J. Amer. Soc. Hort. Sci. 112(3):412–416. 1987.

Foliar-applied Boron Increases Fruit Set in 'Barcelona' Hazelnut

G.K. Shrestha, M.M. Thompson, and T.L. Righetti
Department of Horticulture, Oregon State University, Corvallis, OR 97331-2911

Additional index words. *Corylus avellana*, filbert, mineral elements, nutrition

Abstract. **Boron (B) sprays applied to 'Barcelona' hazelnut orchards induced fruit set increases over controls, averaging 23% in 1984 and 17% in 1985. Leaves from B-sprayed trees had higher B contents than controls throughout the season. Amounts of B in young fruits increased two-fold with B sprays, but, unlike leaf values, differences between treated and control fruits disappeared by mid-summer. In the orchards studied, the B content of developing fruits from unsprayed trees was similar even though leaf B content varied widely. Because fruit set increases were obtained in both seasons with B sprays on trees whose leaf values currently are considered excessive, as well as those considered optimal or deficient, guidelines for B recommendation need revision. Boron content in May fruit from unsprayed trees might be universally low for optimum nut development, indicating that annual B sprays may be required. Foliar sprays in April damaged young leaves and shoot tips; thus, delaying sprays until the 2nd week of May is recommended.**

Foliar boron (B) applications have been reported to increase fruit set in some species of fruits (4–6, 9). Fruit set of 'Italian' prune trees that were not considered B-deficient according to leaf analysis standards was increased when B sprays were applied (7, 8). In a 2-year study of 'Italian' prune trees, also not considered B-deficient, Hanson and Breen (12) reported inconsistent fruit set response from sprays applied in September. Boron increased set during a cool, wet spring, when crops were low, but not in a warm spring, when crops were heavy. Baron (2, 3) reported that B sprays enhanced fruit set in one hazelnut (filbert) orchard, whereas Kelly (13) found no response in another.

The timing of B application may be important. In prunes, prebloom B sprays were ineffective, whereas positive responses to postharvest sprays were observed (7, 8). The stage of flower development at which B was applied was critical for inducing a higher set in 'Leconte' pears (1) and in apples (10). In hazelnuts, Baron (2, 3) sprayed B from February to May and increases in fruit set over controls were highest with the 30 May application.

Total number of flowers and percentage of fruit set are the major yield components in hazelnuts. Therefore, maximizing fruit set has economic importance. The purpose of this study was to determine if variable B nutritional status of different orchards might explain the conflicting reports on hazelnut response to B sprays (3, 13). We wanted to determine the optimum spray timing and concentration and to determine if there was a relationship between fruit set and the B content of current-season vegetative or reproductive tissues. This paper presents the results of a 2-year study of foliar B applications in several hazelnut orchards.

Materials and Methods

Boron sprays were applied in 'Barcelona' hazelnut (*Corylus avellana* L.) orchards in the Willamette Valley of Oregon for two growing seasons. In 1983–84, four orchards were selected that had 25 to 93 ppm B in 1983 August leaves. Treatments included an unsprayed control and two levels of B (300 and 600 ppm). Since the hazelnut life cycle is complex (leaf fall in November, pollination in January, ovary development throughout February–June, fertilization in mid-June, and rapid embryo growth in July), a variety of spray timings was applied. Each B level was applied to separate trees at six different dates of applications (20 Oct. 1983; 20 Apr., 12 May, 11 June, 27 June, and 12 July 1984). In each orchard there were six single-tree replications in a randomized block design. Trees of similar size and vigor were selected in each orchard. Boron was applied as Solubor (78% $Na_2B_8O_{13}\cdot 4H_2$ and 20% $Na_2B_4O_7\cdot 5H_2O$) (US Borax Company) with 300 ppm X-77, a nonionic wetting agent (Shell Oil). Sprays were applied to the point of drip with a handgun sprayer (34 liters·min^{-1}, at 1.38×10^3 kPa). Trees were observed for 10 days after each application to detect spray injury.

For fruit set counts, 500 to 600 flower clusters on three to five branches were counted on each of the 78 trees in each orchard. Fruit clusters on the same branches were hand-picked and counted during the 3rd and 4th weeks of August.

