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and Boron Partitioning in 'Tristar' and 'Benton' Strawberries
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Induced B deficiency can cause strawberry fruit malformation when grown under greenhouse conditions. Yield, deformity percentages, and B partitioning were examined in the field under soil B deficient conditions. Initial soil tests in Feb., 1985 indicated soil B levels of .27 ppm. B applications of 0, 1.1, 2.2, and 4.5 kg/ha B were added before planting the day-neutral cultivar 'Tristar' and the June-bearing cultivar 'Benton'. Aug. soil tests indicated soil B levels of .34, .53, .85, and 1.13 ppm B, respectively.

B application had no effect on fruit yield or deformity percentages of 'Tristar' in 1985, or of 'Benton' in 1986. B application decreased yield of 'Tristar' in 1986 but did not affect deformity. High populations of Lygus bug (*Lygus hesperus*) appear to have caused the fruit deformity in 1985. Current fertilizer guides recommend B application that may be detrimental to strawberry growth and yield.

Tissue analysis of ten plant parts was performed three times

in 1985 for both cultivars and once in 1986 for 'Benton'. These analyses indicated B application increased B concentration, but decreased dry weight, resulting in no net change in total B uptake in nonleaf tissue. At least 85% of the additional B taken up by the plant accumulated in the leaf tissue. Level of B in leaves did not accurately indicate B status of other plant parts.

The Effect of Soil Applied Boron on Fruit Deformity, Yield and Boron Partitioning in 'Tristar' and 'Benton' Strawberries

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Note: This thesis is presented as a series of two papers written in the format required by HortScience and Communications in Soil Science and Plant Analysis.

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CHAPTER 1

INTRODUCTION

Oregon is the second leading producer of strawberries in the U.S. In 1985, total production was 63.5 million pounds with a farm value of $28.5 million. Over 90% of the Oregon crop is processed. The harvest season is from the first of June through the first week of July. Peak production is during June.

Oregon strawberry production consists almost exclusively of June-bearing cultivars. Flower buds differentiate in the fall in response to cool temperatures and short photoperiods, and fruit the following spring (16,59,72). Recently, day-neutral strawberry cultivars have been introduced (16). Day-neutral strawberries continue to flower and fruit throughout the season until cold temperatures stop growth in the fall (61). The principal advantage of growing this type of stawberry would be their added fresh market value in the "off" season.

A day-neutral cultivar trial was planted at the North Willamette Experiment Station, Aurora, Oregon in 1984. All cultivars had a high percentage of deformed fruit. Boron deficiency was suspected because the soil test for boron was low (.27 ppm). According to current soil standards, the coarse, highly leached soils of Western Oregon are often boron deficient. To investigate the relationship between boron and fruit deformity this project was undertaken with two basic objectives:

1) to determine the relationship between boron application, fruit deformity, and yield in day-neutral and June-bearing strawberries; and

2) to investigate how boron is partitioned in day-neutral and June-bearing strawberries.

CHAPTER 2

LITERATURE REVIEW

I. Role and Availability of Boron

Boron has been known to be an essential element for plant growth since 1910 (2). Although its' role is not well understood, boron is involved in many physiological functions. Boron has been implicated in nucleic acid metabolism, carbohydrate biosynthesis, synthesis of hormones, and function of membranes (37,51,56). Dugger (17) hypothesized that boron regulates enzyme reactions, thereby affecting the metabolic functions just cited. Boron is also involved in pollen germination and pollen tube growth (17,29,37,51,66,71), cell development, rate of cell division, and water relations (37,68).

Boron uptake in plants is considered a mainly passive process (51,65). Kohl and Oertli (44) concluded that boron movement occurs in the transpiration stream and that boron does not redistribute itself from leaves because it is not transported in the phloem. This conclusion has been disputed by others (11,17), but no clear explanation about how phloem movement occurs has been offered. Most researchers believe boron is quite immobile and is predominantly transported in the transpiration stream.

Mengel and Kirkby (51) and Tisdale and Nelson (37) report that boron content in soils is usually between 20 and 200 ppm, most of which is unavailable to plants. That fraction which is available to plants is measured by a hot-water extraction technique (26,40). Values obtained by this method vary from 0.1 ppm (7) to 5.0 ppm (28). Boric acid (H_3BO_3) is the predominant form of soluble boron (10,12). Boric acid does not dissociate in the soil (51), therefore the uncharged form can easily be leached from the soil. For this reason, the soils of Western Oregon are often boron deficient.

Many factors affect the boron supply and availability in a soil. Tourmaline is the most important boron containing mineral. It contains 3-4% boron (51). However, tourmaline resists weathering and only slowly releases boron (68). Clay soils adsorb more boron than sandy soils, and may reduce leaching losses, but boron availability in solution is also lower (43). According to Tisdale and Nelson (68) most of the available boron is held by organic matter. Mengel and Kirkby (51) agree, and state that this may be the primary reserve for boron in agricultural soils.

Soil pH and moisture also have an effect on the availability and uptake of boron. Boron adsorption increases as pH rises due to the formation of the anion ($B(OH)_{4-}$) which is subsequently adsorbed to clay minerals (51). Gupta (27) found that barley did not develop boron toxicity symptoms at a high pH but did develop toxicity symptoms at a low pH. The effect of soil moisture is probably two-fold; 1) organic matter does not decompose as quickly in dry soil, consequently inhibiting boron release, and 2) under dry conditions, root growth and boron delivery are restricted, thereby limiting uptake (68).

II. Boron Requirements for Strawberries

Many workers have documented boron deficiency symptoms in strawberries (17,33,39,51,55,62,68). The first sign of deficiency is abnormal, retarded growth of apical meristems. Unless the deficiency is alleviated, the terminal growing point dies, overall growth is reduced, flower and fruit formation is inhibited and the roots become thickened with necrotic tips.

Boron has a very narrow range between deficiency and toxicity. There is disagreement on the critical solution concentration of boron that is required for optimum strawberry growth. In solution culture Neilson and Eaton (52) found that levels of .01 and .05 ppm boron inhibited flower number, fruit set, or fruit size. Levels of .25 ppm boron reduced leaf number while 1.25 ppm B did not seem to affect yield. Their recommended rate of boron was .25 ppm. They did not measure leaf tissue concentration. Hoagland and Snyder (33) reported that 0.1 ppm B prevented B deficiency symptoms under spring conditions but not in the summer. From this study they concluded that strawberries need more than a trace of boron for adequate growth.

In contrast, a sand culture study done by Iwakiri and Scott (35) failed to obtain boron deficiency symptoms even when using solutions lacking boron. Plant growth was reduced when tissue concentrations were below 22 ppm boron.

Eaton (18) reported similar results. Using 'Klondike' strawberries in sand culture he failed to observe any deficiency symptoms even with a trace (0.03 ppm) boron solution. Whole plant boron concentration (on the basis of dry weight) was 44 ppm when grown in the trace solution. Plants grown in a 1 ppm solution had similar dry weights and yield.

A sand culture study by Blatt (8) indicated that cultivar differences exist concerning optimum leaf boron values and boron solution concentration. 'Redcoat' and 'K68-108' achieved maximum growth at 0.2 and 0.4 ppm B with a corresponding leaf value of 58-116 ppm. Deficiency symptoms were associated with leaf B levels of 2-5 ppm for these two cultivars. In comparison, 'Midway' achieved maximum growth at 0.0 ppm B and no deficiency symptoms were evident until the end of the experiment after nearly 4 months. Leaf B values associated with maximum growth were 14-33 ppm. Evidence of cultivar differences is supported by the work of John et.al. (42). Field trials indicated that significant differences in leaf B level existed among 7 genotypes. Leaf values ranged from 25-50 ppm.

Boron deficiency has been difficult to document in the field. In New Hampshire, no increase in yield or runner plant production was obtained when boron was added to a soil believed to be boron deficient (47). Cutcliffe and Blatt (15) substantiated this in eastern Canada. On a soil containing .20 ppm boron no response was obtained from application of 1.1 or 2.2 kg/ha B. Leaf concentration levels ranged from 26-57 ppm. A study by Bjurman (7) revealed mixed results from boron application. No yield response to boron application was measured in seven of eight sites in the first two cropping years. At the eigth site a negative effect was obtained in all three cropping years. Four sites indicated a positive effect in the third year. Leaf boron values varied from 18-104 ppm among sites, while soil values varied from .10 ppm to 1.0 ppm. Paradoxically, the site at which boron application decreased yields in all three years also had the lowest soil boron level of .10 ppm. A study by Blatt (9) had similar results. Using 'Midway' strawberry, he obtained no yield response to boron application. However, optimum crop response occurred with a soil B range of .15-.25 ppm and leaf value of 20-30 ppm. In general these research studies support the tentative critical value of 20 ppm B in leaf tissue stated by Johanson (39).

Strawberries are considered to be very sensitive to boron (58). Field and greenhouse studies indicate variation in applied boron rates which induce boron toxicity. These depend on soil texture, organic matter content, cultivar, and criteria for measuring toxicity (i.e. yield reduction vs. leaf margin necrosis) (7,8,9,18,32,47). Since soil factors are so variable leaf analysis is a common tool for measuring boron toxicity. As Blatt (8) and John et.al. (42) indicated, cultivar differences are still a problem when interpreting leaf analyses. Critical values for boron toxicity tend to range from 50-200 ppm. (7,8,12,32,39,69).

Sampling time, tissue sampled, and plant age must be considered when using tissue analysis. In field studies boron values were consistently lower in two-year-old plants than one-year-old plants (9,15,42,48). John et. al. (41) sampled leaves and petioles every two weeks from May 9 (flowering) to October

10th. Leaf boron declined throughout the season but was relatively stable for six weeks after harvest. Petiole boron was not determined due to a lack of tissue. For most elements, leaf tissue was preferred over petiole since greater concentrations existed in the leaves.

Laurinen and Sako (48) measured boron content of 'Sengana' strawberry fruit and found levels of 18 ppm. This contrasts with data by Albregts and Howard (3) which indicated strawberry fruit contained 1.5-2.0 ppm boron. However, they separated the calyx and when that is included the concentration of boron is 12-14 ppm.

A later study by Albregts and Howard (4) investigates the accumulation of nutrients in plant tissues. They indicate that harvested fruit contained more boron than the rest of the plant. Excluding harvested fruit, leaves and dead foliage contained the most boron while flowers with stalks and unharvested fruit contained the least. Concentration of the tissues was only given for the end of the harvest season. Results varied between the two seasons with dead foliage always having the highest concentration (28-33 ppm) and unharvested fruit the lowest (13-15 ppm). Roots and crowns, petioles, leaves, and flowers with flower stalks did not significantly differ from each other in either season. Concentrations varied from 17-27 ppm.

