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ADDITIONAL BORON DEFICIENCY SYMPTOMS IDENTIFIED IN ALMOND

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Summary

Boron (B) deficiency in almond (Prunus dulcis Mill.) is characterized by leaf tip scorch on vigorous shoots with subsequent leaf drop, watersprout shoot dieback, brown gummy areas in the shell, and embryo abortion with a gummy kernel cavity followed by nut drop in May. Additional symptoms revealed by our work include failure of flowers to set nuts and a drop of the lateral shoot buds. This leads to a vigorous "willow twig" growth pattern. Some cultivars may show these newly recognized symptoms with minimal display of the traditional symptoms.

Introduction

In May 1988, gummy kernels and nut drop of `Peerless' almond occurred in a six year old orchard in Chico, California. These traditional symptoms of boron deficiency were not observed in nearby rows of `Nonpareil', `Carmel', or `Butte' almonds. The latter almond cultivars displayed unproductive scaffold limbs in portions of the canopy, or in a few cases, entire trees grew vegetatively. These symptoms were reminiscent of the nonproductive ("bull") syndrome or of infectious bud failure seen in trees infected by Prunus necrotic ringspot virus (PNRSV). The soil in the affected area is Anita Clay Loam, Reddish Phase which was cut 18-24 inches to level the field at the time the orchard was planted. The fourteen row wide affected area is on a bench slightly higher than surrounding soil series. In the rest of the orchard the same cultivars appeared healthy and productive. These observations resulted in additional investigations leading to the information presented here.

Materials and Methods

Leaves, kernels, hulls, and shells were sampled from `Peerless' and `Nonpareil' cultivars for the 1988 analysis performed in the UC Davis Pomology Department. Six single tree replicates were selected for sampling in May and August. `Peerless' almond trees exhibited typical boron deficiency symptoms and `Nonpareil' almond trees had vigorous vegetative growth without fruit peduncles in some portions of the canopy indicating no fruit set on that wood in previous seasons. Severely deficient trees were completely unproductive at harvest. Moderate deficiency symptoms included some nut drop on `Peerless' and unproductive areas within the `Nonpareil' canopy. Normal unaffected trees had no nut drop on `Peerless' and no unproductive wood on `Nonpareil'. Trees of `Butte' and `Carmel' almond exhibited an unproductive syndrome similar to the `Nonpareil' almond.

In January 1989, a field trial on `Butte' almond was established to compare a 1.5 pound per tree Solubor(20.5% B) soil application to an untreated control. Twelve trees per treatment were divided into four replications arranged in a randomized complete block design. Guard trees surrounded the sample trees in each block. The seasonal boron levels in test trees (treated and untreated) were compared using leaf analysis performed by the UC DANR analytical laboratory at monthly intervals from April to October of 1989 and in July of 1990 and 1991. In February 1994, 20 shoots approximately 18 inches long exhibiting 1989 through 1993 growth were sampled from both boron treated and untreated trees. Shoot length was measured and yield was determined from the number of peduncles present on the wood.

Representative symptomatic trees were assayed for prune dwarf virus (PDV) and Prunus necrotic ringspot virus (PNRSV) in May 1990. Succulent leaf extracts were tested in ELISA microtiter plates in the Plant Pathology Department at UCD to determine if the trees harbored these ILAR viruses.

Results and discussion

Although reminiscent of the nonproductive syndrome, the field pattern is not typical of this disorder. Nonproductive syndrome is a genetic disorder that is often limited to only one cultivar in a planting. In this case, all cultivars in the orchard were affected so this disorder was highly unlikely.

Virus bud failure associated with PNRSV is a disease that could affect individual scaffolds or entire trees and it could affect several cultivars in a planting. Blossoms fail to set fruit on affected limbs and branch dieback may occur. Calico symptoms may be present in leaves and the virus can cause blind wood along the shoots. In this orchard, all almond trees assayed for PDV and PNRSV were negative by ELISA thereby eliminating these viruses as a cause for the lack of production.

