the procedure in addition to possible wood preservative effect. Concentration was 3 and 5% by weight.

Results obtained thus far suggest that true solutions are readily injected and move rapidly through the outer sapwood into the leaves. It shows promise for use as a technique for rapid correction of zinc and other nutrient deficiencies in the east until soil applied nutrients have time to become available to the tree. In high carbonate soils where soil applied nutrients are unavailable, it could be effective as an annual treatment. The cost per tree for the Zn used in our studies was only about 2¢. If feasible, this technique could replace 3-5 foliar sprays now required in these areas. With the development of satisfactory injectable fungicides and insecticides, the technique would have tremendous value for the small grower and home-owner.

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Diffusive Resistance Rates and Stomatal Aperture of Peach Seedlings as Affected by Aluminum Concentration[1]

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Additional index words. Prunus persica, root volume, stomatal density, nutrient solution.

Abstract. **Peach (*Prunus persica* (L.) Batsch) seedlings were grown in nutrient solutions containing 0, 222, 666, 1333 or 2000 μM Al. Diffusive resistance (DR) increased as Al concentrations increased and were significantly higher at 2000 μM Al than at lower concentrations. Stomatal apertures were larger on seedlings grown in 666 μM than those in 222 or 1333, those of the check were smaller, and those in 2000 μM Al were the smallest. Root volume decreased as Al concentrations increased. Changes in DR appeared to be more closely related to root volume than to stomatal aperture or density.**

Increasing Al concn in sand nutrient cultures severely restricts root growth of peach seedlings as a result of the collapse of epidermal cells (7). Root hair eruption sites failed to heal properly and led to basal constriction of root hairs. Similar results occurred in nutrient solution and the foliar toxicity symptoms suggested Ca deficiency (2).

Aluminum-injured roots of other crops (1, 4, 9) are characteristically stubby and spatulate and root tips are killed and turn brown. Cadang-cadang, a physiological disorder that reduces water absorption in coconut trees in the Philippine Islands, is caused by high levels of Al and low levels of Cu in the soil (11).

A primary function of plant roots is H_2O and nutrient absorption. Consequently any root injury may affect ion and H_2O absorption. The objective of this study was to determine the effect of Al concn in nutrient solutions on DR of leaves of peach seedlings.

Seeds from 'Elberta' and 'Lovell' peach were germinated and seedlings grown in sand that had been washed with distilled water in a greenhouse with temp controlled at 24 ± 3°C. Fluorescent lights provided a min of 4 klx at the 4th unfolded leaf from the apex when cloud cover was dense. When seedlings were 8 to 12 cm high, they were transplanted into a pretreatment nutrient solution containing the following concn of salts: 0.25 mM KH_2PO_4, 0.5 mM $Ca(NO_3)_2$, 0.5 mM KNO_3, 0.25 mM $MgSO_4$, 0.5 mM NH_4NO_3, 75 μM Fe DTPA (diethylenetriaminepentaacetic acid), 46 μM B, 9 μM Mn, 0.8 μM Zn, 0.3 μM Cu, and 0.5 μM Mo. Seedlings were grown for 21 days in this solution, and some of them were harvested to estimate growth before initiating Al treatments.

Solution pH was adjusted daily to 4.0 by adding HCl or NaOH. The vigorously aerated solutions were changed at 7-day intervals before Al treatment and were monitored between changes to prevent depletion of nutrients.

Aluminum treatments 0, 222, 666,

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1333 and 2000 μM of Al from $AlCl_2$ were begun after 3 weeks of pretreatment. Other nutrients were maintained as reported above and the aerated solutions changed every 3 to 4 days. Seedlings were harvested after they had been treated with Al for 27 days. Aluminum toxicity symptoms that developed have been reported (2).

DR, stomatal density and aperture data were collected 23 days after treatments were begun. DR of the 4th unfolded leaf from the shoot apex was determined with a Li-cor DR meter with a horizontal sensor (6).