III. Causes of Strawberry Deformities

The achenes on a strawberry are the true fruit (53). The berry, as consumers know it, is an enlarged receptacle. The achenes produce auxins which stimulate the receptacle to enlarge (53). Each fertilized achene produces a small area of growth, therefore the weight of a mature fruit is dependent on the number of fertilized achenes (1,36,53). Poor fruit set or fruit development is a function of poor pollination, fertilization, or achene development. Any conditions that affect pollen production, transfer, or germination will have a negative effect on fruit set. These conditions include environment, insects, and disease, some of which may also affect achene development.

All modern strawberry cultivars are hermaphroditic (23,50). Complete pollination still may not occur due to incomplete transfer of pollen onto the pistils, sterile pollen, or lack of adequate pollen. Valleau (70) believed there were two types of male sterility. One was the development of staminodia, which never produce pollen, and the other, aborted pollen grains. He believed the aborted pollen grains were due to a metabolic defect in the microspores. Guttridge et.al. (31) did not believe these conclusions fully explained the causes of pollen sterility. They observed 'Redgauntlet' flowers initiated in May and flowering in August usually have healthy anthers, while flowers initiated in the fall and that bloom in May often have aborted anthers. These observations indicated to them that an environmental effect was the cause of the abortion. An earlier study by Guttridge and Anderson (30) suggested environmental factors in addition to cultural factors as the cause of anther failure in 'Redgauntlet'. They noted that earlier trusses had poorer anthers than later ones, which would be more protected in the winter. They suggested short days, low light, and low temperatures at the critical stage of anther development to be the causes of poor anther quality. Thompson (67) concurred with this, but found temperature was the major environmental factor affecting pollen formation.

A study by Kronenberg et. al. (46) indicated that fruit set of 'Jucunda' was poor when temperatures were below 17°C, and that the quality and quantity of pollen production was poor. Braak (10) later substantiated the effect of temperature on 'Jucunda' pollen production. He concluded that poor fruit set in 'Jucunda' strawberries was the result of insufficient pollen production when temperatures were below 17°C during flowering.

It is most likely that poor pollen production and poor pollen quality are a result of both environmental and genetic conditions. Both Kronenberg (45) and Hulewicz and Hortynski (34) found differences in fruit set among varieties which were self pollinated. Kronenberg (45) also discovered dramatic differences in anther and pollen quality among cultivars. Gilbert (25) substantiated this. Primary flowers of 'Benton' and 'Tyee' consistently had many unhealthy anthers which released very little pollen. At least 60% of the fruit from these cultivars were deformed. At the same time, 'Olympus' and 'Totem' had good pollen production and only 2-30% of the fruit was deformed. In two seasons, 'Tyee' had the greatest percentage of deformed fruit and 'Totem' the least.

Takahashi (63) investigated the effect of high temperature in greenhouses on strawberry fruit set. Temperatures above 40°C increased fruit malformation, by decreasing pollen viability , but when artificial pollination was included fruit set was not seriously affected by temperature.

Strawberry flowers are self-compatible, consequently not requiring cross-pollination with another cultivar. Flowers in which plenty of viable pollen is produced may still be deformed. This may be from inadequate transfer of pollen to the stigma. Anthers dehisce under tension, allowing pollen to be thrown onto some, but not all pistils (50). Allen and Gaede (5) found caged, undisturbed plants set no fruit; uncaged and disturbed by wind from a fan set 77%, and brush pollinated plants set 97%. This study indicates that mechanical transfer of pollen to the pistils is necessary for good fruit set. In the field this would be accomplished with pollinating insects. Many insects visit strawberry flowers but bees are the only one of importance in transferring pollen (50). Many workers have reported on the importance of bees in strawberry pollination and fruit set (13,14,22,23,38,45,54). Connor and Martin (14) measured stamen height in eleven cultivars and noted it ranged fom 2.5mm to 5.2mm. The cultivars with shorter stamens benefitted from insect pollination more than cultivars with longer stamens.

Even though strawberry fruit set is greatly improved by bee visitation, honey bees are not greatly attracted to strawberries (50). Factors such as more attractive crop competition, cool rainy weather at bloom, and insecticide use will decrease bee visitation, adversely affecting fruit set.

Poor pollen germination has been considered a cause of fruit malformation. Guttridge and Turnbull (29) increased pollen germination on agar films with drops of $Ca(NO_3)_2$, H_3BO_3, and a mixture of $MnSO_4$ and $ZnSO_4$. Application of these solutions also improved anther dehiscence even though there appeared to be plenty of these elements available to the plants. They concluded that a localized deficiency of these elenents at truss emergence was a cause of malformed fruit. However, this experiment, when conducted in the field did not improve anther quality nor decrease fruit malformation. Thompson and Batjer (66) demonstrated increased pollen germination and pollen tube growth when 2.5 ppm boron was included in the germination medium. No field studies were conducted. Vasil (71) found poor germination of pollen in plants that were deficient in boron.

Eaton and Chen (19) observed pollen germination in strawberries was inhibited when captan was sprayed on anthers after dehiscence. Germination was not affected in undehisced anthers until a very high rate of 2000 ppm captan was used. In a further study captan appeared to negatively affect pollen germination but did not interfere with receptivity of the stigma, pollen tube growth or fertilization (20). Takahashi (63) also found fungicides, specifically DPC, inhibited pollen germination.

A number of external factors may cause malformed fruit. Frost destroys pistils, causing them to blacken. It can also damage buds and developing berries (45,55). Herbicide injury can occur.

'Catskill' strawberry plants that received an application of 2,4,-D when flower buds were initiated had severely deformed fruit (55,24).

Gray mold (Botrytis cinerea Pers.) may cause fruit set problems when present during flowering (49,24). Infection is through senescent floral parts and then into the receptacle (68). Ford and Wilhelm (21) reported an imperfect fungus of the Moniliaceae family parasitizes the stigmas of the flower. Fruit deformity occurs because fertilization is prevented when the fungus penetrates the stigma.

Uncontrolled insect populations can cause serious damage in commercial fields. High populations of thrips may cause discoloration, but do not actually cause deformed fruit (5). The most serious insect pest causing fruit deformity is lygus bug (Lygus spp.). This pest is known to cause damage across North America and in Europe (5,6,55,60,64).

There are conflicting statements on how lygus bugs cause malformed fruit. Parker et. al. (55) state that damage from the insects feeding on the pistils causes the deformity. Allen and Gaede (5) found hollow achenes where lygus bugs fed, concluding the insects puncture the achenes. Both hypotheses indicate interference with achene development, consequently restricting or halting auxin production, and halting receptacle enlargement. Schaefers (60) measured yield effects of lygus bug feeding on June-bearing strawberries. Injured fruit ranged from 31% to 67% of total fruit with an 11% to 30% reduction in mean fruit weight, respectively. More injury occurred in early, warm seasons. Using the percent reduction in weight, economic losses were calculated to be \$990-\$2700/ha. Realistically, the economic losses would be much greater since badly deformed fruit would never have been harvested.

CHAPTER 3

THE EFFECT OF SOIL APPLIED BORON ON FRUIT DEFORMITY AND YIELD OF 'TRISTAR' AND 'BENTON' STRAWBERRIES

KEY WORDS: Day-neutral, Fragaria, Lygus, plant nutrition

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ABSTRACT

A field trial was conducted to determine if B deficient soils contribute to low yield and fruit malformation in strawberries. B rates of 0, 1.1, 2.2, and 4.5 kg/ha were applied to a soil testing .27 ppm B, before planting 'Tristar' and 'Benton' strawberries. Aug. 1985 soil tests indicated soil B levels of .34, .53, .85, and 1.13 ppm B, respectively. B application had no effect on yield or deformity the first harvest year, and decreased yield of 'Tristar' the second harvest year. High populations of Lygus bug (Lygus hesperus) were believed to cause fruit malformation in 1985. B fertilizer guides for strawberries may need to be revised.

INTRODUCTION

Malformed strawberry fruit lead to low yield and decreased strawberry returns in Western Oregon. Observations at the North Willamette Experiment Station in Aurora, OR indicated severely malformed strawberry fruit were more apparent on day-neutral cultivars than june-bearing cultivars in 1984. Coarse, highly leached soils, such as those found in Western Oregon, are often B deficient (9). Using current soil standards, 38% of Western Oregon agricultural soils in 1984 were below the critical value of .50 ppm B (J. Hart, Personal Comm.). This has led to speculation that strawberry deformities apparent in the Willamette Valley are associated with B deficiency. Current Oregon State University fertilizer recommendations suggest the use of soil applied B for strawberries grown on low B soils.

B deficiency has been difficult to document in the field (1,2,3,5). Yield increases have not occurred in the first two years following B application (2,3). Bjurman (1) obtained a yield increase from B application, but this was not until the third cropping year, and only at four of eight locations. Induced deficiencies in greenhouse experiments produce fruit deformities and B is involved in pollen germination and pollen tube growth (4,8,10). However, relationships between B deficiency and fruit deformity under field conditions have not been documented.

This study was initiated to determine the effect of soil-applied B on fruit deformity and yield of day-neutral and

June-bearing cultivars, when grown on a low B soil.

MATERIALS AND METHODS

The plots for this study were located on a Quatama loam which was fumigated with methyl bromide and chlorpicrin. Soil samples taken in Feb. 1985 had hot-water extractable B levels of .27 ppm. Application rates were 0, 1.1, 2.2, and 4.5 kg/ha actual B. B was applied 5 Apr. 1985 by dissolving Solubor (20.5% B) in 3.8 liters of water and sprinkling it in a 61 cm wide strip in the row. It was immediately incorporated using a rototiller. At the same time, 56 kg N, 112 kg P and K, and 28 kg S/ha were incorporated.

Dormant 'Tristar' and 'Benton' strawberry plants were planted 9 Apr. 1985. Plots consisted of 32 plants, 30 cm apart within the row and rows 102 cm apart. Ten consecutive plants in the middle of the plot were chosen for yield data. The two cvs. and four treatments were arranged in a randomized complete block with four replications. Plants were deblossomed and runners cut off once a week until 13 June. Runners were cut off once a month after that until late Sept. Plots were irrigated once a week using overhead sprinklers. No insecticides or fungicides were applied in 1985. Pesticide applications in 1986 consisted of Ronilan, Captan, and Benlate fungicides; Thiodan, Keltane, Plictran, and Diazinon insecticides; and Tenoran herbicide. Gray mold and mites were the most common pest problems.

In 1985, berries from the day-neutral cv. Tristar were harvested every 5-7 days from 9 July to 8 Oct., for a total of fourteen harvests. Fresh weight, number of berries, and mean berry weight were determined. Additionally, a deformity rating was determined for each berry harvested. This was based on an approximation of the percentage deformed area of the berry. The deformity ratings were 0,1,3,5,10,20,30,40,and 50+%.

In 1986, berries were harvested every 3-5 days from both 'Tristar' and 'Benton'. Harvest began 9 June and ended 27 June. Fresh weight, number of berries, and mean berry weight were determined. Samples of 25 berries/plot were rated for percentage deformity.

Crowns were counted on 27 June 1985 for both cvs. In 1986, crown counts of 'Tristar' were recorded 3 Apr. Crown counts of 'Benton' were made on 8 July.

