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# Prebloom Foliar Boron, Zinc, and Urea Applications Enhance Cropping of Some 'Empire' and 'McIntosh' Apple Orchards in New York

**Ed Stover[1], Michael Fargione, and Richard Risio**
*Department of Horticultural Sciences, New York State Agricultural Experiment Station, Cornell University, Hudson Valley Laboratory, Highland, NY 12528*

**Warren Stiles**
*Department of Fruit and Vegetable Sciences, Cornell University, Ithaca, NY 14853-5904*

**Kevin Iungerman**
*Cornell Cooperative Extension, 50 West High Street, Ballston Spa, NY 12020*

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***Abstract.* This study was initiated to determine if prebloom sprays of B, Zn, and urea would enhance cropping of apple (*Malus ×domestica* Borkh.) after cold injury, hypothesizing that they may accelerate recovery of damaged vascular tissue. The following foliar nutrient treatments were applied prebloom to 'McIntosh' and 'Empire' trees at two sites in 1994 and 1995: 1) control; 2) B (22.8 mM) at half-inch-green; 3) Zn-EDTA (0.75 mM) at half-inch-green; 4) B and Zn-EDTA at half-inch-green; 5) B, Zn-EDTA, and urea (59.4 mM) at half-inch-green; 6) B and Zn-EDTA at half-inch-green, followed by B, Zn-EDTA, and urea at pink. In 1994, following a very severe winter that caused visible damage to vascular tissue, 'Empire' at both sites cropped more heavily following all treatments that included both B and Zn; such treatments increased cropload by an average of 22% and 35% at the two test sites. Despite a mild winter preceding the 1995 season, prebloom nutrient treatments again increased cropping of 'Empire'. In 1996, treatments included a control and a single foliar treatment (B + Zn-EDTA at half-inch-green followed by B, Zn-EDTA, and urea at pink) on 'McIntosh' and 'Empire' at seven orchard sites. Treatment enhanced cropping in 'McIntosh' at three of the seven sites, but there was no effect on 'Empire'. Factors influencing differences in response were not apparent from this study, although a complex of factors may be involved. Data for all years indicated that prebloom nutrients did not enhance spur leaf development or fruit set; such treatments probably enhance cropping by increasing retention of flower buds that would otherwise abscise before anthesis. Where cropping was increased, mean fruit weight was not reduced at $P \leq 0.05$ but fruit weight was significantly less at $P \leq 0.10$ in 1995. Chemical names used: boron (Solubor, disodium octaborate tetrahydrate); zinc (Zn-EDTA, zinc chelate).**

Apple trees tolerate low midwinter temperatures and are grown in many regions where midwinter lows of –30 °C are routine and temperatures below –40 °C are sometimes experienced. While trees usually survive and bear fruit following exposure to such low temperatures, many are injured, yield is reduced, and fruit size is small. Browning of vascular tissue and pith frequently is evident following very cold winters. The presence of small wrinkled spur leaves has been attributed to cold injury (Forshey, 1990; Stiles, 1987). Since spur leaves are the first fully expanded leaves and provide much of the photosynthate for early fruit development (Hansen, 1971; Lakso, 1984), such weak spur leaves may limit fruit cell division critical for attaining maximal fruit size. Irregular flower bud development is also observed following very low winter temperatures. Many flower buds cease development around the tight cluster stage and are sloughed off.

Vascular tissue damage may restrict movement of mineral nutrients and other xylem-transported materials that are required for spring leaf and flower development. Foliar application of nutrients may speed tree recovery and enhance cropping of cold-injured trees. Similarities in foliar symptoms of winter-injured trees and those deficient in B (delay in bud development) or Zn (very small leaf size) led one of the authors (W.C. Stiles) to suggest prebloom application of these nutrients to cold-injured trees.

