

(3) observed that *Prunus* species which did not supercool all had raceme inflorescences, and they suggested that the ability to supercool was related to bud morphology.

We observed that deep supercooling in *Prunus* flower buds was correlated with the inability of dye to move into the primordia (Table 1). Dye was observed in the primordia of *P. padus*, *P. virginiana*, and *P. serotina*—3 *Prunus* species which do not deep supercool. Dye did not enter the bud primordia of 11 species which have been observed to avoid freezing injury by supercooling.

Water within the bud primordium will supercool only if isolated from ice crystals in adjacent tissues and if there are no heterogeneous ice nuclei within the primordium. Several workers (4, 10) have proposed that a barrier must exist to prevent the propagation of ice through the extracellular space and vascular system and into the primordium. The spread of ice through the vascular system appears to be prevented by the lack of xylem continuity in these tissues.

We have observed that the vascular tissues in dormant peach (1) and apricot flower buds (unpublished data) were not fully differentiated. Cells in the bud vascular traces were elongated, had densely stained cytoplasm, and lacked secondary wall thickenings. The differentiation of the procambium proceeded in the spring during blossom development. The dye uptake experiments support the absence of xylem continuity in *Prunus* species which supercool.

Burke and coworkers (3, 11) have observed that the buds of *Prunus* species which do not supercool possess a different mechanism for resisting freezing injury. These species were generally harder than those which supercool. They have suggested that breeding to eliminate supercooling may be beneficial in order to extend the northern range of commercial *Prunus* species. Dye uptake may provide a simple and inexpensive technique for screening the progeny from such a breeding program.

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Osmotic Adjustment and Stomatal Conductance in Peach Seedlings under Severe Water Stress¹

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Abstract. Seedlings of 'Halford' peach [*Prunus persica* (L.) Batsch] maintained in a growth chamber and exposed to leaf water deficits as low as -38 bars exhibited slight osmotic adjustment before turgor potential reached zero. This adjustment was inadequate to maintain high turgor potential, which decreased until reaching zero at a total leaf water potential of ca. -20 bars. Stomatal conductance was linearly related to total leaf water potential and independent of the average turgor potential of the leaf.

The ability of fruit trees to undergo osmoregulation when exposed to moderate or severe water deficits has received increased attention in recent years. Goode and Higgs (3) recorded parallel changes in osmotic potential and total leaf water potential in apple throughout the growing season. Davies and Lakso (2) found that apple seedlings were able to maintain turgor through osmotic adjustment until total water potential dropped below -15 bars. Lakso (5) reported seasonal changes in stomatal resistance in apple leaves, indicating an ability for stomates to remain open at lower leaf water potentials as the season progressed. These studies seem to in-

dicate a need for preconditioning for the plant to cope with environmental stresses.

Xiloyannis and Martin (8) recently investigated the diurnal and seasonal trends in leaf water potential, stomatal resistance, and ABA levels of field-grown peaches. Leaf water potential seemed to be negatively correlated to stomatal resistance and abscisic acid levels in nonirrigated trees as the season progressed. Proebsting and Middleton (6) compared soil moisture levels and leaf water potential of peaches and pears under extreme stress. Prolonged exposure to leaf water potentials below -30 bars were lethal for peach trees; however, neither study focused on the components of total water potential. Hence, the question of whether active osmotic adjustment could occur in peaches remains unanswered.

We recently reported (9) that irrigated peach seedlings undergoing diurnal variations in leaf water potential of -4 to -15 bars did not show any ability for active osmotic adjustment. The present study was designed to examine the response of water potential components and stomatal resistance in peach seedlings under severe water stress imposed gradually over a longer period of time.

Open-pollinated 'Halford' peach seed were germinated in flats. Uniform seedlings were divided into 4 groups and transplanted to 0.5 × 0.5 × 1.0-m-deep containers (3 containers per group with 5 seedlings per con-

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tainer) 3 weeks after germination. After transplanting, the seedlings were kept in a climate-controlled growth chamber exposed to a 16-hr photoperiod irradiated by Cool White fluorescent bulbs. Photosynthetically active radiation (400–700 nm) was $110 \mu\text{E m}^{-2} \text{ s}^{-1}$ during the photoperiod. Temperature and vapor pressure deficit ranged from 22°C and 8–10 mb (60–70% relative humidity) during the dark period to 25° and 17 mb (45% relative humidity) during the light period. Water and nutrients were applied at regular intervals to a mixture of 2 soil:1 sphagnum peatmoss:1 vermiculite (by volume) until the seedlings were about 1.0-m-tall, 8 weeks after transplanting. Water was then withheld from 3 of the 4 groups while

the fourth was watered regularly as the control. The stressed containers were allowed to dry out to different degrees of stress based on total leaf water potential, which was monitored periodically. A complete set of measurements was taken when the stressed seedlings reached an average leaf water potential of -17 bars (in 2 days), -23 bars (in 10 days), and -32 bars (in 17 days).