RESULTS

B application had no effect on yield, mean berry weight, or percentage deformity in 'Tristar' during 1985 (Table 3.1). A decrease in yield with B application was highly significant (1.0% level) in 1986. Mean berry weight and percentage deformity were not affected by treatment (Table 3.2).

There was no treatment effect on any parameter in 'Benton' during 1986 (Table 3.3). As with 'Tristar' in 1985, a negative trend in yield is apparent with the 4.5 kg/ha application.

Crown production was not affected by treatment in either year for either cultivar (Table 3.4).

DISCUSSION

These results substantiate findings by other researchers (1,2,3,5). Strawberries are considered to be very sensitive to B (7), and it is likely that they are more sensitive than previously believed. Their B requirement appears to be so low that it can be supplied by the organic matter in the soil (51,68).

It is believed that B toxicity was responsible for the yield decline in 'Tristar' during 1986. Although no toxicity symptoms were apparent in 1985, a decrease in dry matter production due to B application occurred (Riggs, unpublished data). Presumably, this decline in vigor caused a decline in inflorescence initiation and development, leading to a decline in yield.

The results with 'Benton' are similar. Although no significant differences existed with B application, a negative trend was evident. Dry matter production in 1985 also decreased with B application (Riggs, unpublished data). Again, no toxicity symptoms were evident, but vigor was affected enough to result in a yield decline.

B treatment had no effect on fruit deformity or mean berry weight at any time in either cultivar. Toxicity had no adverse effect on fruit set, and no deficiency existed. However, deformity percentages varied dramatically over the season (Fig. 3.1). Mean deformity percentages increased rapidly from 9% to 26% during July and August, declining to acceptable levels again in late Sept. and Oct. No pattern was evident for either cultivar through June 1986. Populations of lygus bugs (*Lygus hesperus*) were evident in 1985. It is believed that feeding damage on the achenes, caused by this insect, was responsible for a large majority of the deformity observed.

Current Oregon State University fertilizer guides for strawberries recommend B application for low B soils. Application rates should not exceed a maximum rate of 2.2 kg/ha/year until a soil level of 1.0 ppm B is obtained. This recommendation should be revised. A soil B level of .27 ppm, even on a coarse, leached soil appears to be adequate for 'Benton' and 'Tristar' strawberries. Other cvs. should be tested on low B soils. B toxicity must be monitored carefully. Even though no toxicity symptoms nor fruit deformity is evident, plant vigor may be affected, leading to a decline in yield.

Table 3.1 Effect of boron application on yield, mean fruit weight, and percentage deformity in 'Tristar' 1985.

B Treatment (Kg/Ha)	Yield (T/A)	Mean fruit wt. (G)	Deformity percentage[z]
0.0	8.23	7.94	15.42
1.1	8.33	7.56	16.13
2.2	8.30	7.67	16.12
4.5	7.23	7.60	17.38
	NS	NS	NS

[z] Mean Value of Percentage Deformed Area on each Berry.
NS - Nonsignificant.

Table 3.2 Effect of boron application on yield, mean fruit weight, and percentage deformity in 'Tristar' 1986.

B Treatment (Kg/Ha)	Yield (T/A)	Mean fruit wt. (G)	Deformity percentage[z]
0.0	6.95[a]	9.57	12.53
1.1	4.91[b]	9.51	9.54
2.2	5.40[b]	9.04	12.76
4.5	5.50[b]	10.37	10.66
	**	NS	NS

[z] Mean Value of Percentage Deformed Area on each Berry.

$LSD_{.01}$ = 1.31 T/A.

NS, ** - Nonsignificant (NS) or significant at 1% (**) level.

Table 3.3 Effect of boron application on yield, mean fruit weight, and percentage deformity in 'Benton' 1986.

B Treatment (Kg/Ha)	Yield (T/A)	Mean fruit wt. (G)	Deformity percentage^z
0.0	12.0	9.18	10.11
1.1	12.6	9.40	10.60
2.2	11.22	9.03	9.49
4.5	10.72	9.26	9.59
	NS	NS	NS

^{z}Mean Value of Percentage Deformed Area on each Berry.
NS - Nonsignificant.

Table 3.4 Effect of boron on number of crowns in 'Tristar' and 'Benton'. 1985 and 1986.

	'Tristar'			'Benton'		
B Trt. (Kg/Ha)	85 Crowns	86 Crowns	Diff.	85 Crowns	86 Crowns	Diff.
0.0	3.35	6.37	3.02	5.37	17.75	12.38
1.1	2.87	5.25	2.38	5.70	17.90	12.20
2.2	2.75	5.77	3.02	5.15	17.50	12.35
4.5	2.90	5.65	2.75	4.62	17.47	12.85
	NS	NS	NS	NS	NS	NS

NS - Nonsignificant.

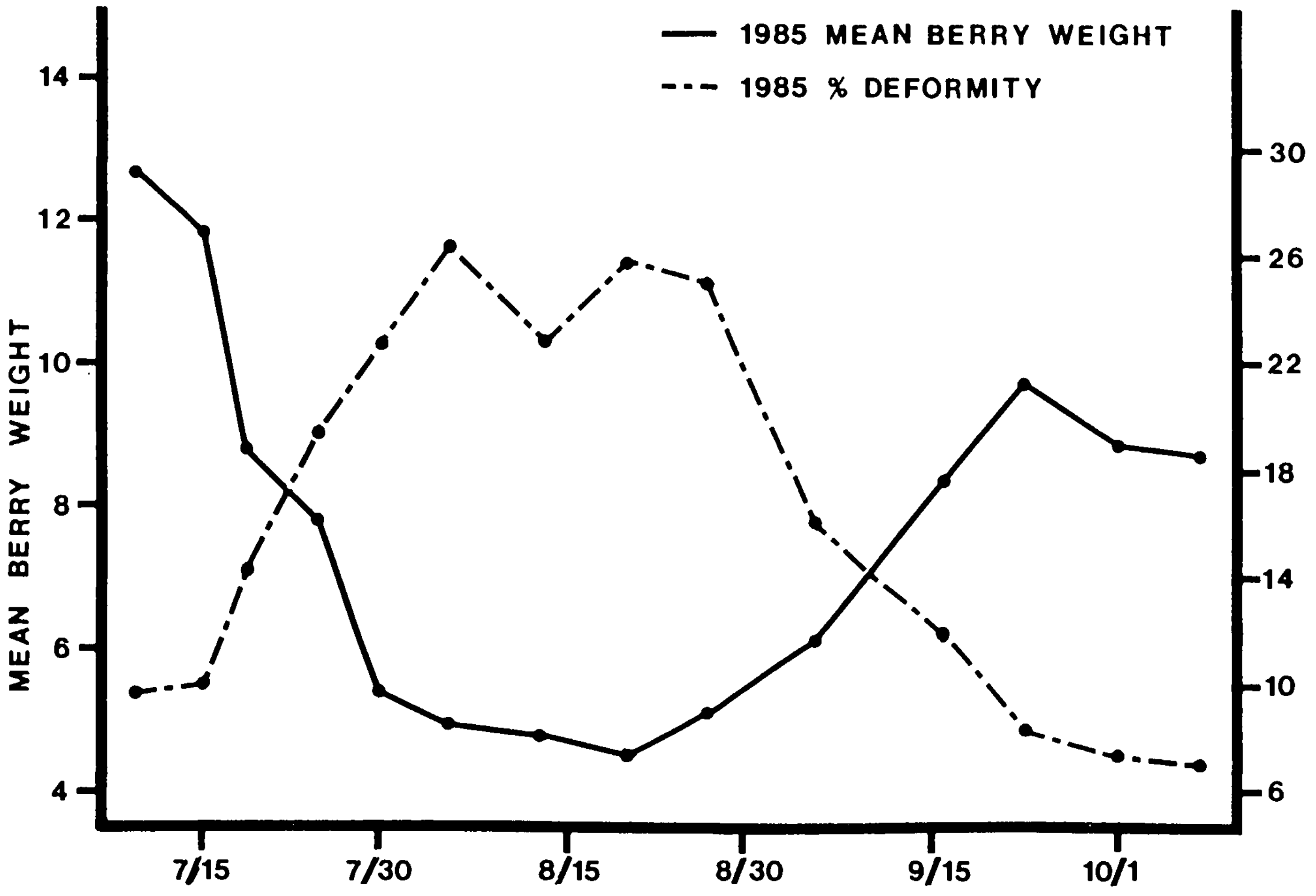

Fig. 3.1 Mean Berry Weight and % Deformity of 'Tristar' Strawberries in 1985.

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CHAPTER 4

THE EFFECT OF BORON APPLICATION ON BORON PARTITIONING IN 'TRISTAR' AND 'BENTON' STRAWBERRIES

KEY WORDS: Day-neutral, *Fragaria*, plant nutrition, tissue analysis

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ABSTRACT

Leaf tissue analysis is the standard tool for diagnosing B deficiency in strawberries. Composite samples of 'Benton' and 'Tristar', grown under soil applied B fertilizer rates of 0, 1.1, 2.2, and 4.5 kg/ha B were taken during June, August, and September in 1985. 'Benton' plants were resampled in April 1986. Tissue concentration and dry weight were determined for up to ten plant parts. Concentrations decreased over time. B application increased leaf concentration and decreased dry weight of leaves. B concentrations in all plant parts were signficantly correlated to leaf concentrations, even though total B uptake of nonleaf tissues did not differ between treatments. At least 85% of the additional B in a plant resulting from soil application of B was found in the leaves. Leaf tissue analysis did not accurately indicate boron status of other plant parts and tissue concentrations can be misleading if total B contents are not evaluated.

INTRODUCTION

B has been known to be an essential element since 1910 (1), and is involved in pollen germination and pollen tube growth (6,7,18,20). Boron deficient strawberries will often have malformed fruit (9,10,15,16), presumably due to an adverse effect on pollen formation, germination, or pollen tube growth (20).

Soil tests suggest B deficiency is a common problem in the highly leached soils of Western Oregon. In 1984, 38% of the soils in Western Oregon were below the critical level of .50 ppm (J. Hart, Personal Communication) for hot water extractable B. Boron deficiency may be a contributing factor to strawberry fruit malformation in this region.

Tissue analysis of strawberries is currently performed on leaves or petioles. Leaf B values fluctuate widely, depending on time of sampling, age of plant, and cultivar (3,4,5,11,12). Even with standardized sampling, conflicting reports indicate normal growth occurs when leaf B is anywhere from 14-116 ppm (2,3,4,5,12), while critical values for toxicity range from 50-200 ppm (2,3,8,10,20).

Uptake of B is a mainly passive process (14,17). Kohl and Oertli (13) concluded that B movement occurs in the transpiration stream, therefore B is not redistributed from leaves to other plant parts because it is not transported in the phloem. This suggests that the leaf is the dominant tissue for B accumulation.