Analysis in May 1988 confirmed that boron was low in the leaves, kernels, hull and shell. As deficiency symptoms increased, boron levels decreased (figure 1) indicating that this nutrient was most likely responsible for the problem we observed. Boron levels in normal and deficient trees had good separation at this time of year in all plant parts tested.

By August (figure 2), severely affected trees had dropped their crop and samples of kernels, shells, and hulls were not available for analysis. Leaf tissue analysis no longer gave a clear separation between deficient and unaffected trees. Once the severely deficient trees dropped their crop, their boron leaf levels were the same as those of the moderately deficient trees. Boron levels in hull tissue provided the best separation between moderately deficient and normal trees at this time of year.

By April 1989, boron in leaf tissue of `Butte' almond trees treated in January was higher than levels in leaves of untreated controls (figure 3). The seasonal trend that year indicated that leaf boron levels in deficient trees peaked in July. The previous critical value for boron in July leaf tissue was 25 ppm. Levels were considered adequate between 30 and 65 ppm and excess at levels greater than 85 ppm. In 1989, boron levels of deficient and treated trees were always above the critical July value (figure 3). July leaf samples over a three year period (figure 4) were again always in the adequate range in spite of the fact that untreated trees had unproductive areas in their canopies and a nut set response was seen from boron treatment (figure 5).

Shoot evaluations in 1994 showed that boron applications had increased the number of nuts per shoot in previously unproductive portions of the tree canopy from zero to an average of 1.95 nuts per shoot (figure 5). Among the boron treated trees, fruit set began in the second year after treatment. During this same time, portions of untreated `Butte' trees continued to be unproductive.

Figure 6 shows effects of boron deficiency correction on nut set and return bloom. Correcting boron deficiency increased the number of nuts per shoot in 1993 and reduced the average number of flower buds per shoot the following year compared to the untreated controls. Boron deficient untreated control shoots set no nuts in 1993 but had a heavy bloom in 1994. Although bloom was present the boron deficient shoots never set nuts.

As mentioned earlier, boron deficiency symptoms can be confused with the nonproductive syndrome or with virus bud failure since the typical gumming of nuts and nut drop associated with boron deficiency in `Peerless' may not occur in all cultivars. Instead, trees will bloom but flowers will fail to set. Lateral shoot buds abort producing elongated spurs as the terminal buds continue to grow. This failure of the lateral shoot and flower buds leads to a "willow twig" symptom on the small fruitwood similar to symptoms of the nonproductive syndrome or virus associated bud failure.

Figure 7 shows the dramatic reduction in "willow twig" shoot growth from 1990 through 1993 following the 1989 boron application. The 1989 application of boron effectively corrected the deficiency, increased fruitfulness (figure 5), and reduced shoot growth as nuts set. In the untreated control treatments, of the 37.1 cm of growth made by sampled shoots from 1987 through 1993, 21 cm or 57% of the growth occurred during 1990 through 1993 as the "willow twig" persisted. After boron treatment only 6.6 cm of growth occurred from 1990 through 1993, or 19% of the 35.4 cm of growth made by these shoots from 1987 through 1993. The shoots became producing spurs once again.

Conclusions

The `Peerless' cultivar displays gummy nuts and nut drop when boron deficient while other adjacent cultivars may appear to be unaffected. We now know that boron deficient `Nonpareil', `Carmel', and `Butte' cultivars may develop "willow twig" symptoms and that unproductive scaffolds or entirely unproductive trees may be present without displaying the gummy nut drop. Once thought more tolerant, these cultivars may actually be more sensitive to boron deficiency than is `Peerless' since their crop aborts before setting rather than after. In an orchard situation, boron deficiency on these cultivars can be more easily overlooked and their unproductive symptoms may be confused with the nonproductive syndrome or the virus associated bud failure disease.

Comparative leaf, hull/shell, or kernel analysis in May gave a better indication of low boron than did leaf analysis in July or August. Our results suggest that for boron determinations, leaf tissue analysis could be done early in the season to better detect low boron levels. Boron critical values for mid-season almond leaves established through previous research should be re-evaluated since deficiency symptoms occurred at currently accepted "adequate" levels.