Stomatal density and aperture were obtained by means of silicone casts (12). The cellulose acetate replica from the cast was placed on a coverslip and inverted on a Neubauer slide with a 0.04 mm^2 grid. Stomata in 13 areas were counted and density (no./cm^2) calculated. Apertures of 25 stomata were measured using oil immersion microscopy.

Root volume was measured when seedlings were harvested. The stem was cut just above the roots, the roots were blotted dry and submerged in a graduated cylinder, and the water displacement was recorded as volume.

Both variability and DR were greater on the 1st, 2nd, and 3rd unfolded leaf from the shoot apex. Variability of DR was less on the 4th unfolded leaf and remained relatively constant on subsequently older, healthy leaves on the 40-day-old plants. Microscopic examination (Fig. 1) of replicas of the young leaves revealed that stomatal maturation increased with leaf maturity up to the 4th leaf. Therefore, the 4th unfolded leaf was used to determine DR of plants as affected by Al concn.

Time of day influenced DR in 'Elberta' seedlings; DR increased from 0830 to 1630 hr (Fig. 2). DR increased rapidly at 1400 hr and decreased 1 hr later with the 2000 μM and at 1530 hr with the 666 μM Al treatments, as if the stomata were closing and opening. Stomata of several species are known to close and open in the afternoon (8). Peach stomata may have been closing as a physiological response to water stress caused by injured roots thus influencing DR. This is hypothetical since stomatal aperture was not measured. The increase in DR could also have been caused by increased osmotic pressure in the leaf as photosynthates accumulated. However, since DR was more stable between 1100 and 1330 hr, this time period was selected for further measurements.

Seedlings treated with 2000 μM Al had significantly higher DR than those in other treatments (Fig. 3). DR appeared to vary inversely with the change in root volume (Fig. 3) and the extent of root injury previously described (2, 7). The high Al concn obviously reduced water absorption capacity. We suspect this reduction was primarily due to a reduced absorbing surface; however, Al treatment also may have influenced water absorption mechanisms.