In 1984, leaves and fruits for mineral analysis were sampled separately in orchard #1 from unsprayed trees and from those that received 600 ppm B sprays applied in Oct. 1983, in Apr., or in early June 1984. Twenty leaves taken from the middle of the current-season's growth were sampled on all sides of a tree at monthly intervals from April to September. Fruit were sampled at 2-week intervals from 9 June (50 to 70 nuts) through 9 Aug. (25 to 30 nuts). In the other three orchards, leaves and fruit were sampled on 9 Aug. In each case, leaves and fruit from two of the six replicated trees were composited for each of three replications per treatment.

In 1985, the number of replications was increased because of the large amount of within-plot variability in fruit set in 1984. The number of trees (10–16) was determined by using the 1984 error term. Since the 300 and 600 ppm treatments did not differ significantly in 1984, only 600 ppm B applied on 15 May and one unsprayed control treatment were used. Mid-May was selected because phytotoxicity was apparent following the earlier application and, although significant in only one orchard, fruit set increases for this application time were higher than the others. Five orchards were selected to represent a range in B status as indicated by the previous August leaf levels (21–117 ppm). In both years, the previous August samples, although from the same orchards, were not from the same trees as those studied, so only current-season tissue contents could be related to fruit set responses. Methods of B application and fruit set counts were the same as in 1984.

In 1985, leaves and fruits were sampled periodically in all five orchards. Leaves were sampled at 20-day intervals from 25

[1]Received for publication 13 Mar. 1986. Oregon Agricultural Experiment Station Technical Paper no. 7814. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

May to 17 Aug. Twenty-one leaves (seven leaves per tree) were sampled for each control and each B treatment in all orchards at every collection date. In 1984, the greatest differences in B levels between fruits of treated and control trees was observed at the earliest sampling date (9 June). Therefore, in 1985, nuts were sampled on 25 May and every 10 days thereafter until 27 July. Because of small nut size at the earlier sampling dates, 70 to 100 nuts per sample were necessary for analyses, while samples taken at later dates used 15–40 nuts per sample. As in 1984, three replications per treatment were analyzed.

Leaves and fruit (husks removed) were washed in a solution of 10 g (ethylenedinitrilo)tetraacetic acid, disodium salt (EDTA) and 10 g Alconox in 20 liters of distilled water. The samples were rinsed twice with tap water and once with distilled water. Fresh weight was recorded before washing and dry weight was recorded after tissues were dried at 70°C for 48 hr. The dried samples then were ground in a Wiley Mill (20-mesh screen). Nitrogen was determined by an automated micro-Kjeldahl apparatus (14). The samples were analyzed for P, K, Mg, Ca, S, Mn, Fe, Cu, B, and Zn by ICP emission spectroscopy (11) after dry-ashing at 500°C and being dissolved in 5 ml of 20% HNO_3, diluted to 5% before analysis.

Both linear correlations and stepwise multiple regression between fruit set and leaf or nut mineral contents were computed for each sampling date. Since absolute fruit set in control trees varied between orchards, a measure of the relative difference between untreated and B-treated trees was useful. Therefore, the relationship between relative fruit set (RFS) and leaf or nut B levels was also determined. RFS is calculated by dividing the fruit set of each tree in a given plot (treated and controls) by the mean fruit set of the treated trees in that plot. This expression eliminates the variability between orchards in fruit set.

Results and Discussion

Effects of B sprays on fruit set. Foliar B applications increased fruit set over controls in both seasons (Table 1). In 1984, every orchard responded positively to both B concentrations at all application times. Since application times and B concentrations were not significantly different, only overall means are shown for each orchard in 1984. Treatment × application time and orchard × treatment interactions were not significant. Although the overall mean for B-treated trees (37.4%) was significantly higher than that of controls (30.5%) when using pooled error terms, increases in individual orchards were significant for only orchard #1 and for one timing (13 May). The lack of significance in other treatments and other orchards is likely due to large tree-to-tree variation and too few replications.

Table 1. Fruit set response and August leaf B content of 'Barcelona' hazelnut as influenced by B sprays.

Year and orchard[z]	Fruit set (%) Control	Fruit set (%) +B	August leaf B (ppm) Control	August leaf B (ppm) +B
1984				
1	22.5	38.7	51	79**
2	33.0	37.0	86	114*
3	30.0	36.3	40	78**
4	36.5	45.2	30	89**
Mean	30.5	39.3**	52	75**
1985				
1	37.5	50.0**	32	89*
2	43.6	54.6**	26	73**
3	51.0	58.4**	59	129**
4	63.1	71.8*	79	143**
5	50.5	52.0	68	113**
Mean	49.1	56.5**	53	109**

[z]In both years #1 was the same orchard but treatments were applied to different trees. The other numbers represented different orchards in the two different years.