The practice of using leaf tissue analysis to diagnose B deficiency that is exhibited in reproductive tissue should be investigated more thoroughly. It is possible that the B status of reproductive tissues is not related to leaf B levels. If this is true, leaf analyses may be of little value in determining B needs of reproductive tissue. Furthermore, soil applications of B may not be the best means of delivering B to target tissues. The partitioning of soil supplied B is an important issue.

Mineral concentrations in diagnostic tissues are used to make recommendations and interpret experimental results. Unfortunately, changes in nutrient concentrations do not necessarily correspond to altered total amounts of a nutrient within a tissue, nor can they be interpreted as changes in the uptake of nutrients from the soil. Without dry matter accumulation data, total uptake and translocation cannot be evaluated.

This study was initiated with three objectives: 1) Determine if total uptake and B partitioning among plant parts is more informative than a leaf or petiole concentration, 2) Determine if soil applied B is an adequate method to supply B to reproductive tissues, and 3) Examine B partitioning in a Day-neutral and in a June-bearing cultivar.

MATERIALS AND METHODS

Plots for this study were located at the North Willamette Experiment Station in Aurora, OR. The soil series was a Quatama loam, which was fumigated with methyl bromide and chloropicrin. Soil test levels of .27 ppm B indicated a severe B deficiency. Boron was applied 5 Apr. 1985 by dissolving Solubor (20.5% B) in 3.8 liters of water and sprinkling it in a 61 cm wide strip in the row before planting. Application rates were 0, 1.1, 2.2, and 4.5 kg/ha actual B. Additionally, 56 kg N, 112 kg P and K, and 28 kg S/ha were applied. All fertilizer was immediately incorporated using a rototiller.

Dormant 'Tristar' (Day-neutral) and 'Benton' (June-bearing) strawberry plants were planted 9 Apr. 1985. Each plot contained 32 plants, 30 cm apart within the rows, with 102 cm between rows. Twenty-two plants in each plot were available for sampling. The other ten were used for yield data not reported in this paper. The two cultivars and four treatments were arranged in a randomized complete block design with four replications. Plants were deblossomed and runners removed once a week until 13 June, and runners were removed once a month thereafter until late Sep. Plots were irrigated once a week using overhead sprinklers. No pesticides were applied in 1985. Pesticides applied in 1986 consisted of Tenoran for weed control; Ronilan, Captan, and Benlate fungicides to control gray mold; and Thiodan, Kelthane, Plictran, and Diazinon insecticides to control spittlebug and mites.

Composite samples of three plants/plot were taken 27 June, 5 Aug., and 23 Sept. 1985 for both cvs. 'Benton' was also sampled 14 Apr. 1986. Plants were divided into roots and crowns (Roots), petioles (Pet), leaf blades (Lvs.), runner plants (Run), flower stalks (FS), flowers and flower buds (FB), immature fruit (IF), and primary, secondary, and tertiary mature fruit (1^o,2^o,3^oFr). The plant parts were washed, dried at 70^oC and ground through a 20 mesh screen. One half gram tissue was ashed at 500^oC and diluted with 10cc 5% HNO_3. Samples were analyzed for B using an ICAP spectrometer.

Analysis of variance was determined using a split-plot model with boron treatments as main plots and plant parts as sub-plots. Boron concentration (ppm), total μg B, and dry weight of each plant part was measured. Correlation coefficients were calculated for all possible comparisons.

RESULTS

Tissues from the June, 1985 sampling contained the highest ppm B. Depending on which tissue, levels varied between 15-127 ppm in 'Benton' and 22-147 ppm in 'Tristar'. Concentrations decreased with time. Significant differences due to treatment were evident in leaf tissue at all three sampling dates in 1985 for 'Benton', but no treatment effect existed in 1986 (Fig. 4.1). 'Tristar' also exhibited treatment differences in leaf tissue for the June and Aug. samplings (Fig.4.2). Although all tissues generally had higher concentrations for B treatments, the only significant differences due to B application existed in leaf tissue. These occurred with the 4.5 kg rate at all 1985 sampling dates for 'Benton'. 'Tristar' had signficant differences with the 4.5 kg rate in June and the 2.2 and 4.5 kg rates in August. At no time was leaf tissue in a deficiency or toxicity range (2,4,8,10,20).

'Benton' leaves contained the greatest amount of total B (64%-84%) of all plant parts at each date in 1985, but the percentage of total B in the leaves diminished with time (Table 4.1). By 1986, total μg B was nearly equivalent in the leaves and roots (Fig. 4.3), with leaves containing only 40% of total B (Table 4.1). Boron application increased total B at each sampling date in 1985. Treatment differences were evident in leaf tissue early in the season, but diminished over time. There was no effect in 1986. Treatment differences were not present for nonleaf tissues at all samplings (Fig. 4.3).

The leaves of 'Tristar', at the June and Aug. samplings, contained more B with B application, but the differences disappeared by Sept (Fig 4.4). Unlike 'Benton', total B in 'Tristar' declined in B treated plots between Aug. and Sept. samplings (Table 1). This was largely due to a decrease in total B in leaf tissue. No treatment differences existed among nonleaf tissues at any time (Fig. 4.4). The percentage of total B contained in leaf tissues was generally similar to 'Benton'.

Dry weight of leaves of both cultivars was negatively affected by B application in the June sample (Figs. 4.5,4.6). There was no effect from B application for reproductive tissues during the June sampling, although a negative trend existed for roots and petioles. No treatment effect was present in the Aug. or Sept., 1985 samples, or in 1986 (data not shown). Roots, petioles, and leaves exhibited a negative trend from B application in Aug. and Sept. for 'Tristar' and only in Aug. for 'Benton'. Root dry weight was greater than any other tissue in 1986. No trend was observed in reproductive tissues at any time. Total dry weight of both cvs. always increased over time.

Dry weight partitioning changed even less than B partitioning. 'Benton' leaves were 55-58% of the total plant dry weight in the June sampling, decreasing slightly through 1985 to 46-48% of dry weight in Sept. In 1986, leaves were 27-29% of the total dry weight and roots were 37-41%. 'Tristar' leaves were similar to 'Benton' in June, containing 53-56% of the dry weight. They did decrease more over the season, as they were 36-38% of the dry weight in Sept. No treatment effect existed at any time with regard to the percentage of dry matter partitioned to different tissues in either cultivar.

Correlation coefficients indicated all plant parts of 'Tristar' were significantly correlated to leaf concentration in the June and August sampling (Table 4.2). The same was true for 'Benton' in 1986.

DISCUSSION

It is clear that B movement occurs mainly in the transpiration stream. In 1985 leaf tissue accounted for 45-58% of the dry weight of 'Benton' but contained 69-84% of the total B. Of the net increase in B from B application, in most cases at least 85% of the additional B is found in the leaves. Data from 1986 is not as clear. However, sampling in 1986 leaves occurred at a time when few new leaves had emerged, while at the same time root growth had been continuing for most of the winter. Cool spring temperatures may have decreased the rate of transpiration resulting in less B movement to the leaves. 'Tristar' followed the same pattern of B accumulation as 'Benton' in 1985 until Sept., when B application apparently had a deleterious effect on plant growth, and no net increase in B was detected.

Boron accumulation increased throughout the 1985 season. 'Benton' had a two to three fold increase between June and Sept., depending on boron treatment (Table 4.1). 'Tristar' had a 19-53% increase between June and Aug., but then up to a 34% decline in B content between Aug. and Sept. Leaf fall due to B toxicity probably accounts for the decline in B content. Treatment effect diminished over time in 'Benton' until all treatments were essentially the same in 1986. This may be explained two ways: 1) Leaf growth declines as the season progresses, resulting in less B movement to the leaves, and 2) The majority of the applied B in the soil is leached out of the rooting zone during the rainy winter months. The slight increase over the control may in large part be due to residual B in the roots (Fig.4.3). The small amount of B in reproductive tissues and fruit at all samplings, and the lack of any treatment effect in these tissues, indicate that a soil application of B is not effective in increasing B levels in reproductive tissues.

Correlation coefficients (Table 4.2) must be interpreted cautiously. Although a relationship exists between B concentration in leaves and B concentration in other tissues, there may not be similar uptake by other plant parts. The increase in B concentration in nonleaf tissue (Figs. 4.1,4.2) may be attributed to the decrease in dry weight (Figs. 4.5, 4.6), rather than to any change in total B accumulation in the tissues (Figs. 4.3,4.4). Despite a strong correlation between leaf concentration, and that in other tissues, it appears that B status of leaves is independent of other plant parts. A great percentage of the soil applied B was translocated directly to the leaves without affecting other tissues. One can then conclude that leaf analysis for B is of little value in identifying deficiency or toxicity levels in reproductive tissues.

Soil guidelines or soil test procedures for B levels may need revision. The soil level of .27 ppm in this study is considered highly deficient, yet no deficiency levels in plant tissue were measured. Additionally, B application caused a decrease in dry weight (Figs 4.5,4.6), and had a negative effect on yield (unpublished data). Strawberries may have a lower B requirement and tolerate low B soils better than is commonly believed.

In an area where a true deficiency has been identified, a B application to the emerging buds should be investigated. This may deliver enough B to the reproductive tissues at a critical time. In areas where soil guidelines reflect a deficiency, annual applications of B will be necessary as winter leaching appears to move most of the applied B below the rooting zone.

TABLE 4.1. Amount of boron (μg) in 'Benton' and 'Tristar' strawberry tissues for control and B fertilized plants on Sampling Dates in 1985 and 1986.

		'Benton'				'Tristar'			
Sampling date	Kg/Ha B	B content (μg)			% in leaves	B content (μg)			% in leaves
		TOTAL	LEAVES	OTHER		TOTAL	LEAVES	OTHER	
June	0.0	1217	835a	382	68.6	1358	1012a	356	74.5
	1.1	1680	1275ab	405	75.9	1546	1190ab	357	76.9
	2.2	1816	1402abc	414	77.2	1716	1327ab	389	77.3
	4.5	2700	2281c	418	84.5	2472	2080b	392	84.2
August	0.0	2299	1507a	792	65.6	2050	1237	813	60.3
	1.1	2471	1602a	870	64.8	2369	1597	772	67.4
	2.2	2935	2101a	834	71.6	2463	1725	738	70.0
	4.5	4304	3260b	1045	75.7	2945	2163	782	73.4
September	0.0	3610	2301	1309	63.7	2192	1288	904	58.8
	1.1	3809	2514	1294	66.0	2234	1274	961	57.0
	2.2	3578	2426	1151	67.8	2031	1220	811	60.0
	4.5	5088	3580	1508	70.4	1938	1125	814	58.0
April	0.0	2325	926	1400	39.8				
	1.1	2646	1055	1591	39.9				
	2.2	2624	1042	1582	39.7				
	4.5	2655	1084	1571	40.8				

Values in the same column followed by the same letter are not significantly different ($p > .05$).