In August, hull analysis for boron gave a better separation between deficient and adequate trees than did leaf, kernel, or shell analysis. To better identify boron deficient trees a hull analysis is preferred during July-August. In this trial, where a true boron deficiency adversely affected the crop, normal, unaffected trees had 44 ppm boron in hulls during August. Trees that were showing symptoms of moderate boron deficiency had 22 ppm boron in the hulls in August. The broad range of 30-80 ppm boron in hull tissue that is currently being evaluated as a deficient range suggests that more research is needed to correctly determine the critical value for boron in almond hull tissue.

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Figure 1. Boron levels in almond, May, 1988.

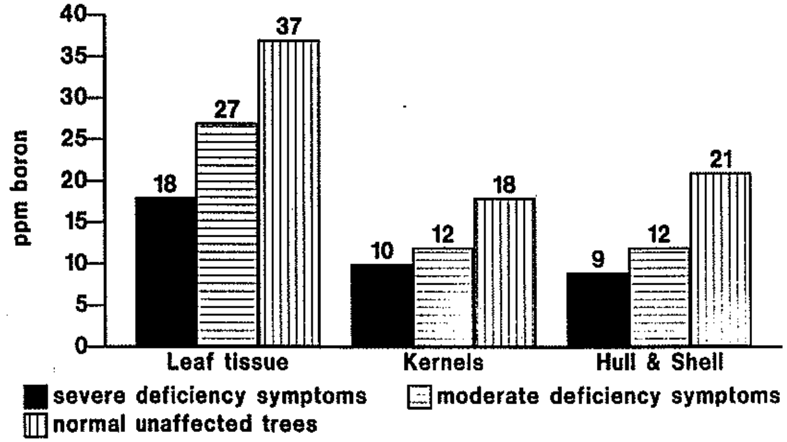
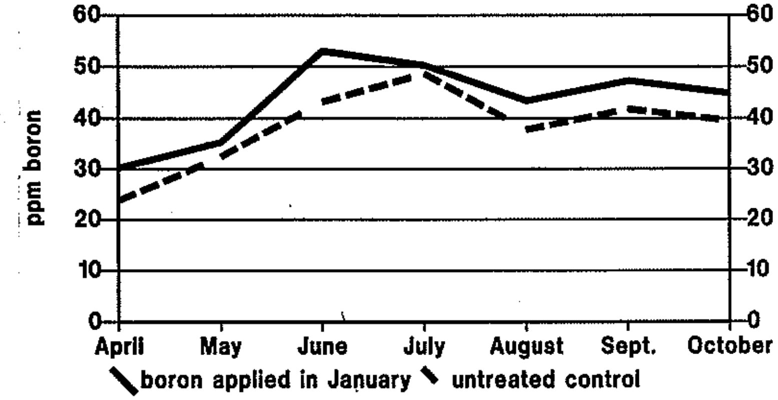
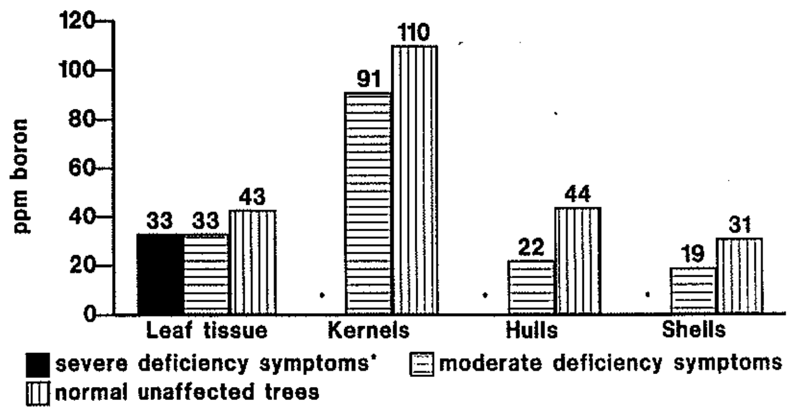


Figure 3. Seasonal trend, boron leaf tissue levels, 1989.
July critical value at 25 ppm.