Boron deficiency increases indoleacetic acid (IAA) oxidase activity (Marschner, 1986) and B may enhance IAA concentration and influence flower bud development. Flowers have a high requirement for B (Woodbridge et al., 1971), and fruit set is often enhanced by B application (Bramlage and Thompson, 1962; Davison, 1971; Shrestha et al., 1987). Zinc is a cofactor for RNA-polymerase and is thus critical for protein synthesis (Faust, 1989), but is also involved in the formation of tryptophan, a precursor to IAA (Marschner, 1986). Indoleacetic acid can be a limiting factor in vascular tissue differentiation. Higher levels are required for xylem compared to phloem development (reviewed in Aloni, 1987). The purpose of this study was to characterize the effectiveness of prebloom applications of B, Zn, and urea to determine what aspects of cropping are affected, and to determine what conditions warrant use of these treatments. Urea was included in the study because low N availability in spring can also result in reduced leaf area.

## Materials and Methods

*Orchard selection and management.* Experiments were conducted in commercial orchards of the Mid-Hudson and Champlain valleys of New York. Grower-cooperators followed standard orchard practices, including chemical thinning with NAA and/or carbaryl, except that foliar nutrient applications were avoided. Sites were selected where 'Empire' and 'McIntosh' were planted in the same year in neighboring rows with M.9 as either the rootstock or interstem. All interstem trees had MM.111 rootstocks. Trees received little containment pruning. The same sites in Modena, N.Y. (Mid-Hudson Valley), and Peru, N.Y. (Champlain Valley), were used all 3 years, but each individual tree was used for only 1 year. In the third year, three additional orchards in the Mid-Hudson Valley and two additional orchards in the Champlain Valley were used.

*Experimental design.* A randomized complete-block design was used with 10 single-tree replications per cultivar for each treatment at each site. In year 1, blocks were established spatially within the rows. For years 2 and 3, 'Empire' trees were blocked by trunk cross-sectional area (TCA), and 'McIntosh' by spur density; 'McIntosh' was blocked by spur density because variable spur production could confound experimental results.

*Nutrient application.* In each year, performance of nontreated controls was compared to trees receiving foliar nutrients. Products were applied as follows: B at 22.8 mM (1.2 g of formulation per L) using the product Solubor (>99% disodium octaborate tetrahydrate; U.S. Borax, Valencia, Calif.); 0.75 mM Zn as Zn-EDTA (Clean Crop, 9% zinc EDTA; Platte Chemical Co., Fremont, Nebr.; 2.5 mL·L$^{-1}$); and 59.4 mM urea (45% N, microprilled, agricultural feed grade; BP Chemicals, Lima, Ohio; 3.6 g of formulation per L). Materials were tank-mixed when more than one nutrient was applied to the same tree at a given phenologi-

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[1]Current Address: Univ. of Florida, Indian River Research and Education Center, 2199 South Rock Rd., Ft. Pierce, FL 34945-3138.

cal stage. Materials were applied to runoff on all tree surfaces with a high-pressure handgun (1740 kPa), using rates suggested in the Cornell tree-fruit recommendations (Stiles and Reid, 1991). In 1994 and 1995, half-inch-green applications were: B; Zn; B plus Zn; and B, Zn, and urea combined. A fifth treatment received B plus Zn at half-inch-green followed by B, Zn, and urea at pink. In 1996, a single nutrient treatment, B and Zn at half-inch-green followed by B, Zn, and urea at pink, was compared with nontreated controls.

*Data collection and analysis*. The number of fruit were counted on each tree in the experiment just prior to commercial harvest. At harvest, trunk circumference was measured 25 cm above the ground and used to calculate TCA. Cropload was calculated as number of fruit per $cm^2$ TCA to reduce the effect of variations in tree size.

Random samples of 25 fruit were collected from each tree at harvest. Fruit weight, diameter, seed number, and grooving were evaluated. Grooving can result from cold injury of parenchyma tissue above the zones where placentae of neighboring carpels fuse (Wilde et al., 1984), and when severe, reduces fruit grade. Rating systems developed to assess grooving differed for 'Empire' and 'McIntosh', since some blocks of 'Empire' displayed uniform calyx lobes that would be classified as grooving using the 'McIntosh' scale. For 'McIntosh': 1 = no grooving; 2 = grooving on the calyx end that did not extend to the fruit equator; 3 = grooving that extended from the calyx to the stem end of the fruit, but the fruit was still perceived as round; and 4 = grooving that extended from the calyx to the stem end of the fruit, and the fruit was no longer round. For 'Empire': 1 = no grooving, no flat spots or valleys at fruit equator; 2 = fruit equator had flattened spots but no grooving; 3 = grooving at the fruit equator, but the fruit was still perceived as round; and 4 = grooving at the fruit equator, and the fruit was no longer round.