TABLE 4.2. Correlation coefficients between B concentration of 'Tristar' and 'Benton' Leaves and other plant parts in harvest years of 1985 and 1986, respectively.

	Sampling Date			
	'Tristar'			'Benton'
Plant Parts	June	Aug.	Sept.	April
Roots	.933***	.852***	.475	.662**
Petioles	.960***	.922***	.383	.843***
FS	.886***	.538*	.323	.771***
FB	.863***	.626*	.192	.541*
IF	--	.800***	.453	--
1^{o}	--	.881***	.473	--
2^{o}	--	.658**	.374	--
3^{o}	--	.812***	.344	--
Run	--	.831***	.550*	--

Values followed by an asterisk indicate statistical significance at 0.1% (***), 1.0% (**), or 5.0% (*) levels.

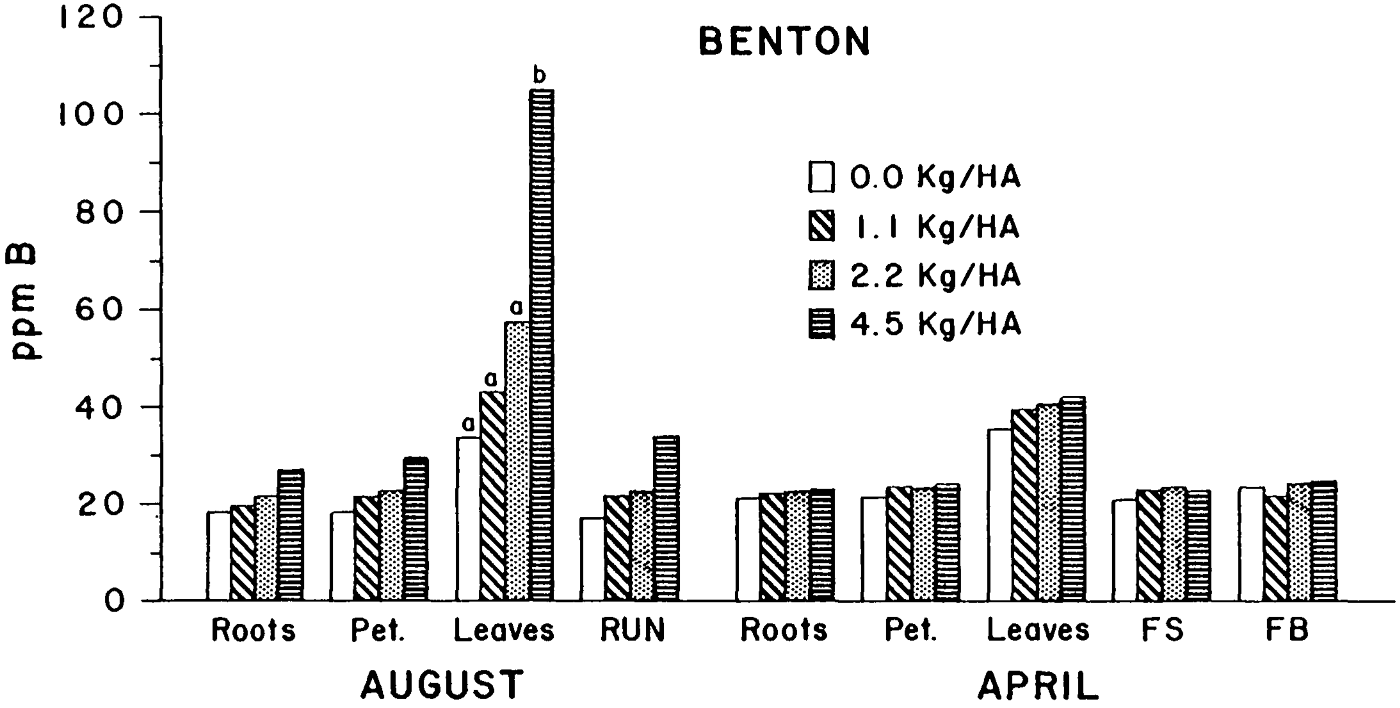

Fig. 4.1. Concentration of 'Benton' plant parts sampled 5 Aug. 1985 and 14 Apr. 1986.

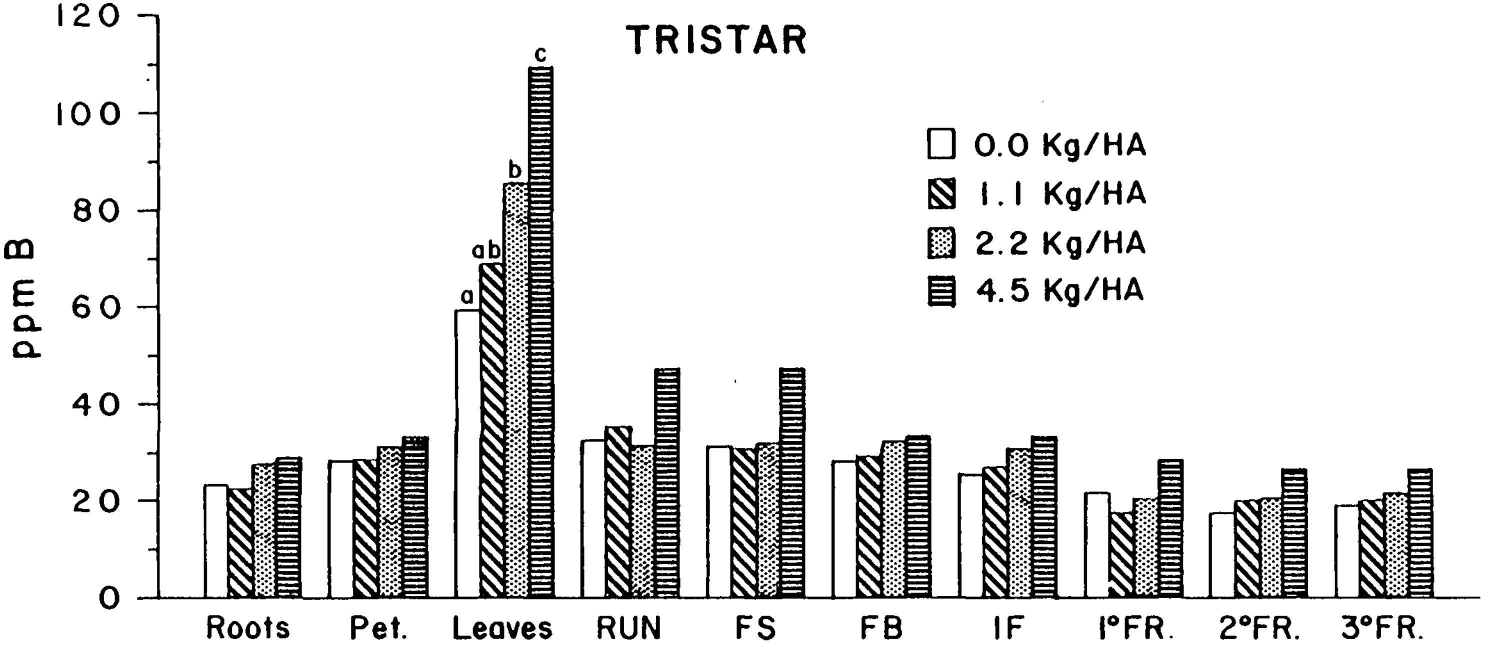

Fig. 4.2. Concentration of 'Tristar' plant parts sampled 5 Aug. 1985.

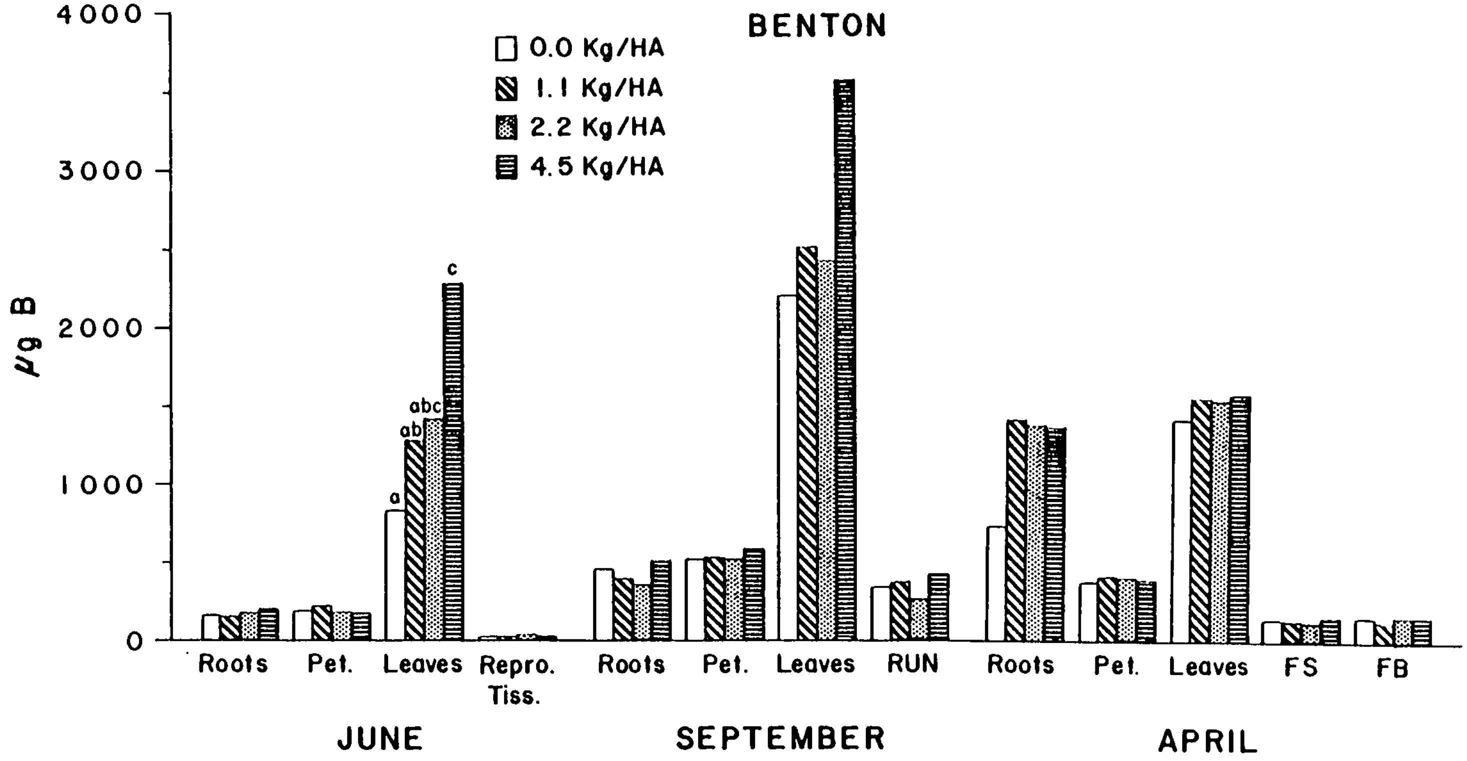

Fig. 4.3. Total boron of 'Benton' plant parts sampled 27 June, 23 Sept. 1985 and 14 Apr. 1986.