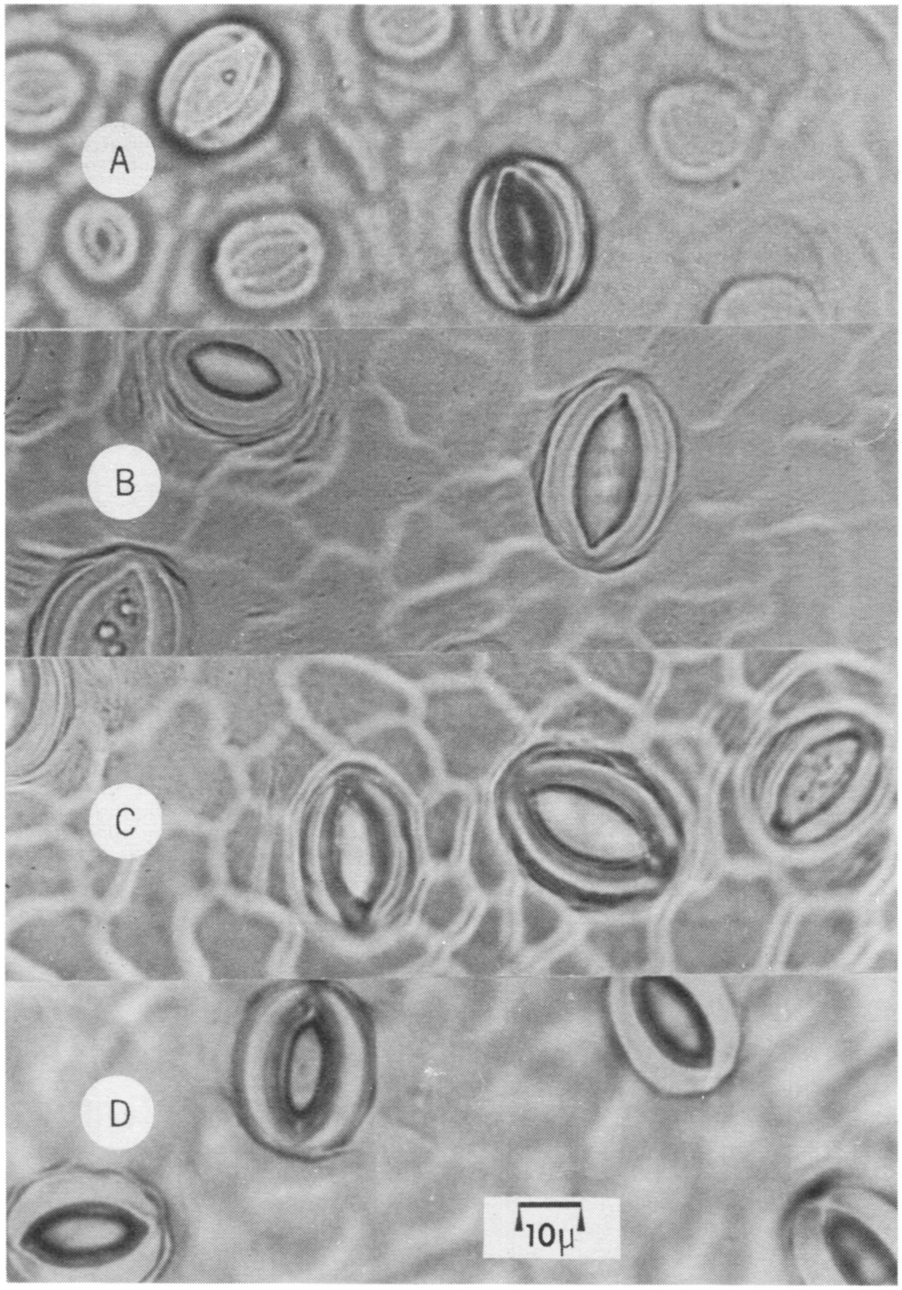

Fig. 1. Stomatal maturation relative to leaf physiological age on the main stem of 'Elberta' peach seedlings. A) 1st unfolded leaf from apex; B) 2nd; C) 3rd; and D) 4th. (Photograph of leaf replica.)

Stomatal aperture increased, then decreased as Al concn was increased (Fig. 3). The reduced aperture in 2000 μM Al appeared to increase DR. The silicon-mold method of measuring stomatal apertures may produce errors when ledges, as reported by Esau (3), are present. Further work is needed to determine whether stomatal aperture or cuticular ledges were actually measured.

Stomatal density increased with increasing Al concn (Fig. 3). This was perhaps caused by differences in leaf size. Leaf size was not measured, but decreased leaf size was apparent from visual observations and was associated with increasing Al concn.

Root volume decreased as Al concn increased (Fig. 3). The root volume of plants in 2000 μM Al was so small that water uptake was perhaps insufficient to open the guard cells; thus, DR increased. In plants treated with 222, 666, or 1333 μM Al, stomatal apertures and densities were greater than the checks, so root volume, or perhaps inability of roots to absorb water, was the contributing factor to higher DR rates.

The relationship between stomatal aperture and soil-water potential remained relatively constant until a threshold level of −7 to −16 bars was exceeded (5), when stomatal apertures