Each year, primary spur leaves were collected during the period from pink to full bloom. Within an orchard, all samples were collected on the same date. Five spurs were collected per tree and leaf dry weight per spur, excluding leaves from bourse shoots, was determined for each sample. The number of primary leaves per spur was counted in 1995 and 1996. In 1996, primary spur leaf area was measured using an automatic area meter (type AAM-5; Hayashi Denco Co., Tokyo).

In 1994, spur leaves collected at pink to full-bloom were used for nutrient analysis. In 1995 and 1996, leaves were collected for analysis in mid-July according to the Cornell orchard nutrition guide (Stiles and Reid, 1991). Nutrient analyses were conducted at the Cornell plant nutrient laboratory.

In 1994 and 1996, fruit set per blossom cluster was evaluated. In 1994, six trees per treatment were evaluated for both 'McIntosh' and 'Empire' at each site. In 1996, all experimental trees were evaluated. Lower branches were selected for evaluation in 1994 since they were more likely to have been injured in the very cold 1993–94 winter. In 1996, representative branches were selected on each tree. Blossom clusters were counted at tight cluster to early pink on three or four typical branches or on entire trees to total 100 or more clusters. Near commercial harvest, fruit were counted on the same branches on which bloom had been evaluated.

In 1994, the effects of the treatments on flower bud development were evaluated at the Champlain Valley site. When a majority of buds were at early pink, 50 buds per tree were assessed for stage of phenological development. These data were analyzed as the percentage of buds not yet showing pink petal tissue.

Data were analyzed using the GLM procedure of SAS (SAS Institute, Cary, N.C.). Statistical significance is expressed at $P \leq 0.05$ unless otherwise indicated.

## Results and Discussion

*1994 treatments*. The 1993–1994 winter in eastern New York was unusually severe. The midwinter low in the Champlain Valley orchard site was –42 °C on 27 Jan. and the low at the Mid-Hudson site was –37 °C on 21 Jan. (Table 1). At both sites, substantial browning of vascular tissues was evident in small shoots and spurs when examined in the spring. The foliar nutrient treatments did not increase fruit set per blossom cluster at either site (data not shown). The B-only application on 'McIntosh' in Peru resulted in a statistically significant reduction in the proportion of buds delayed in development when evaluated at pink (data not shown); however, the absence of any trend among other treatments suggests that this was a random event. Spur leaf development, as measured by dry weight of primary spur leaves, was not enhanced at any site and was actually lower following treatments combining B and Zn in the Peru 'McIntosh'.

In 'Empire' at both sites, contrasts between controls and all nutrient treatments containing B and Zn indicated that combined B and Zn treatment increased cropload an average of 22% in Modena and 35% in Peru without a significant reduction in fruit size (Table 2). For 'Empire' in Peru, similar contrasts showed that nutrient applications increased fruit grooving. However, irregular fruit shape was rarely sufficient to reduce grade.

'McIntosh' in the Champlain Valley was severely damaged by low temperatures (–16 °C) on 25 Nov. 1993, when shoots were actively growing unusually late in the fall. Trees in the experimental block were visibly damaged with sporadic loss of scaffold branches and leaders.