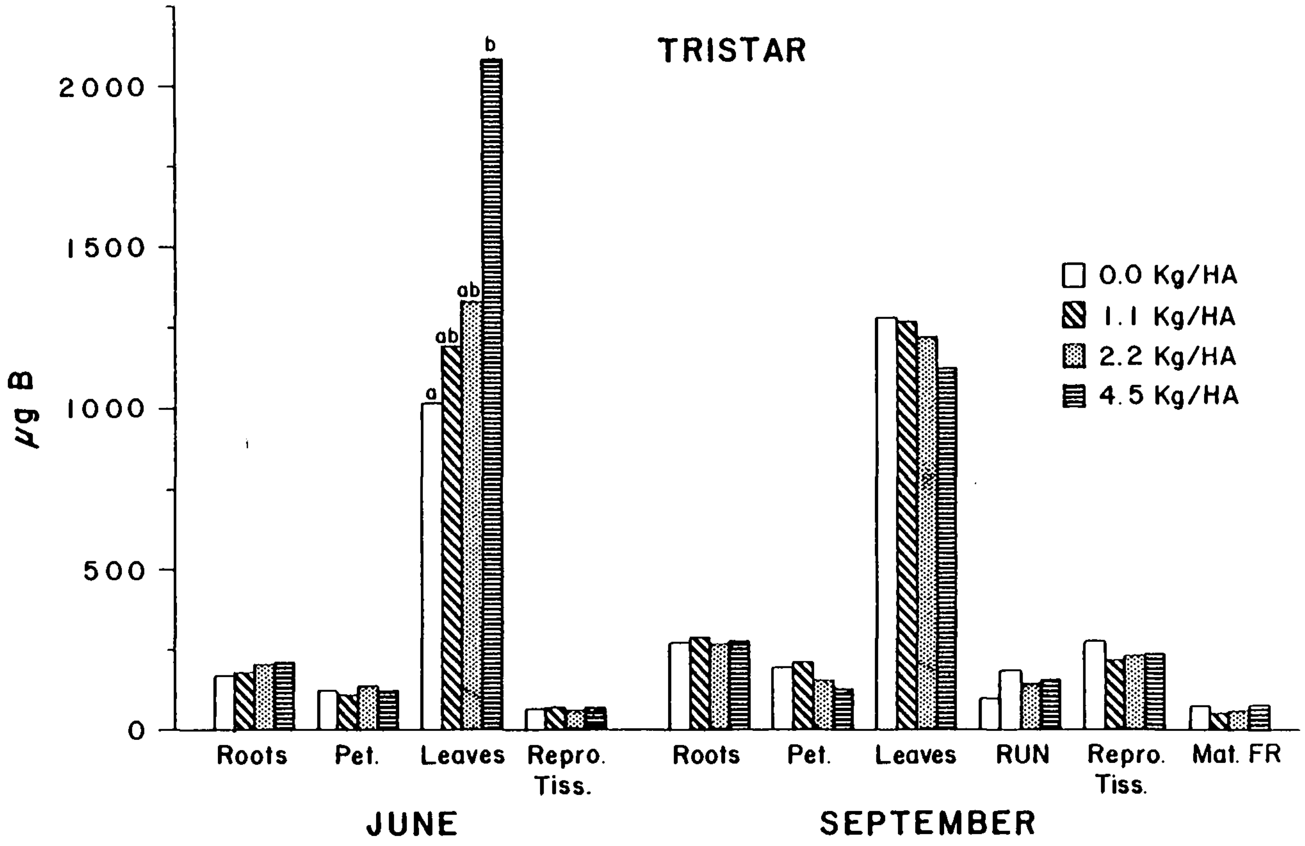

Fig. 4.4 Total boron of 'Tristar' plant parts sampled 27 June and 23 Sept. 1985.

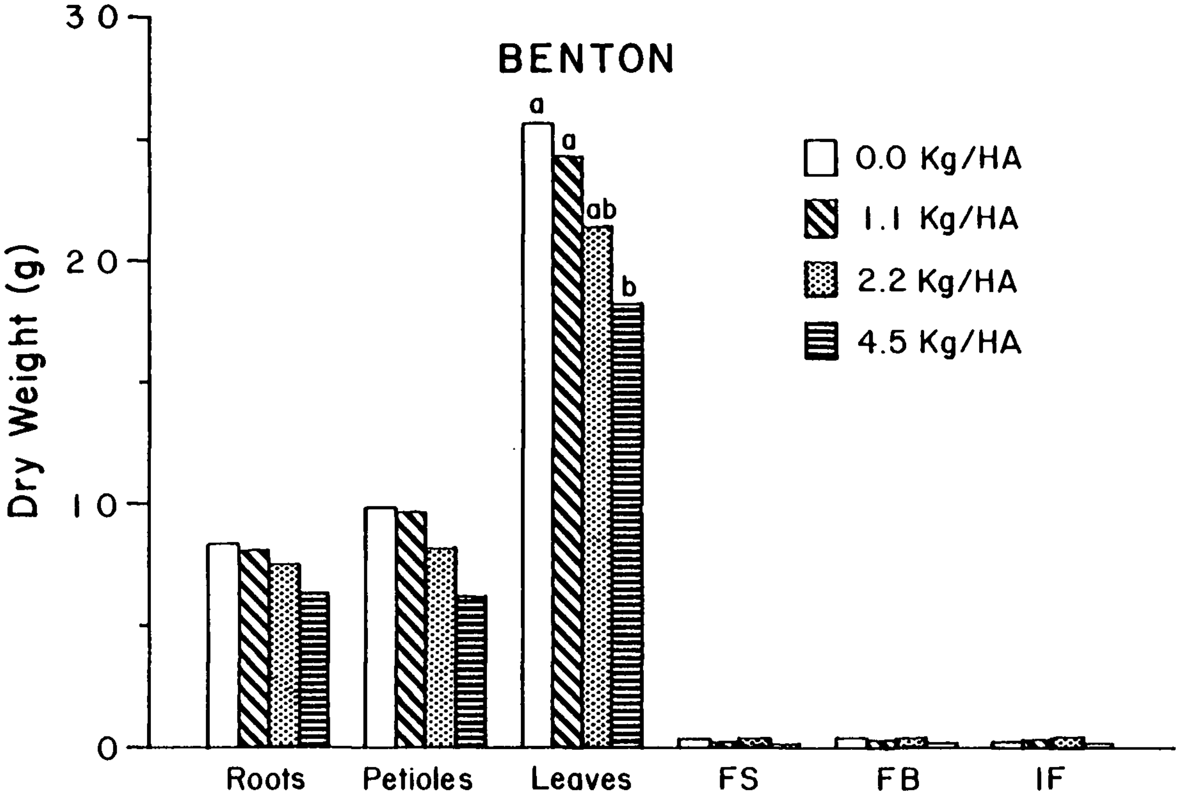

Fig. 4.5 Dry weight of 'Benton' plant parts sampled 27 June 1985.

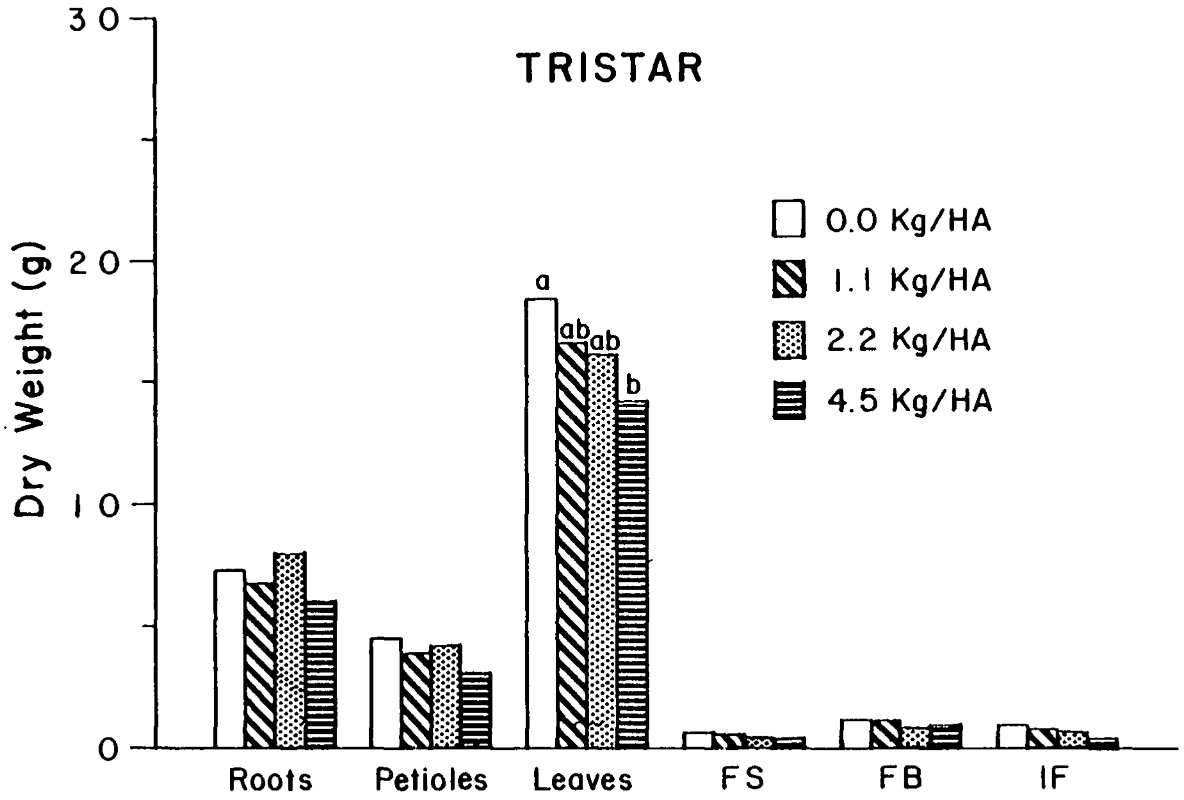

Fig. 4.6 Dry weight of 'Tristar' plant parts sampled 27 June 1985.

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CHAPTER 5

GENERAL DISCUSSION AND CONCLUSIONS

Many of the strawberry growing regions in Western Oregon have B-deficient soils. Preplant soil applications of B fertilizer have been a standard practice for soils testing low in B. This study was initiated to determine the effectiveness of soil applied B to alleviate fruit deformity believed to be caused by B deficiency.

This study has indicated that preplant soil application of B did not affect fruit deformity in either june-bearing or day-neutral cultivars. Patterns of deformity in 1985, when combined with high populations of *Lygus hesperus*, indicated the fruit deformity may have been caused by this insect feeding on achenes. B application did not have an effect on crown production in either cultivar. This is interesting when one considers that B application had a negative effect on yield the second harvest year. One may presume that the yield decline is from a B toxicity causing a general decline in vigor of the plant and depressing effect on floral initiation.