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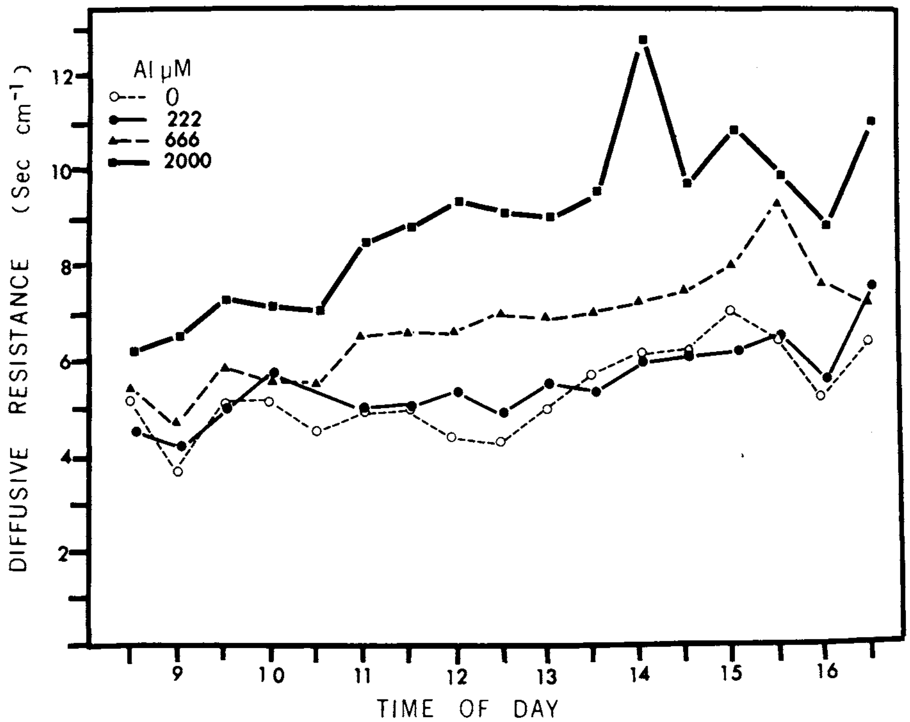

Fig. 2. The effect of Al concn in nutrient solution of DR of 'Elberta' peach seedlings from 0830 to 1630 hr (Averages for days 15 to 20 after beginning of Al treatments).

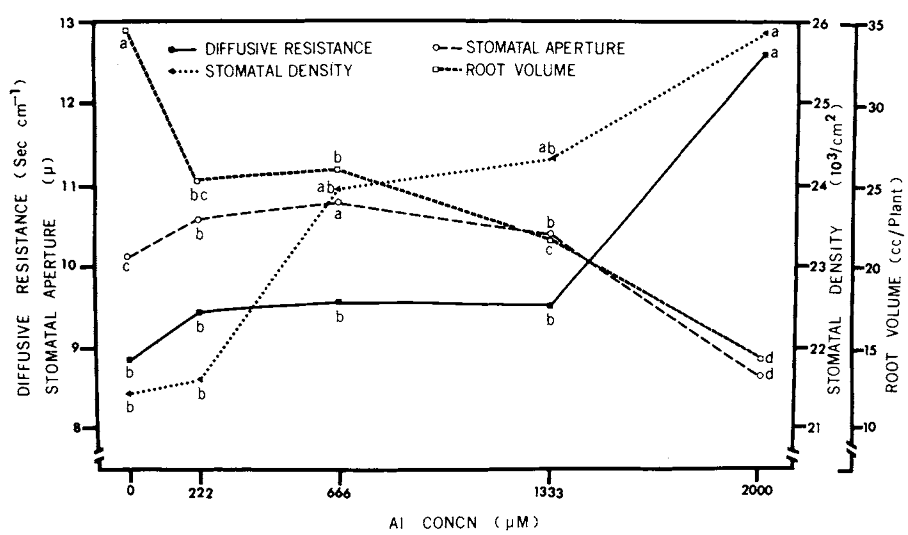

Fig. 3. The effect of Al concn in nutrient solution on DR, stomatal density, stomatal aperture, and root volume of 'Lovell' peach seedlings. Means separated by Duncan's multiple range test, 5% level.

decreased. Water stress in these peach seedlings was physiological because they were grown in solution.

The DR has been shown to be useful in determining severity of root rot (10) in sugar beets. Our data indicate that the DR will also be useful in determining root condition in tree crops when the soil-water potential is not great enough to decrease stomatal aperture. The data also indicate the importance of knowing root condition when using the DR rates in water-plant relation studies.

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