Table 2. Effects of tree location and distribution pattern of the vegetation-free area on trunk cross-sectional area and canopy width of young peach trees (Expt. 2, planted in 1985).

| | Year[z] | | | | |
|---|---|---|---|---|---|
| Tree location | 1985 | 1986 | 1987 | 1988 | 1989 |
| | | | *Trunk cross-sectional area* (*cm*$^2$) | | |
| Center | 6.4 a | 21.4 a | 29.6 ab | 41.2 ab | 58.3 a |
| Edge | 3.9 c | 16.7 b | 25.6 b | 37.1 b | 55.0 a |
| Strip | 4.4 b | 20.5 a | 31.2 a | 44.1 a | 61.1 a |
| | | | *Canopy width (cm)* | | |
| Center | 113 a | 220 a | 288 a | 341 ab | 410 a |
| Edge | 86 b | 196 b | 277 a | 331 b | 405 a |
| Strip | 96 b | 212 a | 298 a | 359 a | 418 a |

[z]Means separated within columns by Duncan's multiple range test, $P = 0.05$.

than those of trees grown either in the center of the vegetation-free square or strip during the first two growing seasons in both experiments (Tables 1 and 2). During the last 3 years of both studies, the TCA and CW tended to be largest for the strip treatment, and peach tree growth was not affected by tree placement in the vegetation-free square treatment. There was no difference in leaf N concentration (range 2.4%–3.3%, Expt. 1; 2.6%–3.8%, Expt. 2) due to the tree placement, except for the first year in both experiments, where the leaf N concentration was less in those trees planted at the edge of the vegetation-free area (3.4% and 3.6%, respectively) than in those from the center (3.9% both years) or those from the strip (3.8% and 4.0%, respectively). The initial growth suppression of trees growing at the edge of the vegetation-free square, compared with those in the center of the vegetation free square, was overcome by the 3rd year, indicating that the root system of the tree was fully using the vegetation-free area provided. Fertilizer applied in 1986 and 1988 in Expt. 1 and 1988 and 1989 in Expt. 2 increased leaf N relative to 1987 when no fertilizer was applied; however, treatment effects on leaf N were nonsignificant. The uniform lack of treatment response to fertilizer application indicates that the distribution pattern of the vegetation-free area had no effect on the ability of the peach tree to use available nutrients within the vegetation-free area. Peach trees grown in the center of the square treatment were separated by 1.9 m of sod within the row, and trees grown in the strip treatments had no barrier between trees. Trees grown in the strip treatments had a significantly larger TCA in Expt. 1 and tended to have a higher TCA in Expt. 2 during the last 3 years, indicating that peach trees may be less sensitive to competition from another peach tree than they are to competition from grass. We have shown in previous studies that K-31 sod reduces fine root production in peach (Glenn and Welker, 1986). These studies suggest that the most favorable distribution pattern of a constant size vegetation-free area for maximum growth of young peach trees would be in a strip within the tree row, rather than in a square pattern. These studies also suggest that there is latitude in the configuration of a constant size vegetation-free area in devising management strategies in mature peach trees with minimal impact on tree growth.

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# Sour Cherry Trees Respond to Foliar Boron Applications

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*Additional index words.* *Prunus cerasus*, fruit set

***Abstract.*** **Seven trials were conducted over 3 years in several Michigan locations to study the response of sour cherry (*Prunus cerasus* L. cv. Montmorency) to foliar B sprays. Orchards ranged in age (6 to 12 years) and leaf B concentrations (19 to 32 μg B/g dry weight). Treatments consisted of a 500 mg B/liter spray applied to leaves in late September or early October, and an untreated control. Boron sprays increased B concentrations in dormant buds and flowers by 94% and 54%, respectively, but did not consistently change leaf levels. Boron applications increased fruit set and production by as much as 100% in one trial, but had no effect in others. Fruit set and production were most consistently increased in trees containing leaf B levels of 19 to 25 $\mu g \cdot g^{-1}$ dry weight. In trees with leaf B concentrations of 25 to 32 $\mu g \cdot g^{-1}$, responses to B were less consistent and smaller in magnitude.**

Boron deficiency initially affects meristematic tissues of plants, reducing or terminating growth of root and shoot apices. Tissue B concentrations associated with the appearance of vegetative deficiency symptoms have been identified in many crop species. Shear and Faust (1980) suggested that temperate tree fruit crops should be considered deficient in B (symptoms may appear) if leaf concentrations <15 or 20 μg B/g dry weight (D.W.), depending on species.

