm) resulted in significantly lower B content of the SST. Little difference was found between the higher application rates (0.2 - 1.1 ppm). As with the MST, little accumulation of B occurred between 130 and 144 DAP. The MST and SST differed slightly, but had lower B content than the LT.

In general, Ca had no effect on the B content of pods on either the MPT or SPT. B application had a marked effect on the B content excluding the MPT at 144 DAP (Table 7). It seems apparent that increasing B application levels from 0.5 to 1.1 ppm did not raise B concentrations as much. Low B (0.1 ppm) resulted in greatly reduced amounts of B in the tissue of both the main- and side stem pods. The absence of a dilution effect in the MPT can be explained by the fact that these pods tend to mature first and that very little DM accumulation of these pods took place after 130 DAP.

### **Aluminium**

Ca application levels suppressed Al concentrations in leaves at most of the sampling dates except at 88 DAP. Although B had some effect on Al during the early stages, means varied a lot and were inconsistent.

The Al content of the MST were not affected by Ca or B during the early growth stages. Although significant differences were present at later stages, these were inconsistent.

Analysis of SST showed that Al concentrations reacted to Ca rates at 130 DAP but not at 144 DAP. B application had a slightly negative effect on Al content (Table 6).

The application of Ca had a suppressing effect on the Al content of both the MPT and SPT except for the SSP at 144 DAP. The effect of B on the Al content seems to be complex. No effect can be seen in the Al content of the MPT at 130 DAP but it was significantly affected by B at 144 DAP. There was some indication of a suppressing effect of B on Al content in the SPT although it was only significant at 130 DAP (Table 8).

## **CONCLUSION**

The data confirms that levels of all elements vary between plant tissues and with their physiological age. Some elements tended to build up in certain parts of the plant (Ca, Mg, Mn and B in LT) while others were diluted at rates that depended on the growth of the specific plant part analyzed ( N, P, K, Na, Cu, Zn and Fe).

Although an interaction between Ca and B is often reported, it only affected leaf-B (Figure 2) and main stem-Ca (Figure 1) in this study. Furthermore, the effect of applied Ca on plant Ca content was small. Presumably these results are due to the constant supply of these elements in the different nutrient solutions. Ca effects on most elements were very small or negligible and unclear. Some effects on K and Mg were seen and can be explained by differences in the concentrations applied due to cation corrections.

Although B had significant effects on most macro and micro elements in the plant these effects were not always clear. Low B (0.1 ppm) resulted in elevated levels of N, P, K, Ca and Mg in the MST and SST. This could be explained by a reduction in growth of these plant parts as was shown in Chapter I. The only consistent effect of B, was a negative effect on Mn content in all of the tissue analyzed.

B appears to accumulate in the leaves, the end of the transpiration stream, but not in the stem as the plant ages. This makes the B in stem tissue more stable and thus more suitable for analysis when physiological age of tissue cannot be accounted for. As B tend to accumulate in LT the physiological age of LT is therefore critical when used for analysis. Low B (0.1 ppm) caused low B values in stem tissue but increasing  $\bar{B}$ , beyond the second level, did not increase B levels accordingly. This may give a false indication of the B status of plants since higher B levels are not reflected in stem tissue. B content in LT was better correlated with application rates than the B content of other tissue analyzed. However, care should be taken as B content was dependant on the physiological age of the tissue.



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## SUMMARY

THE INFLUENCE OF BORON AT DIFFERENT CALCIUM LEVELS ON THE GROWTH, YIELD AND MINERAL CONTENT OF CANOLA, *Brassica napus* L.

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### VEGETATIVE GROWTH

Many previous studies dealing with the effect of B mainly concentrates on yield and yield components. Literature on the effect of B on vegetative growth is scarce.

A well known occurrence in plant nutritional studies, is the interaction between Ca and B in uptake, the one being antagonistic towards the other. Although some interaction was found in this study, no clear pattern was experienced during both trials. It was, however, observed during the second experiment, where Ca application rates differed more, that B deficiency symptoms where more severe at the highest level of Ca than at the lowest level.

It seems to be difficult to induce a Ca-deficiency in canola. Although a relatively low level of Ca was used in experiment 2, no deficiency symptoms developed. This may be due to the fact that nutrients were supplied with the irrigation water on a daily basis, or the ability of canola to tolerate low Ca-levels.

Although the effect of B on growth components was not clear, some variables were affected, especially when less than 0.2 ppm B was applied. During the first experiment, B levels had almost no effect on the variables measured. Most variables were, however, significantly affected by lowering of the lowest B rate during the second experiment.

