EFFECTS OF REPRODUCTIVE AND VEGETATIVE SINK ACTIVITY ON LEAF CONDUCTANCE AND WATER POTENTIAL IN PRUNUS PERSICA L. BATSCH.

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ABSTRACT


Reproductive and vegetative sink activities on mature trees of nectarine (Prunus persica L. Batsch, cultivar 'Fantasia') were controlled by removal of fruit buds and treatment with the chemical plant growth regulator paclobutrazol (PP-333), respectively. During the period corresponding to Stage III of fruit growth in fruiting trees, de-fruited trees had higher mean leaf water potential (ψ₁) and lower leaf conductances (g₁) than fruiting trees in a given paclobutrazol treatment. However, paclobutrazol-treated trees generally had both higher g₁ and ψ₁ than untreated trees within a given fruit treatment. Therefore, across both levels of vegetative growth activity, fruiting trees maintained higher g₁ for a given ψ₁ than non-fruiting trees.

Keywords: nectarine; paclobutrazol; (PP 333); peach; Prunus persica L. Batsch.

Abbreviations: g₁ = leaf conductance; gₘ = mesophyll conductance; ψ₁ = leaf water conductance.

INTRODUCTION

Reproductive sinks such as flowers, seeds and fruit have often been reported to have substantial effects on photosynthesis and transpiration in crop plants (Lenz, 1979). Reports of fruit effects on photosynthesis have been particularly prevalent in research with perennial fruit crops, and among horticulturists it is commonly thought that the presence of fruit is necessary to stimulate leaves to function at their full potential (Avery, 1975). Avery (1975) reports that in apples the majority of measurements have shown that the rate of CO₂ assimilation by leaves associated with fruits is 45--60% greater than that of leaves without fruit. Chalmers et al. (1975) and Crews et al. (1975) have reported similar effects of fruit on leaf photosynthesis in peach. Recent field measurements of CO₂ assimilation in peach under
conditions that favor vegetative growth indicate a 10–15% increase in CO₂ assimilation in leaves associated with fruit during Stage III of fruit growth (DeJong, 1985). This latter research also indicated that most of the increased assimilation could be accounted for by increases in \( g_l \) and not by increases in mesophyll conductance \( g_m \) or the intrinsic leaf carboxylation capacity.

The influence of fruit on photosynthesis and \( g_l \) is often interpreted as a response to the increased demand for photosynthates generated by rapid fruit growth that prevents a "feedback inhibition" of photosynthesis (Hansen, 1970). However, the physiological mechanisms that regulate this response are unclear (Neales and Incoll, 1968; Herold, 1980). If feedback inhibition is involved and the increased rates of photosynthesis are a response to increased photosynthate demand, then one might expect larger effects of fruit on leaf activity under conditions when vegetative growth and carbohydrate demands are limited, compared to when conditions favor rapid vegetative growth and carbohydrate demand.

Recent research indicates that the plant growth regulator paclobutrazol can bring about 68% reduction in vegetative shoot growth in 'Fantasia' nectarines (Prunus persica L. Batsch.) without inhibiting fruit growth or tree yields, or substantially influencing leaf CO₂ assimilation, \( g_l \) or \( g_m \) during the fruit growth period (DeJong and Doyle, 1984). In the present research, paclobutrazol was used to experimentally manipulate vegetative sink activity and then investigate the interactions between fruit and vegetative sinks and \( g_l \).

In addition, interactions between fruit effects on \( g_l \) and plant water status were studied by following daily patterns of \( \psi_l \) and \( g_l \) while withholding irrigation over a 4-week period. In cereals, stomatal sensitivity to water stress has been reported to be lower during reproductive phases compared to vegetative phases of plant growth (Morgan, 1977; Henson et al., 1983). There is very little information regarding similar responses in trees, and knowledge of such responses are important in developing further understanding of fruit effects on leaf conductance and carbon assimilation.