All measurements were taken 30 min after the beginning of the 16-hr photoperiod. Stomatal resistance was determined *in situ* using a Licor LI-65 diffusion porometer (1). Stomatal conductance was calculated as the inverse of resistance. The leaf was then detached and total leaf water potential measured by the pressure bomb technique of Scholander

et al. (7). The leaf was then sealed in a plastic bag, excluding as much air as possible, immediately frozen on dry ice, and transferred to a freezer to be stored at -85°C for subsequent osmotic potential determination. Osmotic potential was measured on the frozen and thawed leaves using a Wescor model L-51 leaf psychrometer connected to a Wescor model HR-33T dew point microvoltmeter which had proved most reliable in previous studies (9). Osmotic potential values were not corrected for "bound" water as in the previous study (9), since results indicated that this correction was not significant at high potentials and may be in error at lower potentials. Turgor potential was therefore determined as the difference between total leaf water potential and osmotic potential. Matric potential in living tissue was assumed to be negligible (4).

Leaf turgor potential (ψ_p) decreased with total water potential (ψ_w) between -8 and -23 bars (Fig. 1a). However, this significant linear correlation ($r^2 = 0.95$) was apparently not a solitary relationship. The slope of the ψ_p versus ψ_w relationship was 0.73, significantly different from 1.0 at $P < 5\%$. In other words, the drought-induced decrease in total water potential was not completely accounted for by a corresponding decrease in turgor potential. About 30% of the drought-induced decrease in ψ_w appeared to be due to a decrease in osmotic potential (ψ_s), with this decrease occurring at nonzero turgor potentials (Fig. 1b). Obviously, a 1:1 relationship between ψ_s and ψ_w existed when turgor reached zero. Whether or not the slight osmotic adjustment observed indicates the ability for field-grown peaches to undergo active osmotic adjustment during stress cannot be concluded from this study. The relatively low light levels in the chamber may have limited carbohydrate synthesis enough to limit the seedlings' ability to osmotically adjust. It does appear, however, that peach may have the capacity for active osmotic adjustment when drought stress is imposed gradually.

While no relationship between stomatal conductance (C_s) and ψ_p was obvious, a linear relationship between C_s and ψ_w was observed ($r^2 = 0.82$) (Fig. 1c). This relationship did not change when ψ_p reached zero, indicating that C_s was independent of average leaf turgor. The apparent dependence of C_s on ψ_w rather than on ψ_p is trivial, however, if ψ_s of peach guard cells is more negative than the bulk leaf ψ_s . If this is the case, then guard cells will have $\psi_p > 0$ at ψ_w where the majority of cells in the leaf have $\psi_p = 0$. Hence, stomates will remain open even when the average leaf turgor pressure is zero, and stomatal conductances will be proportional to ψ_w . Further work is required to test this hypothesis.