Table 1. Location, cultivar, rootstock, approximate midwinter lows, and foliar nutrient levels in control trees in experimental blocks.

| Year | Region | Location | Cultivar | Rootstock | Approximate midwinter low temp. (°C) | Time of foliar analysis | Foliar N (%) | Foliar B ($mg \cdot kg^{-1}$) | Foliar Zn ($mg \cdot kg^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| 1994 | Mid-Hudson | Modena | Empire | M.9/MM.111 | –37 | pink | 4.1 | 35 | 47 |
| | | | Marshall McIntosh | | | | 4.0 | 43 | 32 |
| | Champlain | Peru-1 | Empire | M.9 | –42 | | 3.5 | 31 | 47 |
| | | | Summerland McIntosh | | | | 3.3 | 32 | 46 |
| 1995 | Mid-Hudson | Modena | Empire | M.9/MM.111 | –24 | late July | 2.2 | 24 | 20 |
| | | | Marshall McIntosh | | | | 2.3 | 25 | 19 |
| | Champlain | Peru-1 | Empire | M.9 | –28 | | 2.4 | 35 | 16 |
| | | | Summerland McIntosh | | | | 2.3 | 33 | 15 |
| 1996 | Mid-Hudson | Clintondale | Empire | M.9/MM.111 | –25 | | 2.3 | 23 | 18 |
| | | | Marshall McIntosh | | | | 2.6 | 22 | 15 |
| | | Gardiner | Empire | | –27 | | 1.9 | 33 | 14 |
| | | | Roger's Red McIntosh | M.9 | | | 2.2 | 36 | 14 |
| | | Milton | Empire | M.9/MM.111 | –25 | | 2.3 | 35 | 11 |
| | | | Marshall McIntosh | | | | 2.4 | 38 | 12 |
| | | Modena | Empire | | –27 | | 2.0 | 29 | 16 |
| | | | Marshall McIntosh | | | | 2.6 | 27 | 22 |
| | Champlain | Keeseville | Empire | M.9 | –29 | | 2.1 | 50 | 21 |
| | | | Roger's Red McIntosh | | | | 2.2 | 44 | 21 |
| | | Peru-1 | Empire | | –30 | | 2.8 | 37 | 19 |
| | | | Summerland McIntosh | | | | 3.0 | 42 | 18 |
| | | Peru-2 | Empire | M.9/MM.111 | –29 | | 2.5 | 35 | 57 |
| | | | Marshall McIntosh | | | | 2.4 | 37 | 90 |

Flower buds within a cluster, and some entire clusters, are often shed between tight cluster and pink following severe cold. Since cropping was increased without enhancing fruit set per blossom cluster, foliar nutrient treatments probably increased the number of flowers retained between bud break and pink. In all blocks where cropping was enhanced by nutrient treatments in 1994, the resultant croploads increased the likelihood of poor return bloom. However, all trees produced return bloom sufficient for a full commercial crop.

*1995 treatments*. The 1994–95 winter in eastern New York was less severe, and no obvious winter injury was observed at experiment sites in the spring. The midwinter low in the Peru orchard site was –28 °C on 11 Jan. and the low at the Modena site was –24 °C on 8 Feb. 'McIntosh' did not respond to treatments at either site.

Despite the absence of visible winter injury, the treatments increased cropping of 'Empire' at both sites as indicated by contrast between controls and all nutrient treatments combining B and Zn (Table 2). The increase in cropload from these treatments averaged 22% in Modena and 16% in Peru. The reduction in fruit size was significant at $P \leq 0.10$ but not $P \leq 0.05$. As in 1994, all blocks where nutrient applications enhanced cropping produced such large crops that the likelihood of poor return bloom was increased. Again, all trees produced return bloom sufficient for a full commercial crop.

*1996 treatments*. In 1996, trees throughout eastern New York appeared to enter dormancy late, and many leaves did not abscise until January. The 1995–96 winter lows (ranging from –25 to –30 °C) were similar to those in 1994–95, and browning of cambial tissue indicated some winter injury in the Champlain Valley. In 1996, only B and Zn at half-inch-green followed by B, Zn, and urea at pink was compared to nontreated controls at seven sites in the Mid-Hudson and Champlain valleys. Cropping was only significantly increased in three blocks, all 'McIntosh', (Table 3). At these sites, two in the Champlain (Keeseville and Peru-2) and one in the Mid-Hudson Valley (Clintondale), cropload was increased by 21% to 27% without significantly reducing fruit size. Control trees were undercropped in two of these blocks (Keeseville and Peru-2) but the third block (Clintondale) carried a very large crop even on nontreated trees. Analysis of all 'McIntosh' blocks together indicated that the prebloom nutrient treatment enhanced cropping by 9.6%. Overall cropping was light on nontreated 'McIntosh' trees, so increased cropload provided an economic advantage. In 1996, none of the 'Empire' blocks responded to the nutrient treatments with increased cropping, even though two of the blocks (Modena and Peru-1) had responded well in the two previous years.