Boron applications have enhanced fruit set in some tree crops even when leaf B concentrations appeared adequate, suggesting that adequate B concentrations for normal vegetative growth may not be sufficient for optimum fruit set. Foliar B sprays increased fruit set of 'Italian' prune (*Prunus domestica* L.) trees with leaf B concentrations between 27 and 38 $\mu g \cdot g^{-1}$ D.W. and no visible symptoms of B deficiency (Callan et al., 1978; Chaplin et al., 1977; Hanson and Breen, 1985b). Similar effects were observed on 'Barcelona' hazelnut (*Corylus avellana* L.) trees showing no deficiency symptoms and containing foliar B concentrations from 26 to 86 $\mu g \cdot g^{-1}$ D.W. (Shrestha et al., 1987). The usual range of B in hazelnut leaves is 11 to 40 $\mu g \cdot g^{-1}$ D.W. (Shear and Faust, 1980).

Effects of B sprays on apples and pears have been inconsistent. Bloom sprays in-

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Table 1. Details of experimental sites and foliar spray treatments for B trials on 'Montmorency' sour cherry in Michigan, 1987–90.

| Trial | Location | Year planted | Spacing (m) | Experiment design$^z$ Type | Reps | Trees | Treatment date(s) | Spray volume (liter/tree) |
|---|---|---|---|---|---|---|---|---|
| A | Shelby | 1980 | 5.5 × 5.5 | CRB | 5 | 1 | 28 Sept. 1987 | 2.6 |
| B | Shelby | 1980 | 5.5 × 5.5 | RCB | 6 | 12 | 23 Sept. 1988 | 3.0 |
| C | Clarksville | 1982 | 3.0 × 6.1 | RCB | 6 | 3 | 26 Sept. 1988 | 3.8 |
| D | Onekama | 1980 | 5.5 × 5.5 | RCB | 5 | 10 | 25 Sept. 1988<br>and<br>4 Oct. 1989 | 3.8 |
| E | Traverse City | 1982 | 4.3 × 5.5 | RCB | 5 | 15 | 27 Sept. 1988<br>and<br>4 Oct. 1989 | 3.0<br>4.7 |
| F | Shelby | 1980 | 5.5 × 5.5 | RCB | 6 | 10 | 4 Oct. 1989 | 4.0 |
| G | Shelby | 1984 | 5.5 × 5.5 | RCB | 6 | 15 | 4 Oct. 1989 | 2.6 |

$^z$CRB: completely randomized design, RCB: randomized complete block design, Reps: no. of replications, trees: no. trees per plot.

Table 2. Effect of fall-applied sprays of 500 mg B/liter on tissue B concentrations, growth$^z$, fruit set, and yield of 'Montmorency' sour cherry trees during the subsequent year.

| | | Boron ($\mu g \cdot g^{-1}$ dry wt) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Trial | Treatment | Dormant buds | Flowers | Midshoot leaves | TCA (cm$^2$) | Fruit set (%) | Yield (kg/tree) | Yield efficiency (kg·cm$^{-2}$ TCA) |
| A | Control | ---$^y$ | --- | 19 | 96.2 | 13.6 | 14.4 | 0.15 |
| | + Boron | --- | --- | 20 | 83.3 | 28.5** | 25.0 | 0.30* |
| B | Control | 30 | 37 | 20 | 96.7 | 11.7 | 26.1 | 0.27 |
| | + Boron | 75** | 56** | 20 | 95.1 | 12.9 | 35.2 | 0.37* |
| C | Control | 61 | 45 | 32 | 95.5 | 23.5 | 27.7 | 0.29 |
| | + Boron | 160** | 83** | 33 | 86.8 | 31.5** | 29.5 | 0.34 |
| | | | | | *1989* | | | |
| D | Control | 41 | 42 | 27 | 87.4 | 8.6 | 20.1 | 0.23 |
| | + Boron | 110** | 81** | 27 | 84.4 | 10.0 | 22.8* | 0.27 |
| | | | | | *1990* | | | |
| | Control | 33 | 28 | 22 | 109 | 15.6 | 23.8 | 0.22 |
| | + Boron | 64** | 48** | 28* | 104 | 20.4* | 26.2 | 0.25* |
| | | | | | *1989* | | | |
| E | Control | 48 | 39 | 28 | 80.2 | 13.8 | --- | --- |
| | + Boron | 79** | 60** | 28 | 84.2 | 13.2 | --- | --- |
| | | | | | *1990* | | | |
| | Control | 33 | 26 | 25 | 88.3 | 11.6 | 8.3 | 0.10 |
| | + Boron | 44** | 38** | 30* | 95.2 | 9.4 | 8.9 | 0.10 |
| F | Control | 68 | 44 | 32 | 159 | 17.0 | 31.5 | 0.20 |
| | + Boron | 82* | 47* | 34 | 153 | 19.6 | 31.0 | 0.21 |
| G | Control | 34 | 27 | 23 | 70.4 | 20.7 | 8.8 | 0.12 |
| | + Boron | 53* | 34* | 26 | 71.2 | 22.5 | 10.1 | 0.14* |