*,**Significant at the 0.05 and 0.01 levels, respectively.

Although not significantly different from each other, fruit set increases relative to unsprayed controls occurred over a wide range of B spray timings. Considering all four orchards, the increase over control was minimum (18%) with the 12 July application and maximum (29%) with the 13 May spray. Fall-applied B sprays averaged 22% higher set than controls. The effectiveness of fall B sprays on hazelnuts has not been reported, although such sprays benefitted prune set (7, 8, 12). Baron (2, 3) also obtained increased set when B was applied to trees at 15-day intervals from 1 Feb. to 30 May. Maximum set occurred from 30 May B sprays. This 2-week difference in optimal spray timing, as compared to our results, could be due to seasonal and site differences. The orchard used by Baron was located in a cooler area, where there may be 1 to 2 weeks delay in phenological development.

In 1985, in spite of the fact that overall response was reduced (57.4% in treated vs. 49.1% in controls), the increase in replication resulted in the detection of significant fruit set increases due to 600 ppm B sprays on 15 May in four of the five orchards (Table 1). The orchard (#1 in both 1984 and 1985) that had the lowest set in controls had the best response in both years. It is possible that the wetting agent (X-77) had an effect on fruit set, since the controls were unsprayed. Although the manufacturer has not observed biological effects, this possibility should be considered.

Although B sprays increased set significantly in both years, the increase was smaller in 1985 (the large crop year). Baron (2) found that B treatments increased set by 30% in 1968 when set was low, but only by 19% in 1967 when fruit set was high. Stebbins (15) reported that Solubor sprays enhanced hazelnut yield in three of four years. There was no response in 1975 when the crop was unusually heavy, and the maximum increase (23%) was when yield was lowest (in 1974) (15). Similar results have been reported on other fruit crops. Hanson and Breen (12) recorded significant fruit set increases of 'Italian' prune trees treated with foliar B sprays in a small crop year, but not in a large crop year. Boron sprays significantly increased initial set of 'Cox's Orange Pippin' apples in 1973 when the control trees set 57 fruit/100 fruit buds, but the effect was not significant in 1974 when control trees set 105 fruit/100 fruit buds (16). Although B increased the final (harvest) set 23% in 1973, and 4% in 1974, in neither year was the increase significant for 'Cox's Orange Pippin' apples.

Seasonal changes in B content in leaves and fruits. Because changes in leaf B levels in control and sprayed trees from the orchard sampled in 1984 were similar to the mean of five orchards sampled in 1985, seasonal changes in leaf B content are shown only for the latter (Fig. 1A). Leaf B concentrations (ppm) increased slightly over time in control trees. When B was applied the 2nd week of May, leaf B levels tripled early in the season (25 May), remained high, and then decreased somewhat as the growing season ended. In both control and B-sprayed leaves total B content (micrograms per leaf) increased until 27 July and then declined. Fall-applied treatments did not significantly increase B content (58 ppm in B-treated vs. 50 ppm in