Measurement of B in each plant part has added further insight into the problem. Tissue analysis indicated a higher concentration of B in the leaves with increased B application. Associated with the increased leaf concentration was a decline in the leaf dry weight. Total B was unchanged between treatments.

Correlation coefficients indicated a strong correlation between leaf B concentration and B concentration in other plant parts. In actuality, when total B uptake was considered, non-leaf tissues had large differences in uptake in comparison with leaf tissue. B application had no effect on total uptake. In addition, more than 85% of the soil applied B was found in the leaves.

These findings lead to multiple conclusions. 1) Current B fertilizer recommendations should be revised. Strawberries appear to obtain necessary amounts of B from soils testing low in B, and even small additions of B can have a negative effect on yields. 2) Soil-applied B does not deliver B to reproductive tissues where deficiencies can cause fruit deformity. An investigation should be conducted using B application on emerging flower buds. 3) Fruit malformation, as documented in 1985, was not from a B deficiency but most likely from *Lygus hesperus* feeding damage. Prospective growers of day-neutral strawberries in the Willamette Valley should be prepared to control this pest.

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APPENDIX

Lygus Greenhouse Experiment

Cultivar: Tristar

Duration of Experiment: February 24, 1986 to April 28,1986

Treatments:

1. No pollination, no *Lygus*
2. Hand pollination, no *Lygus*
3. No pollination, with *Lygus*
4. Hand pollination, with *Lygus*
5. Partially developed receptacle, with *Lygus*

Trt.	Deformity Percentage	Mean Fruit Weight
1	30.0	5.2
2	5.2	10.8
3	59.7	3.7
4	68.2	3.1
5	20.0	3.1

Fig. A.1. Healthy achenes from well formed fruit 1985. (25x)

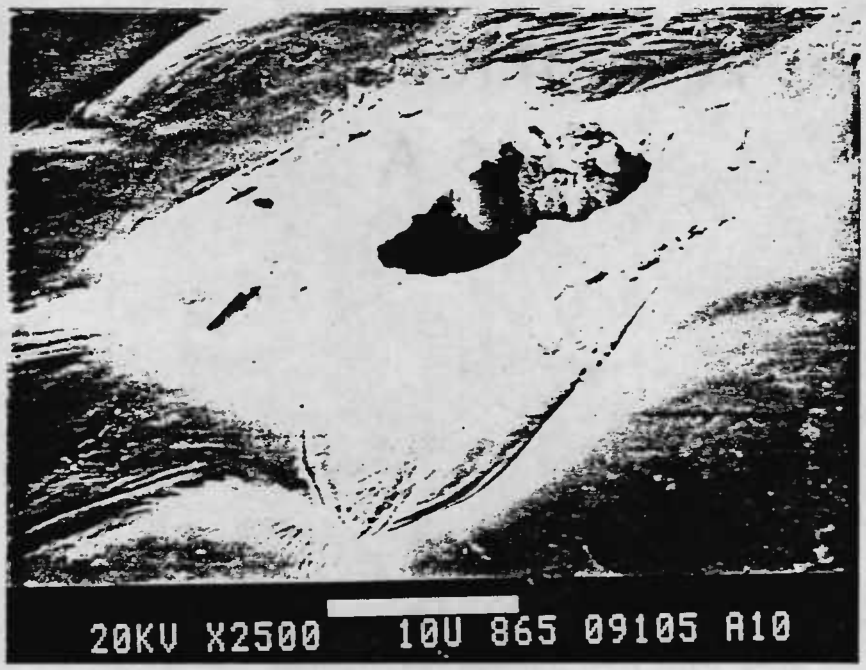

Fig. A.2. Possible puncture wound in achene from malformed fruit 1985. (2500x)

Fig. A.3. Pollinated and nonpollinated achenes from trt. 1 (no pollination, no <u>Lygus</u>) 1986. (14x)

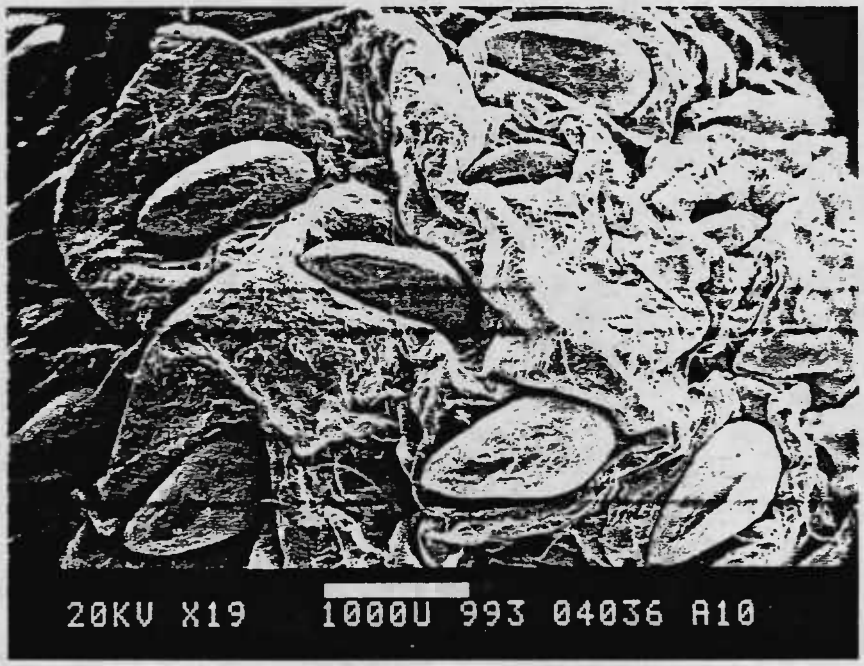

Fig. A.4. Pollinated achenes from trt. 2 (with pollination, no <u>Lygus</u>) 1986. (19x)

Fig. A.5. Pollinated and nonpollinated achenes from trt. 3 (no pollination, with <u>Lygus</u>) 1986. (14x)

Fig. A.6 Possible puncture wound in achene from trt. 4 (with pollination, with <u>Lygus</u>) 1986. (2000x)

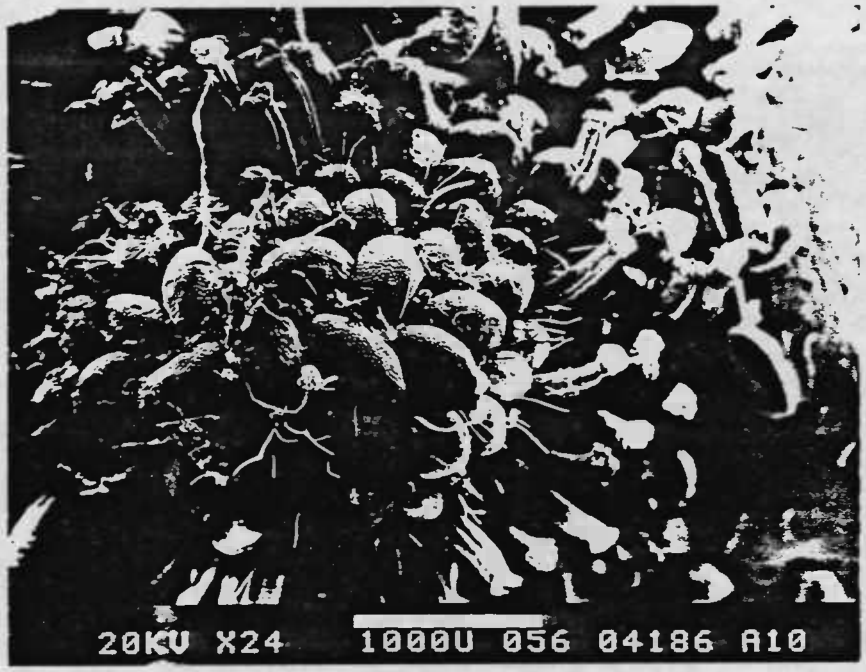

Fig. A.7. Nonpollinated achenes from trt. 4 1986. (24x)

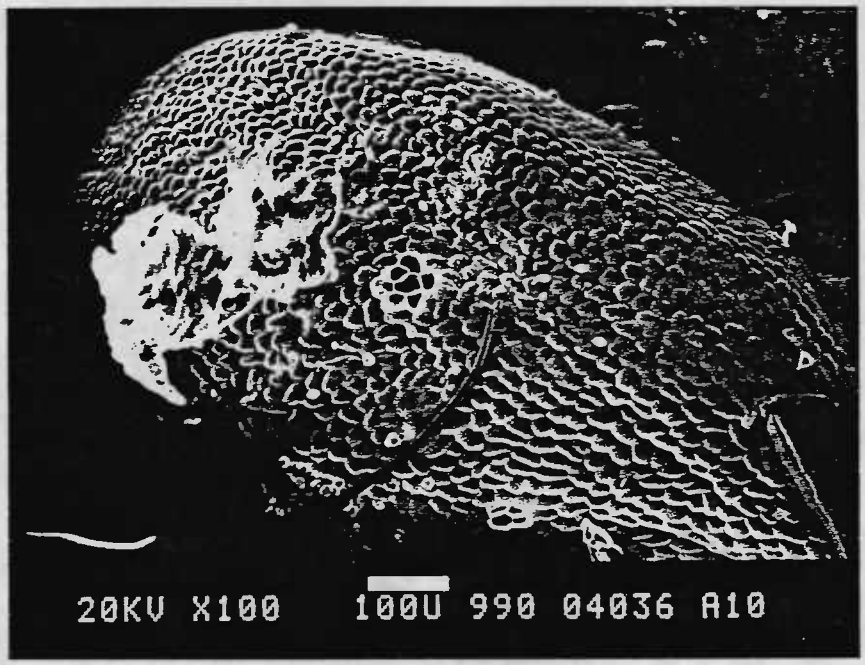

Fig. A.8. Possible puncture wounds in achene from trt. 5 (partially developed receptacle, with <u>Lygus</u>) 1986. (100x)

Table A.1 Boron Concentration (ppm) of 'Benton' Plant Parts 1985-1986.

Kg/Ha B	Roots	Pet.	Lvs.	Run	FS	FB
			June			
0.0	20.0	20.0	33.0	14.5	18.75	20.5
1.1	20.25	22.75	52.75	18.25	23.75	28.0
2.2	25.0	23.75	66.0	17.75	24.25	29.25
4.5	31.75	29.75	127.0	26.75	36.75	47.75
			August			
0.0	18.25	18.75	33.75	17.0		
1.1	19.75	21.75	43.25	21.25		
2.2	21.25	22.5	57.75	22.5		
4.5	26.5	29.25	105.0	34.0		
			September			
0.0	19.0	20.25	39.5	17.5		
1.1	17.25	22.0	45.0	23.25		
2.2	17.75	22.0	45.25	19.5		
4.5	21.25	24.5	60.75	23.0		
			April			
0.0	21.25	21.75	35.25	--	20.75	23.75
1.1	22.0	23.75	39.5	--	22.5	21.75
2.2	22.25	23.0	40.25	--	23.25	24.25
4.5	22.75	24.0	42.0	--	22.25	24.75

Table A.2 Boron Concentration (ppm) of 'Tristar' Plant Parts 1985.