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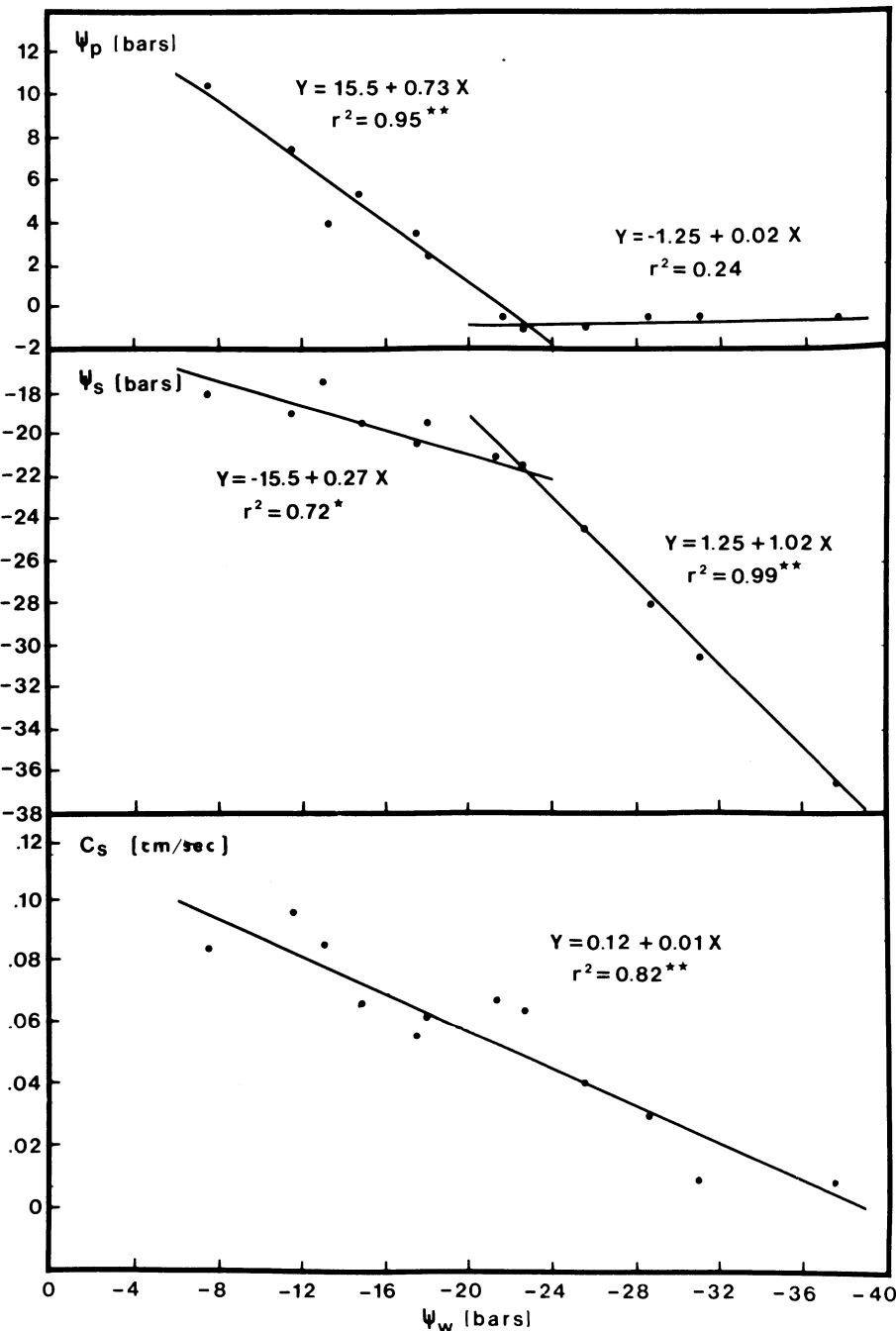


Fig. 1. Leaf turgor potential (ψ_p) (Fig. 1a), leaf osmotic potential (ψ_s) (Fig. 1b), and stomatal conductance (C_s) (Fig. 1c), vs. total leaf water potential (ψ_w) in peach seedlings under severe water stress. Each data point is a mean of 3 measurements from each of 3 replicates.

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Effect of Nitrogen Source on Leaf Element Composition of Greenhouse-grown Peach Seedlings¹

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Abstract. The nutrient element composition of mid-shoot leaves of peach [*Prunus persica* (L.) Batsch] was influenced by different N sources. Leaf N was significantly higher with applications of $(\text{NH}_4)_2\text{SO}_4$ than with the 6 other carriers at the 3 sampling dates, and was significantly lower with ureaform at the first and second sampling date. The N source has little influence on Mg, Zn, Mn, or Fe leaf level at the June sampling date, but caused significant variation of these elements in the July and August samples. There was significant variation in leaf levels of Cu, B, Mo, Al, and Na at the 3 sampling dates.

In peach trees, the leaf concentrations of N, P, K, Zn, Cu, and B decreased, Ca, Fe, and Mn increased, and Mg and S were irregular as the season progressed (1, 6, 9). Similar results were reported with 'Valencia' orange trees (5). In Japan, it was observed that the seasonal trend of foliar N, P, and K of the 'Okubo' peach decreased, and Ca and Mg remained nearly constant, while in 'Shogyoka' the foliar N, P, and K was well as Ca and Mg tended to increase (8). Applications of $(\text{NH}_4)_2\text{SO}_4$ did not influence the direction of change of any macronutrient in 'McIntosh' apple leaves (2). This was the only reference which referred to a N source and its effect on the concentration of other elements. Other investigators found no effect of N application on the downward seasonal trend of leaf-N content in peach trees (4, 7).