The number of primary leaves per spur was also significantly affected by prebloom nutrient treatments in four of the 14 blocks. Since primordia for these leaves were present before the nutrient applications, the treatments could not have influenced the number of leaves that developed, but could have increased the loss of spur leaves before the measurement date. There were no significant effects on dry mass or leaf area of primary leaves per spur (data not shown).

*Factors affecting response to prebloom nutrients*. No clear relationship was observed between winter severity or observed winter injury and response to prebloom nutrients.

Table 2. Effect of prebloom nutrient application to 'Empire' and 'McIntosh' apple on weight of primary leaves at pink or full bloom, and on cropload and grooving at harvest, at two sites in eastern New York in 1994 and 1995.

| | | 1994 | | | 1995 | | |
|---|---|---|---|---|---|---|---|
| Cultivar | Treatment[z] | No. fruit /cm² TCA[y] | Leaf DW (g/spur) | Fruit grooving[x] | No. fruit /cm² TCA) | Leaf DW (g/spur) | Fruit weight (g) |
| | | | | *Modena* | | | |
| Empire | Control | 9.8 | 0.19 | 1.8 | 9.9 | 0.15 | 148 |
| | B | 10.0 | 0.21 | 1.8 | 10.0 | 0.14 | 147 |
| | Zn | 11.4 | 0.20 | 2.0 | 10.4 | 0.16 | 148 |
| | BZn | 11.7 | 0.20 | 1.9 | 11.5 | 0.19 | 141 |
| | BZnU | 12.2 | 0.19 | 2.0 | 12.6 | 0.15 | 140 |
| | BZn + BZnU | 12.0 | 0.21 | 1.9 | 12.1 | 0.17 | 136 |
| Contrast control vs. all | *P* | 0.090 | NS | NS | 0.072 | NS | NS |
| Contrast control vs. all B + Zn | *P* | 0.040 | NS | NS | 0.020 | NS | 0.085 |
| Marshall McIntosh | Control | 7.2 | 0.22 | 1.7 | 7.2 | 0.16 | 126 |
| | B | 8.6 | 0.21 | 1.7 | 7.2 | 0.15 | 124 |
| | Zn | 9.1 | 0.22 | 1.7 | 7.4 | 0.15 | 127 |
| | BZn | 8.4 | 0.23 | 1.7 | 6.9 | 0.13 | 123 |
| | BZnU | 7.2 | 0.21 | 1.7 | 7.4 | 0.11 | 129 |
| | BZn + BZnU | 9.2 | 0.23 | 1.6 | 6.7 | 0.19 | 135 |
| Contrast control vs. all | *P* | 0.103 | NS | NS | NS | NS | NS |
| Contrast control vs. all B + Zn | *P* | NS | NS | NS | NS | NS | NS |
| | | | | *Peru-1* | | | |
| Empire | Control | 6.6 | 0.23 | 2.0 | 11.4 | 0.23 | 135 |
| | B | 7.5 | 0.23 | 2.1 | 12.9 | 0.25 | 132 |
| | Zn | 7.6 | 0.22 | 2.3 | 13.7 | 0.23 | 130 |
| | BZn | 8.2 | 0.20 | 2.1 | 13.8 | 0.25 | 126 |
| | BZnU | 9.0 | 0.21 | 2.1 | 12.5 | 0.23 | 131 |
| | BZn + BZnU | 9.5 | 0.22 | 2.2 | 13.3 | 0.26 | 125 |
| Contrast control vs. all | *P* | 0.019 | NS | 0.015 | 0.039 | NS | 0.099 |
| Contrast control vs. all B + Zn | *P* | 0.004 | NS | 0.032 | 0.039 | NS | 0.066 |
| Summerland McIntosh | Control | 4.5 | 0.28 | 1.6 | 3.2 | 0.23 | 159 |
| | B | 4.4 | 0.29 | 1.6 | 3.5 | 0.26 | 156 |
| | Zn | 3.9 | 0.23 | 1.8 | 2.9 | 0.24 | 154 |
| | BZn | 4.1 | 0.22 | 1.8 | 2.7 | 0.26 | 157 |
| | BZnU | 3.3 | 0.26 | 1.8 | 3.1 | 0.23 | 154 |
| | BZn + BznU | 3.5 | 0.23 | 1.7 | 3.5 | 0.23 | 158 |
| Contrast control vs. all | *P* | NS | 0.105 | NS | NS | NS | NS |
| Contrast control vs. all B + Zn | *P* | NS | 0.049 | 0.108 | NS | NS | NS |