$^z$Growth expressed as trunk cross sectional area (TCA).

$^y$Data not collected (---).

*,**Differences between means significantly different at $P = 0.05$ or 0.01, respectively, by F test.

creased fruit set on 'Anjou' pear (*Pyrus communis* L.) (Batjer and Thompson, 1949) and 'Stayman' apple (*Malus domestica* Borkh.) (Bramlage and Thompson, 1962) trees showing no symptoms of B deficiency. Leaf B concentrations in the 'Stayman' trees were relatively low (15 to 18 ppm), whereas levels in the 'Anjou' trees were described as within the luxury range (no levels given). In additional trials on 'Anjou' pear (Degman, 1953) and other apple cultivars (Bramlage and Thompson, 1962; Yogaratnam and Greenham, 1982), B sprays had no or inconsistent effects.

Reduced fruit set often accompanies the appearance of vegetative symptoms of B deficiency. Fruit set was reduced on young peach (*Prunus persica* L.) trees supplied inadequate or excess B levels (Kamali and Childers, 1970), and inadequate B reduced fruit set in strawberry plants (*Fragaria* ×*ananassa* Duch.) (Neilson and Eaton, 1983). Boron applications also increased yield of cranberries (*Vaccinium macrocarpon* L.) (DeMoranville and Deubert, 1987), presumably by enhancing fruit set.

The B requirements of sweet cherry (*Prunus avium* L.) and sour cherry are poorly understood. The deficient level of 15 ppm B in leaves of sweet and sour cherry (Shear and Faust, 1980) apparently was based on leaf B concentrations in healthy trees and those associated with deficiency symptoms in young, container-grown sweet cherry trees (Christensen, 1968; Woodbridge, 1955). No reports of the response of cherry trees to B applications in an orchard setting were found. Sour cherry orchards in Michigan contain relatively low foliar B levels (Hanson, 1989), and B often is applied commercially to trees containing <20 µg B/g D.W.

Yields of 'Montmorency' sour cherry, the primary commercial cultivar, are often limited by low fruit set (Diaz, 1979). The reasons for this are unclear. 'Montmorency' is self-fruitful, although insect pollinators are critical for pollen transfer (Shoemaker, 1928). Although up to 40% of sour cherry ovules may be nonfunctional, this does not explain fully why set is so low (Furukawa and Bukovac, 1989). Fruit set in 'Montmorency' is not influenced strongly by competition between flowers or flower clusters (Diaz, 1979), so variations in flower density are not likely to affect set. The purpose of this work was to determine if foliar B applications would enhance fruit set and yield of sour cherry.

Seven studies were conducted on 'Montmorency' sour cherry orchards in various Michigan locations, between 1987 and 1990 (Table 1)l. Trees were either sprayed with a solution of 500 mg B/liter or were left untreated (control). Sprays were applied in late September or early October, to runoff, using Solubor (78% $Na_2B_8O_{13} \cdot 4H_2O$, 20% $Na_2B_4O_7 \cdot 5H_2O$, U.S. Borax Corp. Anaheim, Calif.) as the B source and a handgun sprayer to control spray drift. Trials A, B, C, F, and G were conducted for 1 year (treated in the fall, evaluated the following season), whereas treatments and evaluations were repeated for a second year in trials D and E.