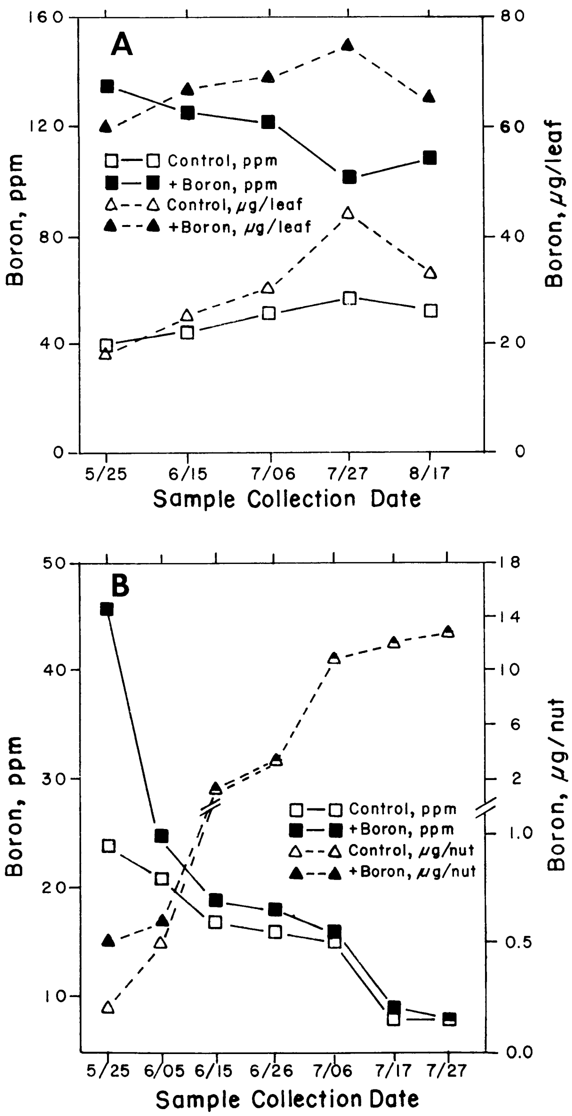

Fig. 1. Seasonal changes in B content of leaves and nuts from boron-treated and from control trees in 1985. (**A**) Leaf B vs. dates of sampling. (**B**) Nut B vs. dates of sampling.

controls) in leaves sampled the following August. Callan et al. (7) also found no significant effect of fall B sprays on 'Italian' prune leaf levels sampled the following summer. Apparently, B was diluted through vegetative growth in spring and summer.

There was a similar seasonal trend in B content of fruit in both years; thus, levels are given only for 1985 (Fig. 1B). Unlike leaf values, fruit levels (ppm) decreased through the season. Although foliar B sprays increased B concentrations (ppm) two-fold in fruit early in the season, by the 2nd week of July fruit B levels were virtually the same in both sprayed and control trees. This decrease in concentration was due to the rapid increase in fruit size and a high rate of accumulation of dry matter.

Mid-May foliar sprays doubled total B content in 25 May fruit tissues, from 0.24 µg to 0.46 µg per fruit (Fig. 1B). On 27 July the B content of unsprayed and B-sprayed fruits was 12.82 µg and 13.05 µg, respectively, which was not a significant difference. However, the absolute difference in B content between treated and untreated fruits in July averaged 0.24 µg, almost the same as in fruits collected on 25 May (0.22 µg). Thus, B content in the fruits was increased only by the amount absorbed in the fruits when the spray was applied. Although sprays also increased leaf B levels, it appears that there is no net movement of B from leaves to fruits. This conclusion is supported further by the fact that, in 1985, although August leaf levels of unsprayed trees varied from 26 to 79 ppm, B concentrations in May fruits from control trees were remarkably similar in all orchards (Fig. 2), and late July fruits were almost identical (9 to 10 ppm). A similar situation was apparent in the 1984 data (not shown). In both years, by mid-June, fruit from both treated and control trees in all orchards had similar B levels, regardless of B treatment or broad differences in current-season August leaf levels. It appears that the B content of fruit tissues is generally similar and independent of leaf B across orchards with a wide range of leaf B levels.

Relationship between fruit set and B levels in leaves and fruits. Orchards were purposely selected to provide a wide range of August leaf levels. These levels were determined on the basis of random leaf sampling, whereas our study was conducted on relatively few specific trees in each orchard. Although the same trees were not sampled, there was no clear relationship between an orchard's previous year August leaf B and the likelihood of a fruit set response. Because four of the five orchards in 1985 responded to applied B, regardless of previous August leaf levels, it is not possible to predict the need for B application on this basis. Callan (6) also was unable to relate previous August leaf levels to fruit set responses in prunes following B sprays. Since, in our study, B sprays that caused an increase in fruit set, while causing no toxic symptoms, also raised August leaf levels to a level currently considered excessive, current guidelines for B fertilization are inappropriate for hazelnuts.

Boron content of current-season leaves was positively related to fruit set when all trees (both control and B-treated) are used in the correlation. This relationship occurred at all collection dates, as shown in Table 2. However, relationships are insignificant when controls and B-treated plots are evaluated separately, even though a wide range of B concentrations exists within each group. Thus, although B treatments increased both leaf B and fruit set, they may not be directly related.