[z]B = 22.8 mM B (in Solubor) applied at half-inch green (HIG); Zn = 0.75 mM Zn (in Zn-EDTA) applied at HIG; BZn = tank mix of B and Zn treatments at HIG; BZnU = tank mix of B and Zn treatments plus 59.4 mM urea at HIG; BZn+BZnU = BZn treatment as described applied at HIG followed by BZnU materials applied at pink.

[y]TCA = trunk cross-sectional area.

[x]Fruit grooving, a form of cold injury, was assessed on a four-point scale from 1 = no grooving to 4 = severe.

Our experimental results suggest that many winter-injured trees may benefit from prebloom nutrients, but many trees with no apparent winter injury may also respond. Understanding the factors influencing response to prebloom nutrients would permit growers to use such treatments only when economically advantageous. Our results suggest that prebloom nutrient treatments may not enhance cropping by directly enhancing recovery of damaged vascular tissue as we had hypothesized. Similar responses were observed in the Modena 'Empire' block in 1994 and 1995, even though microscopic evaluation indicated abundant damage to vascular tissue in 1994 vs. little in 1995 (data not shown).

Foliar nutrient levels are indicated for each block in Table 1. The nutrient samples for 1994 were taken at pink and cannot be compared with those taken in July or with Cornell nutrient recommendations. As in most orchards in eastern New York, control trees in most blocks were below the recommended levels of 30 mg·kg$^{-1}$ for B and/or Zn for July sampling (Stiles and Reid, 1991). In 1996, the Peru-2 site was the only one not deficient in B or Zn, and yet 'McIntosh' at that site responded to prebloom nutrient treatments. Varying responses between cultivars and orchard blocks from year to year suggest that predisposition of blocks or cultivars to these treatments also does not play a significant role. Since the prebloom foliar nutrients appear to decrease loss of weak flower buds during early spring, conditions during the previous growing season that influence bud development (reviewed in Faust, 1989) may determine whether or not trees will respond to these treatments. The blocks in which 'Empire' responded were cropped quite heavily throughout these experiments, which probably compromises several aspects of bud development (Buszard and Schwabe, 1995). The one year when 'Empire' did not respond to these treatments (1996) was preceded by a warm fall when leaves were retained for an unusually long time. This may have enhanced bud development and reduced response to treatments. Both 'Empire' and 'McIntosh' trees had extended leaf retention prior to the 1996 season, but the cultivars responded quite differently, with no late growth in 'Empire' but substantial growth in 'McIntosh'. Prolonged commitment of resources to fall shoot growth in 'McIntosh' may have compromised bud development in 1996 and contributed to greater response to treatment.