Plots in Trial A (single trees) were located in the same row. In all other trials, control and B plots for each replication were positioned directly opposite one another in adjacent rows to minimize location effects.

Between 150 and 300 flower buds were collected 1 to 2 m above ground from each plot before bud swell (February to early March) the year following treatments. Flowers were collected at anthesis (May) from similar positions (30 to 50 flowers per plot). Samples of between 30 and 50 leaves were collected from the middle of current year shoots at fruit harvest (mid-July to early August) the season following treatments.

Leaves were washed for 1 min in distilled water, then dried at 65C for 7 days. Buds and flowers were not washed before drying. All tissues were ground in a Wiley mill to pass a 40-mesh screen (0.60-mm), then ashed in a muffle furnace at 500C. Ash was dissolved in 3 N $HNO_3$ and analyzed for B with a DC plasma emission spectrophotometer.

Fruit set was measured by counting flowers and mature fruit on individual branches. Branches were 0.3 to 1.0 m long, 1 to 2.5 m above ground level, and bore 50 to 300 flowers. The number of branches per plot varied: four in Trial A, five in C, G, F, and six in B, D, E. Branches were selected on all sides of trees, and, in trials with large plots (B–G), distributed on different trees throughout the length of the plot. Flowers were counted shortly before or during full bloom, and the number of fruit remaining on the same branches was recorded shortly before harvest.

Fruit in Trial A were hand-harvested (without stems) and weighed. Those in Trial

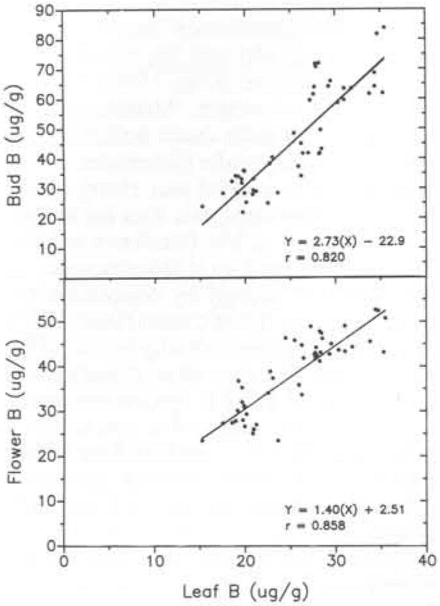

Fig. 1. Relationship between B concentrations in leaves near harvest vs. those in dormant flower buds (top) and flowers (bottom) of 'Montmorency' sour cherry. Data collected from unsprayed trees over 3 years and seven orchard sites.

C were mechanically shaken from trees before being weighed (without stems). In all other trials, the fruits were mechanically harvested and placed in standard volume, water-filled tanks. Fruit weight was then calculated from the depth of cherries, measured with a standard cherry tank probe (Whittenberger et al., 1969).

Trunk cross-sectional area (TCA) was calculated from trunk circumference measured at harvest 15 cm below the lowest scaffold limb. Yield efficiency was calculated as kilograms of fruit per square centimeter TCA. All data were subjected to analysis of variance, and significant differences between treatment means were determined by an F test.

Boron concentrations were generally highest in buds, intermediate in flowers, and lowest in leaves (Table 2). Bud and flower B concentrations in untreated trees correlated closely with leaf B concentrations (Fig. 1). On average across all trials, fall B sprays increased B concentrations in dormant buds by 94% and in flowers at anthesis by 54% (Table 2). At harvest, B concentrations in leaves were not affected by a single spray applied 10 to 11 months earlier, but were increased slightly by sprays applied for two consecutive years (Trials D, E).

Boron applications had inconsistent effects on fruit set, yield, and yield efficiency (Table 2). The greatest response was observed in Trial A, where fruit set was increased by 110% and yield efficiency by 100%. In other trials, set and productivity were increased to a lesser extent if at all. No foliar symptoms of B deficiency were observed in these trials. Boron sprays had no effect on TCA (Table 2) and did not appear to enhance canopy growth (no measurements taken).

Yield efficiency was increased by B treatments in Trials A, B, D (1 year) and G (1 year), but yield and/or fruit set were increased only in Trials A, C, and D. Some of the inconsistency might be explained by the relatively high amount of variability in fruit set [coefficient of variation (CV) = 20% to 65%] and yield (CV = 15% to 45%). Yield efficiency was a less variable measure of productivity (CV = 5% to 30%) than yield.