By early June, B levels in fruits were similar in all orchards, although fruit set varied greatly; thus, nut B content was not related to fruit set. When correlation coefficients between RFS and fruit B levels for all sampling dates were computed, only

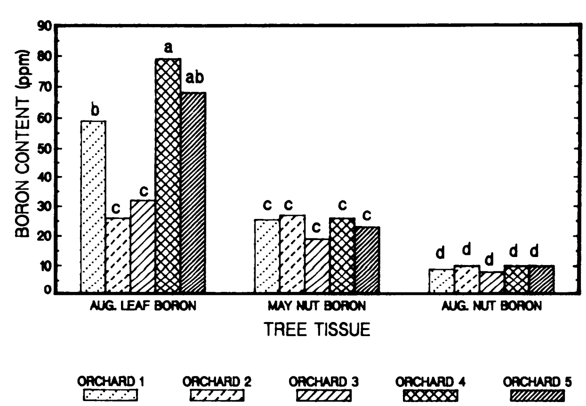

Fig. 2. Average B concentrations for unsprayed filbert plots in five commercial orchards. May nut values were generally similar and August nuts varied little regardless of August leaf levels. Bars labeled with the same letter are not significantly different ($P < 0.05$, Student–Newman–Keuls).

Table 2. Coefficients for elements from tissues sampled at various dates that were significantly correlated with fruit set, 1985.

Plant organ and date	Element									
	N	P	K	S	Mg	Mn	Fe	Cu	B	B[z]
Leaf										
25 May	0.49**	−0.48**	0.67**	0.52**	−0.31	0.74**	0.71**	−0.48**	0.52**	0.57**
15 June	0.32	−0.43*	0.56**	0.58**	−0.21	0.76**	0.21	−0.42*	0.40*	0.43*
6 July	0.44	−0.53*	0.54**	0.36*	−0.37*	0.71**	−0.09	0.16	0.38*	0.45*
27 July	0.44*	−0.50**	0.61**	0.39*	−0.32*	0.72**	−0.04	0.39*	0.47*	0.45*
17 Aug.	0.56**	−0.60**	0.67**	0.70**	−0.40	0.70**	−0.11	0.34	0.54**	0.44*
Nut										
25 May	0.21	−0.07	0.35*	0.34	−0.26	0.37*	0.39*	−0.66**	0.27	0.63**
5 June	0.11	−0.44*	−0.07	0.19	−0.32	0.64**	0.08	−0.68**	0.08	0.13
15 June	−0.24	−0.45*	0.14	0.08	−0.41*	0.58**	0.18	−0.69**	−0.03	0.30
26 June	0.17	−0.48**	0.06	−0.31	−0.46**	0.61**	−0.01	−0.77**	−0.16	0.11
6 July	0.04	−0.18	0.35	0.32	−0.14	0.55**	0.09	−0.65**	−0.18	0.07
17 July	0.32	0.01	0.43*	0.45*	0.02	0.64**	−0.01	−0.47**	−0.03	0.09
27 July	0.02	−0.08	0.29	0.20	−0.08	0.60**	0.33	−0.61**	0.01	0.07

[z] *r* values between relative fruit set and B content in leaves and nuts.
*,**Significant at the 0.05 and 0.01 levels, respectively.

25 May nut B was significantly related (r = 0.63**), as shown in Table 2. This r value, although higher than r values for leaf analyses at any date, was still not high enough to be predictive of the need for B sprays. Even if the relationships were stronger, analyzing fruits in late May to evaluate B requirements would be too late for spring application.

Correlation between fruit set and concentration of other minerals in leaves and nuts. Correlation coefficients were calculated for fruit set and 10 other essential mineral elements in leaves. Nitrogen, P, K, S, Mg, Mn, Fe, and Cu leaf levels occasionally were correlated with fruit set (Table 2). Several elements were as strongly related to fruit set as was B, but, with the exception of Mn, relationships generally were inconsistent. At all sampling dates where leaf minerals were significantly correlated (positively) with fruit set, the order of r values was Mn > K > S > B. Phosphorus and Mg were negatively correlated, but the latter element was significant only on 6 July. In stepwise multiple regressions between fruit set and 11 leaf minerals on each sampling date, Mn and B were consistently the first two elements related to fruit set, with r^2 values ranging from 0.66 to 0.72. Adding other minerals only slightly increased r^2 values.