Kg/Ha B	Roots	Pet.	Lvs.	Run	FS	FB	IF	1° Fr.	2° Fr.	3° Fr.
					June					
0.0	22.5	27.25	55.75	21.5	21.75	22.0				
1.1	26.25	29.0	71.75	24.5	26.0	26.75				
2.2	25.75	31.0	83.0	26.5	28.5	27.0				
4.5	33.5	39.25	147.0	33.75	34.0	39.5				
					August					
0.0	23.75	28.25	59.5	32.75	31.25	28.0	25.25	21.75	18.5	19.0
1.1	22.75	28.5	68.5	35.5	30.75	29.25	27.0	18.5	20.0	20.0
2.2	27.75	31.0	85.5	31.75	32.0	32.0	30.5	20.0	20.25	21.25
4.5	29.0	33.75	109.0	47.5	47.25	33.5	33.25	28.25	26.25	26.25
					September					
0.0	22.25	29.5	59.0	44.0	31.5	29.75	22.0	17.25	17.25	18.75
1.1	23.5	31.25	60.5	39.5	32.25	30.75	22.25	14.0	17.75	18.5
2.2	20.75	28.75	61.0	42.25	30.0	27.5	20.5	16.0	17.25	19.75
4.5	27.0	31.5	67.75	43.25	32.0	30.5	23.25	16.75	19.25	19.5

Table A.3 Total μg Boron of 'Benton' Plant Parts 1985-1986.

Kg/Ha B			June			
	Roots	Pet.	Lvs.	Run	FS	FB
0.0	498.7	587.1	2503.8	16.9	24.8	19.5
1.1	491.8	648.7	3824.4	18.2	24.8	32.3
2.2	562.2	581.0	4205.2	23.8	32.1	42.4
4.5	607.1	555.1	6843.8	16.0	29.1	47.4
			August			
0.0	721.3	1004.3	4521.2	650.2		
1.1	726.4	971.2	4804.5	911.0		
2.2	706.8	944.3	6302.7	851.2		
4.5	855.8	1052.4	9778.7	1225.4		
			September			
0.0	1354.3	1542.3	6902.0	1031.5		
1.1	1183.9	1587.1	7542.9	1112.2		
2.2	1099.9	1554.7	7279.1	799.4		
4.5	1506.2	1751.9	10740.6	1264.3		
			April			
0.0	2183.8	1128.3	2762.9	--	444.0	457.8
1.1	2750.9	1231.9	3165.4	--	411.3	378.0
2.2	2667.1	1208.9	3124.4	--	407.4	463.0
4.5	2616.1	1183.8	3251.9	--	453.3	458.9

Table A.4 Total µg Boron of 'Tristar' Plant Parts 1985.

Kg/Ha B	Roots	Pet.	Lvs.	Run	FS	FB	IF	1^{o} Fr.	2^{o} Fr.	3^{o} Fr.
					June					
0.0	491.3	359.3	3036.1	44.4	78.1	65.0				
1.1	524.3	335.1	3568.9	45.2	93.5	71.6				
2.2	601.9	385.3	3980.2	38.8	82.0	58.5				
4.5	610.3	358.6	6241.0	49.1	104.8	51.9				
					August					
0.0	568.3	576.6	3710.1	400.8	209.0	58.4	191.6	142.8	171.1	120.4
1.1	560.0	573.5	4790.2	181.4	206.9	85.9	256.7	126.4	212.1	113.1
2.2	563.0	583.3	5174.8	291.1	167.6	86.9	197.6	79.1	146.3	99.0
4.5	565.9	462.8	6488.0	277.8	297.8	76.3	195.5	136.1	209.5	124.1
					September					
0.0	812.6	576.0	3862.7	288.3	335.4	97.2	390.1	68.1	64.5	80.0
1.1	876.9	634.5	3820.8	552.8	286.0	88.2	276.9	47.9	69.8	49.2
2.2	670.2	467.9	3660.0	439.6	282.2	76.6	321.2	57.4	88.6	30.5
4.5	685.7	377.8	3373.7	460.8	272.5	71.2	349.1	64.6	105.2	54.1

Table A.5 Dry Weight (g) of 'Benton' Plant Parts 1985-1986.

Kg/Ha	Roots	Pet.	Lvs.	Run	FS	FB
			June			
0.0	25.0	29.5	77.0	1.2	1.3	1.0
1.1	24.3	28.7	72.8	1.0	1.1	1.2
2.2	22.7	24.6	64.0	1.3	1.4	1.5
4.5	19.2	18.7	54.5	0.6	0.8	1.0
			August			
0.0	39.4	53.0	130.5	36.7		
1.1	36.6	44.5	109.8	40.3		
2.2	33.4	41.7	108.2	38.7		
4.5	32.7	36.9	94.2	35.7		
			September			
0.0	71.5	76.7	176.6	58.7		
1.1	68.6	72.1	167.9	46.2		
2.2	62.0	70.0	159.3	42.0		
4.5	71.2	71.7	177.4	56.4		
			April			
0.0	101.5	51.5	77.8	--	21.3	19.0
1.1	124.8	51.0	79.8	--	17.8	17.3
2.2	119.5	52.5	77.5	--	17.3	19.3
4.5	115.3	49.0	77.5	--	20.0	18.5

Table A.6 Dry Weight (g) of 'Tristar' Plant Parts 1985.

Kg/Ha B	Roots	Pet.	Lvs.	Run	FS	FB	IF	1^{o} Fr.	2^{o} Fr.	3^{o} Fr.
					June					
0.0	22.0	13.4	55.2	2.1	3.6	2.9				
1.1	20.0	11.6	49.9	1.9	3.6	2.7				
2.2	23.9	12.6	48.4	1.5	2.9	2.2				
4.5	18.1	9.2	42.5	1.5	3.1	1.3				
					August					
0.0	24.8	20.6	62.0	11.8	6.7	2.1	7.7	6.6	9.9	6.9
1.1	24.7	20.3	69.7	5.3	6.7	3.0	9.6	7.0	10.5	5.7
2.2	20.7	19.3	63.0	8.5	5.1	2.7	6.2	3.8	6.9	4.9
4.5	19.4	13.8	59.8	4.7	5.7	2.3	5.9	5.0	8.1	4.7
					September					
0.0	36.4	19.4	63.9	6.6	10.7	3.2	18.0	4.1	3.8	4.5
1.1	37.4	20.4	62.0	13.7	9.0	2.9	12.4	2.6	4.0	2.7
2.2	33.2	16.7	60.0	10.3	9.3	2.7	15.5	3.5	4.9	1.6
4.5	25.6	12.0	49.6	10.7	8.5	2.3	14.8	3.6	5.4	2.7

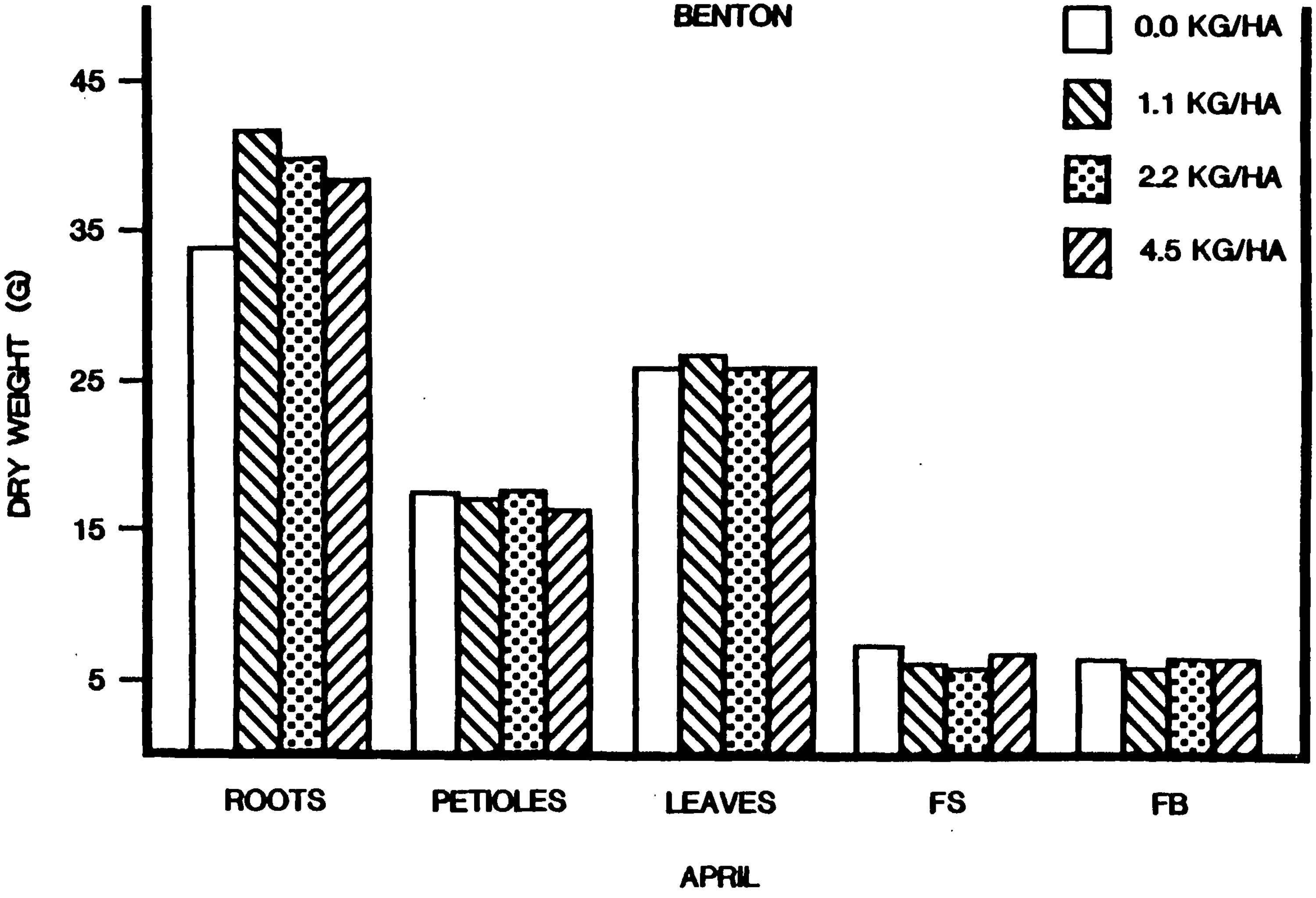

Fig. A.9. Dry weight of 'Benton' plant parts sampled 14 Apr. 1986.