Considerable variability in the leaf mineral element content has been noted in greenhouse-grown fruit trees which were being used for physiological studies by the Pomology Department at Cornell University. This study

was conducted to investigate the effect of different N carriers on the mineral element composition of peach leaves at 3 physiological ages.

In March 1973, 1-year-old 'Halford' peach seedlings headed back to 30 cm were grown in 15-cm diameter plastic pots in the greenhouse. A 1:1:1 mixture by volume of perlite, vermiculite, and sphagnum peatmoss, amended with 4.8 kg dolomitic limestone and 1.2 kg of superphosphate (20% P_2O_5) per M^3 , was used for the growing medium. Throughout the study, each tree was fertilized biweekly with 100 ml N-free standard Hoaglands solution and intermittently watered to keep the growing medium moist. No supplemental light was used in this study. All dormant buds were allowed to grow following planting to reduce the N reserves in the trees. After most of the shoots had terminated growth and set terminal buds, they were pruned to 8 selected shoots per tree. The trees were then randomly divided to establish 8 treatments, with 2 trees per treatment in each of 5 replications.

Each tree, with the exception of the control trees, reviewed 624 mg of actual N as a soil application in the form of NaNO_3 , $\text{Ca}(\text{NO}_3)_2\text{KNO}_3$, NH_4NO_3 , $(\text{NH}_4)_2\text{SO}_4$, urea, ureaform. The first nitrogen application was made April 7 and the second application May 7. Composite samples of 30 leaves were collected from the mid-portion of shoots of the paired trees on June 13, July 13, and August

12. The samples were dried in a forced-draft oven at 75°C for 48 hr and then ground in a Wiley mill to pass a 20-mesh stainless steel sieve. Total N was determined by a modified Kjeldahl method (3); all other elements were analyzed by a Jarrell-Ash Model 975 Inductive Coupled Argon Plasma spectrograph in the Plant Tissue Analysis Laboratory. Duncan's multiple range test was used to evaluate the treatment means at each of the 3 sampling dates.

The primary emphasis of this study was to evaluate the effect of various nitrogen carriers on the mineral element content of peach seedlings at 3 physiological ages. Although the data was not statistically analyzed between sampling dates, it is of interest to note the effect of the 7 nitrogenous fertilizers on the N content of mid-shoot leaves. The N content of mid-shoot leaves of trees receiving NaNO_3 , $\text{Ca}(\text{NO}_3)_2$, and NH_4NO_3 increased as the season advanced to the midseason and then decreased; KNO_3 , $(\text{NH}_4)_2\text{SO}_4$, and urea remained relatively constant until mid-season and then decreased. Ureaform, due to its slow solubility and slow release of N, caused a gradual increase in the N content with time. However, at the termination of the experiment (Aug. 12) no significant differences were found in the leaf-N content of the trees receiving ureaform, urea, $\text{Ca}(\text{NO}_3)_2$, or KNO_3 (Table 1).

With the exception of ureaform, all fertilizer materials became available about the same time and at the same rate. However, $(\text{NH}_4)_2\text{SO}_4$ seemed to be capable of supplying N in the form which was readily available for plant utilization. It was clear that peach seedlings could utilize both the ammonical and nitrate forms of N, since the growing medium was a synthetic soilless medium. Significantly higher levels of leaf-N content were detected in $(\text{NH}_4)_2\text{SO}_4$ -treated trees compared to the other treatments at the 3 sampling dates. The 3.5% N obtained from this treatment is the same value used in the Cornell Leaf Analysis Service as the standard value for peaches.

Analysis of mid-shoot leaf samples of other nutrient elements showed significant changes in leaf composition as the season advanced (Tables 1, 2). Foliar P, Zn, Mn, Fe, and B contents showed a tendency to accumulate continuously with time with the treatments KNO_3 , NH_4NO_3 , $(\text{NH}_4)_2\text{SO}_4$, and control. Application of $\text{Ca}(\text{NO}_3)_2$ had a similar effect on leaf P, Zn, Mn, and Fe, but the leaf-B content increased to midseason and then

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