Boron applications generally had the greatest effect when tissue B concentrations were low. In trials where fruit production (yield or yield efficiency) was increased (A, B, D, G), control trees contained foliar B concentrations from 19 to 27 $\mu g \cdot g^{-1}$ D.W. at harvest. When applications had no effect on fruit production (Trials C, E, F), foliar B levels in control trees ranged from 25 to 32 $\mu g \cdot g^{-1}$ D.W.

Although leaf B concentrations were relatively low the 2nd year of Trial E (25 $\mu g \cdot g^{-1}$ D.W.), B sprays had no effect on fruit set or production. An unusual combination of high winds, low minimum temperatures (0 to 1C), and snow during bloom probably reduced fruit set and yields in this and surrounding orchards.

How B applications in Trial C increased fruit set 34% but not yield or yield efficiency is not clear. Reduced fruit size as a result of heavy production may have offset the gain in fruit number; however, fruit size was not measured. Also, B sprays increased yield efficiency in Trial B, when production was similar to that in Trial C.

No attempt was made in these studies to determine how B functions in the process of fruit set. Boron enhances pollen germination and pollen tube growth of tree fruit crops in vitro (Thompson and Batjer, 1950), and may have affected fruit set through one of these mechanisms. However, B-enhanced fruit set in 'Italian' prune was not associated with increased pollen germination (Callan et al., 1978) or pollen tube growth rates (Callan et al., 1978; Hanson and Breen, 1985b).

How sour cherry might respond to other rates or application dates is not known. Only one concentration of B was used in these trials (500 mg B/liter). This concentration also increased fruit set in 'Italian' prune, which responded to concentrations as high as 980 mg B/liter (Chaplin et al., 1977), and as low as 123 mg B/liter (Callan et al., 1978). Therefore, other concentrations may also be effective on sour cherry.

Sprays were applied in the fall because this timing was more effective than spring applications in enhancing fruit set of 'Italian' prune (Callan et al., 1978; Chaplin et al., 1977) and correcting "blossom blast," a B-deficiency disorder of pear (Johnson et al., 1954). Flower B levels are increased by fall applications to both prune and cherry. Boron absorbed by leaves in the fall moves out of leaves and into adjacent twigs and buds, and supplies developing flowers the following spring (Hanson, 1991; Hanson and Breen, 1985a). Concentrations of B in cherry leaves in midsummer were changed little by applications 10 to 11 months earlier, presumably because applied B was diluted by the current season's growth.

On average, fall sprays in 1988 increased B levels in cherry buds by 136% and flowers by 72%. Similar sprays in Fall 1989 increased B levels to a much lesser extent (51% in buds, 37% in flowers). Sprays in 1989 were applied 6 to 10 days later than in 1988, and some leaves were beginning to senesce when treated. Since most foliar-applied B is exported from cherry leaves over 3 weeks (Hanson, 1991), a portion of the B absorbed by leaves may have been lost when leaves abscised. Earlier sprays might have been more effective.

These studies indicate that fruit set and production of sour cherry trees containing leaf B levels of 20 to 30 $\mu g \cdot g^{-1}$ D.W. can often be increased by B applications. Additional work is needed to determine how B influences fruit set.

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# Rootstock Affects Vegetative Growth Characteristics and Productivity of 'Delicious' Apple

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*Additional index words.* shoot and spur leaves, spur density, *Malus domestica*

*Abstract.* **Fruit and leaves were harvested from sample branches in Oct. 1987 and 1988 from 'Starkspur Supreme Delicious' apple (*Malus domestica* Borkh.) trees on nine rootstocks (Ottawa 3, M.7 EMLA, M.9 EMLA, M.26 EMLA, M.27 EMLA, M.9, MAC-9, MAC-24, OAR 1) planted in 1980. Harvested leaves were separated into shoot leaves and spur leaves. Based on a standardized unit (centimeter of limb circumference), rootstocks strongly influenced the number, area, dry weight, and percentage of leaves in each category in both years. Yield per centimeter of limb circumference (limb yield efficiency, LYE) varied widely among rootstocks. LYE was highly correlated with spur density and with spur leaf variables but not with shoot leaf number, dry weight, or area. Rootstock effect on spur density may partially explain their effect on yield characteristics. The rootstock OAR 1 affected some of these characteristics differently than the others.**