MATERIALS AND METHODS

Plant material. — This research was conducted in the field on mature 12-year-old trees of a mid-season nectarine (Prunus persica L. Batsch. 'Fantasia' on 'Nemaguard' rootstock) located at the University of California Kearney Agricultural Center, Parlier, CA, U.S.A. In the winter of 1984, the soil at the base of 3 pairs of adjacent trees was treated with 2 g (AI) of the chemical growth regulator, paclobutrazol [PP-333 or (2RS,3RS)-1-(4-chlorophenyl)-4, 4-dimethyl-2(1,2,4-triazol-1-yl)-pen- tan-3-01] developed by I.C.I. Americas, Inc. Another set of 4 pairs of trees was left untreated. At bloom, all of the flowers were removed from 1 tree of each of the pairs of chemically treated and untreated trees. All of the blossoms on the remaining tree of each pair were allowed to mature naturally through the season with no artificial fruit thinning.
All trees were irrigated regularly with a flood system during the first part of the growing season. On 28 June 1984, the trees received their last irrigation before measurements began, and water was withheld until 26 July 1984.

**Leaf water potential and conductance measurements.**—Daily patterns of leaf water potential ($\psi_1$) and leaf conductance to water vapor ($g_l$) were measured with a Scholander pressure chamber (Plant Water Status Console, Soil Moisture Equipment Inc.) and a steady-state porometer (LI-1600, LI-COR), respectively. Measurements were made at weekly intervals from 2 July to 31 July 1984, during Stage III (Chalmers et al., 1975) of fruit growth.

On each measurement day, $g_l$ and $\psi_1$ were successively measured on a minimum of 8 well-exposed, mature leaves from each treatment during each of 3 sampling periods (morning, 08.00–09.30 h; mid-day, 12.00–13.30 h; afternoon, 16.00–17.30 h). Pre-dawn $\psi_1$ was measured on an additional set of leaves on the same days. Timing of replicate measurements on each treatment was randomized during the sampling periods.

**RESULTS**

Treatment with paclobutrazol resulted in reductions in vegetative growth similar to those reported previously (DeJong and Doyle, 1984). Except for the pre-dawn measurement period, the fruited trees generally had lower mean ($\psi_1$) and higher mean ($g_l$) than the unfruited trees in both paclobutrazol-treated and untreated trees (Fig. 1). Similarly, for any given daylight measurement period and fruit treatment, the paclobutrazol-treated trees usually had both higher $\psi_1$ and $g_l$ than the untreated trees. However, the mean pre-dawn $\psi_1$ of paclobutrazol-treated trees was usually lower than in the untreated trees.

The diurnal pattern of $\psi_1$ and $g_l$ on any given measurement day was strongly influenced by ambient weather conditions for that particular day. On 2 July, the sky was partly cloudy during much of the day and in most treatments $\psi_1$ and $g_l$ remained relatively stable throughout the daylight measurement period (Fig. 1). There were clear skies during the remainder of the measurement days and $\psi_1$ dropped gradually throughout each day, while daily patterns of $g_l$ were less consistent.

In the paclobutrazol-treated trees there was a trend for differences in $\psi_1$ and $g_l$ between fruiting and non-fruiting trees to become less distinct as the soil dried between 2 July and 25 July (Fig. 1). However, the same trend was not as apparent in the untreated trees (Fig. 1).

When the data from all measurement days and treatments are combined and $g_l$ is plotted against $\psi_1$ it is clear that control of vegetative growth through application of paclobutrazol had less influence on stomatal regulation than did control of reproductive growth through removal of fruit
Fig. 1. Results for paclobutrazol-treated (left) and untreated (right) nectarine trees. Diurnal patterns during Stage III of fruit growth of leaf water potential ($\psi_1$, lower 2 lines in each small graph) and leaf conductance ($g_l$, upper 2 lines in each small graph) in de-fruited and fruiting trees: o o o, $\psi_1$ de-fruited; o ... o, $\psi_1$ fruiting; • — •, $g_l$ de-fruited; • — •, $g_l$ fruiting. Vertical bars indicate ± standard error.