Similarly, correlation coefficients were calculated for fruit set and fruit mineral concentrations. Nut minerals that were significantly related to fruit set throughout the season were Mn (positive) and Cu (negative) (Table 2). Phosphorus (negative) was significant only in June. The stepwise multiple regression for nut minerals indicated that the relationship of these elements to fruit set was inconsistent. Copper (earlier dates) and Mn (later dates) appeared on the first step, while K, Fe, B, Zn, S, and P were on the 2nd step. Since Mn content of both leaves and nuts was the element most highly correlated with fruit set (Table 2), Mn fertilization should be investigated further to see if soil or foliar application will increase hazelnut set.

Spray injury. All B sprays applied on 20 Apr. damaged the small, young, tender leaves and some shoot tips. Symptoms were more severe with 600 ppm concentration. Leaf margins became pale green within 2 days, followed by cholorosis and then necrosis within 7 days. Some leaves eventually became completely necrotic and fell off. Leaves not severely injured, however, continued to grow but were cup-shaped, mostly downwardly, and deformed. Although these early symptoms initially appeared severe, on the average, fruit set was still higher than controls. No damage occurred with later applications for either rate.

We conclude that most hazelnut orchards in the Willamette Valley require B sprays for optimal fruit set. In the orchards studied, the boron content of developing fruits is generally similar and appears to be independent of leaf B across a wide range of leaf B concentrations. The existing recommended August leaf levels (30 to 80 ppm B) for optimal tree performance are inappropriate for predicting maximum fruit set. Since fruit set is a major yield component, B guidelines may need revision. Apparently, high levels of B in young developing fruits are essential for maximum fruit set, and these high levels are best achieved by sprays applied directly to the developing fruits. Even though relative differences in fruit B between treated and untreated trees rapidly disappear, initial increases in B content following sprays are beneficial. Since B sprays that caused an increase in fruit set also raised August leaf levels to a level currently considered excessive, hazelnut trees may have a much higher B tolerance than other orchard trees. Boron toxicity has been observed on mature trees at leaf B content of 384 ppm (H.B. Lagerstedt, personal communication), but more definitive toxicity levels are not available. Further studies are necessary to determine more precisely what levels are toxic and if those toxic levels occur after prolonged annual applications at rates used in this study.

Literature Cited

1. Badawi, A.M., A.M. Sweidan, M.A. Fayek, and A.H.I. El Hawary. 1981. Effect of B, Zn, and Ca on growth, fruit quality and storage ability of 'le Conte' pear. Faculty of Agr., Ain Shams Univ. Res. Bul. 1656, p. 20.
2. Baron, L.C. 1968. Waking up the sleeping giant. Nut Growers Soc. of Oregon and Washington 54:22–28.
3. Baron, L.C. 1973. The value of boron sprays on filberts. Nut Growers Soc. of Oregon and Washington 58:22–28.
4. Batjer, L.P. and A.H. Thompson. 1949. Effect of boric acid sprays applied during bloom upon the set of pear fruits. Proc. Amer. Soc. Hort. Sci. 80:64–72.
5. Bramlage, W.J. and A.H. Thompson. 1962. The effects of early-sprays of boron on fruit set, color, finish, and storage life of apples. Proc. Amer. Soc. Hort. Sci. 80:64–72.
6. Callan, N.W. 1977. Effect of boron sprays on fruit set, fruit

quality, boron distribution and floral morphology of 'Italian' prune (*Prunus domestica* L.). PhD Diss., Oregon State Univ., Corvallis.
7. Callan, N.W., M.M. Thompson, H.H. Chaplin, R.L. Stebbins, and M.N. Westwood. 1978. Fruit set of 'Italian' prune following fall foliar and spring boron sprays. J. Amer. Soc. Hort. Sci. 103:253–257.
8. Chaplin, M.H., R.L. Stebbins, and M.N. Westwood. 1977. Effect of fall-applied boron sprays on fruit set and yield of 'Italian' prune. HortScience 12:500–501.
9. Chauturiya, I.A. 1974. Effect of trace elements on the percentage of setting of citrus fruits. Subtrop. Kul't. 2:48–50.
10. Davison, R.M. 1971. Effect of early-season sprays of trace elements on fruit setting of apples. N.Z. J. Agr. Res. 14:931–935.
11. Isaac, R.A. and W.C. Johnson. 1985. Elemental analysis of plant tissue by plasma emission spectroscopy: Collaborative study. J. Assn. Offic. Anal. Chem. 68:499–505.
12. Hanson, E.J. and P.J. Breen. 1985. Effects of fall boron sprays and environmental factors on fruit set and boron accumulation in 'Italian' prune flowers. J. Amer. Soc. Hort. Sci. 110:389–392.
13. Kelley, J.R. 1980. An analysis of the effects of boron and plant growth regulators on flower development in filbert, *Corylus avellana* L. MS Thesis, Oregon State Univ., Corvallis.
14. Schuman, G.E., A.M. Stanley, and D. Knudson. 1973. Automated total nitrogen analysis of soil and plant samples. Soil Sci. Soc. Amer. Proc. 37:480–481.
15. Stebbins, R.L. 1977. New information on foliar feeding of tree fruits and nuts. Proc. Ore. Hort. Soc. 68:92–94.
16. Yogaratnam, N. and D.W.P. Greenham. 1982. The application of foliar sprays containing nitrogen, magnesium, zinc and boron to apple trees: I. Effects on fruit set and cropping. J. Hort Sci. 52:151–158.