Soil application, 1.5 lbs of 20.5% B material/tree, 1/4/89

Figure 2. Boron levels in almond, August, 1988.



* Nuts dropped, unavailable on severely deficient trees.

Figure 4. Boron in July leaf tissue.

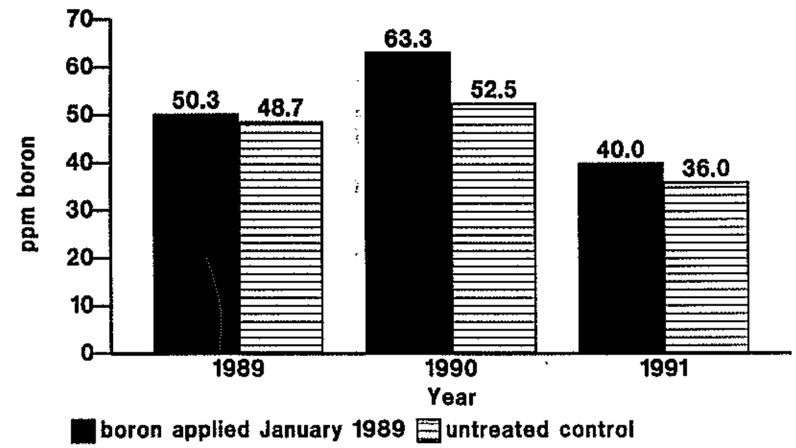
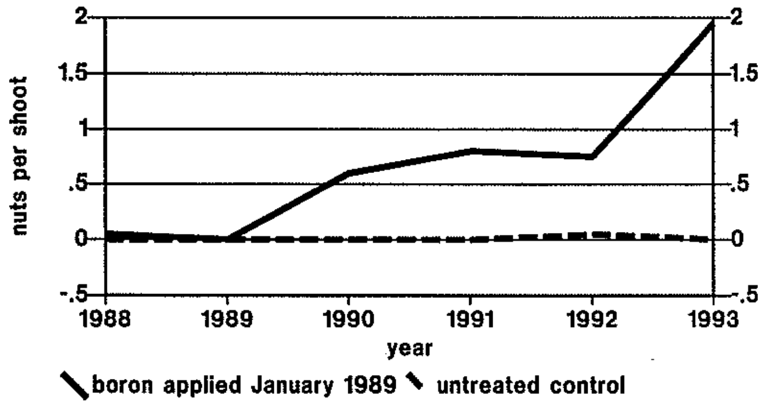


Figure 5. Yield trend for 'Butte' almond.

Mean of 20 shoots



Soil application, 1.5 lbs of 20.5% B material/tree, 1/4/89

Figure 7. Shoot growth response of 'Butte' almond.

Mean of 20 shoots

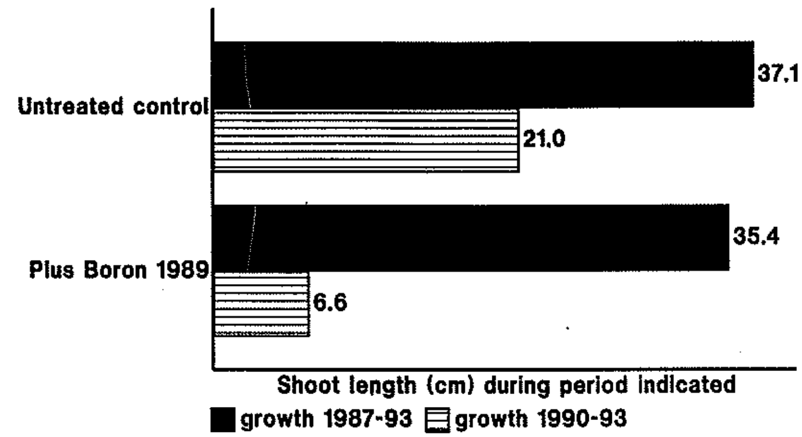


Figure 6. Nut set and return bloom.

Mean of 20 shoots