Apple rootstocks differ in their influence on partitioning of photosynthetically produced dry matter between fruit and wood in the scion (Forshey and Elfving, 1989). Heinicke (1964) suggested that the greater yield efficiency of trees on M.9 compared to more vigorous rootstocks was due to improved light distribution in the canopies of smaller trees. However, yield efficiency varies for diverse rootstocks that produce trees of similar size (Ferree and Morrison, 1975). Rootstock characteristics influence the seasonal vegetative increment in fruiting and nonfruiting trees (Avery, 1969; Forshey and McKee, 1970). Maggs (1958) suggested that differences in allocation of dry matter among tree parts in the absence of fruit might partially explain the effect of rootstock on tree size.

Apple tree foliage can be divided into shoot and spur leaves. Shoot leaves are larger than spur leaves and often contribute more proportionally to canopy leaf area (Forshey et al., 1983, 1987; Forshey and Marmo, 1985). Barden and Ferree (1979) reported a slight effect of rootstock on specific leaf weight (SLW) but not on shoot growth or leaf number in 1-year-old, nonfruiting, container-grown trees of two 'Delicious' strains on rootstocks of differing size-control capacity (M.9, M.26, M.7, M.2, MM.106, MM.111, seedling). In a similar study, Ferree and Barden (1971) observed differential effects of MM.106, M.7A, and seedling rootstocks on both scion leaf size and leaf dry weight.

Leaf count, dry weight, and area per tree of shoot and spur leaves can vary with factors such as cultivar, vigor, pruning, and cropping without affecting the total canopy leaf area (Barlow, 1964; Forshey and Marmo, 1985; Lakso, 1984; Palmer and Jackson, 1977). Cropping in apple trees is associated with reduced total canopy leaf area (Avery, 1969; Hansen, 1971; Maggs, 1963; Proctor et al., 1976), more but smaller spur leaves (Forshey and Marmo, 1985; Singh, 1948), and a reduction in shoot leaf count with no change in the area per shoot leaf (Forshey and Marmo, 1985).

The objectives of this study were to determine: 1) rootstock effects on shoot and spur leaf count, dry weight, and area: 2) rootstock influence on spur density; and 3) whether variation in yield efficiency in mature 'Delicious' trees on different rootstocks can be associated with differences in canopy structure.

'Starkspur Supreme Delicious' apple trees on nine rootstocks were planted at Simcoe,

Table 1. Effect of rootstock on trunk cross-sectional area (TCSA) and shoot and spur leaf development, 1987.

| | | Per centimeter limb circumference[z] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Shoot leaves | | | Spur leaves | | |
| Rootstock[y] | Fall TCSA ($cm^2$) | No. | Dry wt (g) | Area ($cm^2$) | No. | Dry wt (g) | Area ($cm^2$) |
| MAC-24 | 168 a | 69 a | 12 a | 913 a | 47 bcd | 5 bcd | 392 ab |
| M.7 EMLA | 92 b | 51 b | 10 ab | 707 b | 38 d | 4 cd | 323 bc |
| M.26 EMLA | 67 c | 41 bcd | 8 b | 540 bc | 64 ab | 7 a | 530 a |
| OAR 1 | 62 c | 26 cd | 4 c | 292 de | 74 a | 5 abc | 478 a |
| Ottawa 3 | 54 cd | 47 b | 8 b | 520 bc | 57 abc | 5 abc | 434 ab |
| M.9 EMLA | 46 d | 39 bcd | 7 bc | 476 cd | 40 cd | 4 bcd | 320 bc |
| M.9 | 29 e | 39 bcd | 7 bc | 440 cde | 61 ab | 6 ab | 452 ab |
| MAC-9 | 23 e | 42 bc | 7 bc | 411 cde | 49 bcd | 4 bcd | 334 bc |
| M.27 EMLA | 10 f | 23 f | 4 c | 237 e | 34 d | 3 d | 221 c |

[z] Each mean contains five observations, except for trees on Ottawa 3 and M.9 EMLA, which contains four observations.

[y] Means within columns separated by LSMEANS ($P = 0.05$).

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