(Fig. 2). Although the data points were somewhat scattered, $g_l$ was positively related to $\psi_1$ in both the fruiting and non-fruiting trees ($P = 0.01$). Statistical comparison of the 2 regression lines (Snedecor and Cochran, 1967) indicates that the elevation of the regression line for the fruited trees was significantly higher than the line for the non-fruiting trees ($P = 0.001$). This indicates that the fruited tree generally maintained higher $g_l$ for a given $\psi_1$ regardless of growth regulator treatment.
Fig. 2. The composite relationship between leaf water potential (ψ₁) and leaf conductance (g₁) for fruiting trees (circles, solid line) and de-fruited trees (triangles, dashed line) for all daytime measurements and sampling dates. Data for paclobutrazol-treated trees are indicated by closed symbols and untreated trees by open symbols. Each data point indicates the mean values of g₁ and ψ₁ obtained from a minimum of 8 leaves for a specific time, day and treatment. Regressions are significant at P = 0.01.

DISCUSSION

The results of this study clearly indicate that the presence of fruit influenced stomatal regulation relative to plant water status in mature peach trees. In both the paclobutrazol-treated trees and the controls, fruited trees maintained higher g₁ for a given ψ₁ than in the de-blossomed trees. On the other hand, trees where vegetative sinks were controlled by the plant growth regulator tended to have higher ψ₁ than control trees, and the higher ψ₁ corresponded with higher g₁. These data indicate that fruit may have specific influences on stomatal regulation in bearing fruit trees rather than a more generalized "feedback inhibition" phenomenon involving CO₂ metabolism. Research with wheat (Morgan, 1977) and pearl millet (Henson et al., 1983) has also shown that flowering plants maintained higher leaf conductances at low water potentials than non-flowering plants, particularly during periods of mild water stress. Henson et al. (1983) attributed the differences in responses to lower concentrations of ABA in flowering plants, but the relationship between endogenous ABA and crop load is not consistent in all species (Jones et al., 1976; Ciha et al., 1978; Goldschmidt, 1984). Although g₁ of peach leaves has been correlated with ABA levels (Xiloyannis et al., 1980), there are no studies that indicate higher levels of ABA in non-fruiting compared to fruiting peach trees.

The present research lends support to similar research on fruit trees regarding the effects of fruit on g₁ and ψ₁. Jones and Cumming (1984) have reported substantial reductions in g₁ on de-blossomed and/or de-fruited bourse shoots compared to fruiting shoots in field-grown apple trees. However, they rarely found differences in ψ₁ between fruiting and non-fruiting shoots. The lack of difference in ψ₁ may be because they apparently only de-fruited certain branches and not entire trees. Chalmers
et al. (1983) have summarized data from several sources that also report substantial effects of rapid fruit growth on $\psi_1$ and $g_1$. However, the magnitude of the "fruit effects" in the present study is generally less than those summarized by Chalmers et al. (1983). This may be attributable to differences in growing conditions and levels of stress between the various experiments. Chalmers et al. (1983) report that the maximum $g_1$ in exposed leaves of the peach canopy was 0.34 cm s$^{-1}$ day after irrigation, whereas mean $g_1$ of fruited, control trees on the first measurement day after irrigation in this study was 0.87 cm s$^{-1}$. They also report that the minimum $\psi_1$ 9 days after irrigation was -2.42 MPa, whereas the mean minimum $\psi_1$ of exposed leaves 27 days after irrigation in this study was -2.03 MPa. These differences in $g_1$ and $\psi_1$ may be attributable to differences in soil depth and irrigation methods. It may be that under the more stressful conditions reproductive sink effects on leaf activity are more pronounced because vegetative sinks are limited.

Although treatment with the plant growth regulator paclobutrazol resulted in substantial reductions of vegetative growth similar to those reported previously (DeJong and Doyle, 1984), it appeared to have no significant interactive effects on the fruiting vs. non-fruiting treatments. The decrease in leaf area brought about by the treatment (DeJong and Doyle, 1984) apparently reduced transpirational demands and allowed higher daytime $\psi_1$ and sometimes higher $g_1$. Because the paclobutrazol treatments affected the internal water balance in the trees, the experiments did not efficiently test the effect of vegetative vs. reproductive sink activity on stomatal activity in the way that was initially envisioned. However, the fact that the relationship between $g_1$ and $\psi_1$ (Fig. 2) in fruited and non-fruited trees was similar for both paclobutrazol-treated and untreated trees indicates that fruit effects are consistent between trees with substantially altered growth characteristics.

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REFERENCES