Contrary to the expected, application of B at 0.2 ppm, which is below the norm for normal growth, had almost no effect on vegetative growth of canola. Application of levels below 0.2 ppm did, however, cause a failure of normal vegetative growth. Of the parameters measured, length of main and side stems were the most sensitive with leaf area exhibiting high tolerance to B deficiency. Since leaf area was not significantly reduced by low B levels, yield increases caused by added B, must therefore lie in a requirement of B by canola for reproductive growth and not in increased vegetative growth.

## **REPRODUCTIVE GROWTH**

Many plant nutritional studies report interaction between Ca and B where it was found that B uptake is inhibited by high Ca levels. No difference between Ca application rates or any significant Ca x B interaction was found with any one of the parameters measured during both experiments. It was, however, noted that the detrimental effect of the lowest B level, on the number of pods and pod mass per plant was more pronounced at the high Ca level in the second experiment.



B had a clear effect on the amount of seeds produced per plant. During the first experiment the effect of B on the amount of pods formed, pod weight per plant or the amount of seeds per pod was not clear although some indication of a negative effect at the lowest B rate could be seen. However, the accumulated effect of this resulted in a marked effect of B on the amount of seeds per plant, seed mass per plant and the harvest index (HI).

Decreasing the lowest B rate from 0.2 to 0.1 ppm during the second experiment, did cause plants to have significantly less pods, a lower pod weight per plant, and less seeds per pod. The number of seeds per plant, seed mass per plant and the HI were also detrimentally affected by the low B-level.

Literature cited attributed a negative effect of low B on yield to less seeds per pod, rather than less pods per plant formed. Whether or not the reduced production of seed at B rates below 0.2 ppm was caused by less pods per plant formed or less seeds per pod, could not be seen as B had no effect on either of these parameters during the first experiment. During the second experiment lowering the lowest B rate to 0.1 ppm affected both of these parameters, again making it difficult to conclude the reason for loss of seed production. Research findings which ascribed a yield response to B in the absence of clearly defined symptoms, to the requirement for B in pollination, strongly suggest that similar effects were achieved during these experiments.

It is the opinion of the authors that application of B at levels higher than that which would sustain normal vegetative growth would not affect the amount of pods formed. The effect of low B levels on yield is probably caused by less seeds per pod through the effect of B on pollination. Below a B-level that would sustain normal vegetative growth, the formation of pods would be negatively affected, with the resulting loss of yield.

## **MINERAL CONTENT**

The data confirms that levels of all elements vary between plant tissues and with their physiological age. Some elements tended to build up in certain parts of the plant (Ca, Mg, Mn and B in leaf tissue) while others were diluted at rates that depended on the growth of the specific plant part analyzed ( N, P, K, Na, Cu, Zn and Fe).

Although an interaction between Ca and B is often reported, it only affected leaf-B and main stem-Ca in this study. Furthermore, the effect of applied Ca on plant Ca content was small. Presumably these results are due to the constant supply of these elements in the different nutrient solutions. Ca effects on most elements were very small or negligible and unclear. Some effects on K and Mg were seen and can be explained by differences in the concentrations applied due to cation corrections.

Although B had significant effects on most macro and micro elements in the plant these effects were not always clear. Low B (0.1 ppm) resulted in elevated levels of N, P, K, Ca and Mg in the main- and side stem tissue. This could be explained by a reduction in growth of these plant parts. The only consistent effect of B was a negative effect on Mn content in all of the tissue analyzed.

B appears to accumulate in the leaves, the end of the transpiration stream, but not in the stem as the plant ages. This makes the B in stem tissue more stable and thus more suitable for analysis when physiological age of tissue cannot be accounted for. As B tend to accumulate in leaf tissue the physiological age of LT is therefore critical when used for analysis. Low B (0.1 ppm) caused low B values in stem tissue but increasing B, beyond the second level, did not increase B levels accordingly. This may give a false indication of the B status of plants since higher B levels are not reflected in stem tissue. B content in leaf tissue was better correlated with application rates than the B content of other tissue analyzed. However, care should be taken since the B concentration was dependant on the physiological age of the tissue.

As a new crop to the region, a lot has still to be learned about canola. These results, however, gives a better understanding of the importance of B fertilisation in the production of canola and stresses that the absence of visual symptoms of B deficiency is never the only assurance of adequate B nutrition.