J. AMER. SOC. HORT. SCI. 112(3):416–423. 1987.

Effects of Salinity on Growth and Accumulation of Organic and Inorganic Ions in Cultivated and Wild Tomato Species

M.C. Shannon[1]
Agricultural Research Service, U.S. Department of Agriculture, U.S. Salinity Laboratory, 4500 Glenwood Drive, Riverside, CA 92501

J.W. Gronwald
Agricultural Research Service, U.S. Department of Agriculture, Plant Science Research Unit, 1509 Gortner, University of Minnesota, St. Paul, MN 55108

M. Tal
Department of Biology, Ben-Gurion University of the Negev, P.O. Box 653, Beer-Sheva, 84120, Israel

Additional index words. *Lycopersicon esculentum, L. cheesmanii, L. peruvianum, L. pennellii,* salt tolerance, selection

Abstract. **The salt tolerances of a cultivated tomato (*Lycopersicon esculentum* L. cv. Heinz 1350) and three wild species [*L. cheesmanii* (Hook) C.H. Mull, *L. peruvianum* (L.), and *L. pennellii* (Cornell) D'Arcy] were determined in both sand and solution cultures. Curvilinear and two-piece linear methods were used to obtain response curves for fresh and dry weights of shoots. In solution cultures containing 0, 50, 100, and 150 mM added salt composed of 1:1 molar ratio of NaCl and $CaCl_2$, 'Heinz 1350' was as salt-tolerant as any of the wild species. On the basis of relative decreases in vegetative dry weight, ecotype 1400 of *L. cheesmanii* was more sensitive to salt than ecotype 1401. After 4 weeks growth in sand cultures irrigated with nutrient solutions containing 0, 12.5, 25, 50, 75, and 100 mM added salts (5:1 molar ratios of NaCl and $CaCl_2$), *L. pennellii* had higher relative salt tolerance than the other species. After 14 weeks, the cultivated species and *L. pennellii* were more sensitive at low salinity than the other two species. However, relative yield decreases with increasing salinity were not significantly different between the cultivated tomato and the 1401 ecotype of *L. cheesmanii* at higher salt concentrations. *L. peruvianum* and *L. pennellii* accumulated less leaf Cl^- and more leaf Na^+ than the other species. Significant differences in the partitioning of ions between mature and developing leaves were found for all species. The physiological mechanisms involved in tolerance at moderate salinities may differ from those required for survival at high salinity.**

The improvement of salt tolerance in agricultural species has been promoted as an agronomic approach to the exploitation of large areas of saline soils and the efficient use of the relatively abundant saline water supplies that currently have little agricultural value (6, 14). Genetic variability for salt tolerance is quite sufficient for breeding purposes in some species (5); in others, it is limited and there is a need to increase variability through interspecific crosses. Lyon (11) suggested that salt tolerance in the cultivated tomato might be improved by transferring genes from related wild species. High salt tolerance has been reported in several wild relatives of the cultivated tomato (4, 11, 16, 18, 23).

The purpose of our study was to determine the differences in salt tolerance among four tomato species under similar conditions and to detect physiological differences that might provide

Received for publication 11 Apr. 1986. This research was supported by a grant from the United States–Israel Binational Agricultural Research and Development Fund (BARD). We thank Charles Rick of the Univ. of California, Davis, for providing seeds of the wild species that were used in this study and Donald Layfield and Catherine Grieve of the Salinity Laboratory for their analytical help. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

[1]Research Geneticist.