Table 3. Effects of prebloom nutrient application on cropload at harvest and weight of primary spur leaves of 'McIntosh' and 'Empire' in 1996 at seven orchard sites in New York.

| Location | Cultivar | Nutrient[z] | No. fruit /cm² TCA[y] | Leaves (no./ spur)[x] |
|---|---|---|---|---|
| Clintondale | Empire | no | 14.6 | 8.9 |
| | | yes | 13.4 | 8.8 |
| | | Sig. | NS | NS |
| | Marshall McIntosh | no | 9.3 | 7.8 |
| | | yes | 11.3 | 7.2 |
| | | Sig. | * | NS |
| Gardiner | Empire | no | 2.9 | 8.6 |
| | | yes | 3.5 | 7.9 |
| | | Sig. | NS | * |
| | Roger's Red McIntosh | no | 3.6 | 7.0 |
| | | yes | 3.6 | 6.8 |
| | | Sig. | NS | NS |
| Milton | Empire | no | 9.3 | 8.4 |
| | | yes | 9.4 | 7.6 |
| | | Sig. | NS | * |
| | Marshall McIntosh | no | 3.4 | 7.4 |
| | | yes | 3.2 | 6.9 |
| | | Sig. | NS | * |
| Modena | Empire | no | 8.0 | 8.3 |
| | | yes | 9.0 | 8.3 |
| | | Sig. | NS | NS |
| | Marshall McIntosh | no | 5.4 | 7.1 |
| | | yes | 5.6 | 7.2 |
| | | Sig. | NS | NS |
| Keeseville | Empire | no | 5.4 | 8.4 |
| | | yes | 5.3 | 8.0 |
| | | Sig. | NS | NS |
| | Roger's Red McIntosh | no | 2.9 | 7.5 |
| | | yes | 3.7 | 7.4 |
| | | Sig. | * | NS |
| Peru-1 | Empire | no | 8.7 | 9.0 |
| | | yes | 7.8 | 8.3 |
| | | Sig. | NS | * |
| | Summerland McIntosh | no | 4.2 | 7.7 |
| | | yes | 3.6 | 7.6 |
| | | Sig. | NS | NS |
| Peru-2 | Empire | no | 6.8 | 9.3 |
| | | yes | 8.2 | 9.3 |
| | | Sig. | NS | NS |
| | Marshall McIntosh | no | 3.9 | 8.1 |
| | | yes | 4.8 | 8.2 |
| | | Sig. | * | NS |

[z]B and Zn applied at half-inch-green followed by B, Zn, and urea applied at pink.
[y]TCA = trunk cross-sectional area.
[x]Determined at pink to full bloom.
[NS, *]Nonsignificant or significant at $P \leq 0.05$, respectively.

*Commercial application.* Although the 1996 trials focused on a repeated treatment at both half-inch-green and pink, a single application of B and Zn, or B, Zn, and urea, at half-inch-green was never less effective (based on LSD, data not shown) than the double application for 'Empire' in 1994 or 1995. Growers need to be aware that inclusion of oil with B, or application of B when trees are wet with oil, may cause B toxicity through excessive uptake (Stiles and Reid, 1991). Reduced leaf number per spur from 1996 nutrient treatments in four of 14 blocks and lower leaf dry weight in one block in 1994 (when spur leaf number was not determined) may reflect a mild phytotoxic response.

If the prebloom foliar nutrient treatments were only effective on cold-injured trees or on trees with reduced fruiting potential, then they could be used routinely without fear of disrupting cropping. Adequate control of cropping is critical for most commercial apple orchards. Failure to reduce cropload properly may significantly reduce crop value by reducing fruit size and may compromise return bloom and cropping for the following growing season (Forshey, 1986). In this study, many orchards where foliar nutrient treatments enhanced cropping produced excessive crops even on nontreated trees. However, little deleterious effect of overcropping was observed.

Application of foliar nutrients, when effective, increased cropping with little or no decrease in fruit size. This suggests that these treatments might increase fruit size at a similar cropload if more aggressive thinning were employed. However, covariance analysis of fruit size vs. cropload showed no significant increase in our experiments (data not shown). Fruit size was reduced by heavy cropping (at $P \leq 0.10$) in 1995, and this may be economically disadvantageous in some circumstances. The most prudent use of these treatments may be on blocks where cropping is expected to be light due to routinely sparse production or following cold injury.

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