4 and 6, did not exceed 12% of the corresponding intercept or slope co-efficients. This supports the usefulness of average crop value as a potential predictor of optimal harvest timing.

This relationship could also be useful in measuring the true yielding potential, in dollars per ha, of cultivars or other experimental treatments. Since the relationship between yield (MT/ha) and dollar value/MT is linear, yield ($/ha) could be estimated from fruit weights alone, by taking small sub-samples at 2 different growth stages in the development of the crop.

Further analysis of the co-efficients of the linear equations together with examination of the data in Tables 1 and 2 indicate that criterion to indicate optimum harvest date for cucumbers, treated with growth regulators to induce parthenocarpic fruit set, differ substantially from those for pollinated cucumbers.

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Seasonal and Diurnal Variations in Abscisic Acid, Water Potential, and Diffusive Resistance in Leaves from Irrigated and Non-irrigated Peach Trees[1]

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Abstract. **Water potential, diffusive resistance, and abscisic acid (ABA) were measured at 10-12 day intervals from May to October in leaves from irrigated and non-irrigated peach (*Prunus persica* L. cv. Fay Elberta) trees, and measurements were taken at intervals from sunrise to sunset on September 8. Leaf water potential, before sunrise, was between –5 and –8 bars in irrigated trees during the entire season whether drip irrigated at 100% evapotranspiration (ET) or 50% ET. Non-irrigated trees showed a decrease in pre-dawn leaf water potential with time, following a pattern similar to that of decreasing soil moisture. Leaf water potential values taken during the afternoon were not associated with soil moisture and did not reflect the stressed condition of the trees. In non-irrigated trees stomatal resistance at mid-day increased rapidly after mid-summer as leaf water potential decreased. ABA concentration in leaves from irrigated trees ranged from 30 to 80 ng/g fresh wt during the entire season. In non-irrigated trees the ABA concentration increased sharply after mid-summer; this was associated with an increase in leaf diffusive resistance and a decrease in leaf water potential. Diurnal variations in leaf water potential were associated with changes in soil moisture, air temperature, relative humidity, and stomatal resistance. Leaf diffusive resistances were similar for all treatments until 1100 hr after which a notable increase occurred with increasing stress, ultimately leading to stomatal closure. ABA concentrations in leaves from irrigated and non-irrigated trees increased as leaf diffusive resistance increased; however in stressed trees, high levels of ABA in the morning were not associated with closed stomata.**

Soil moisture stress (10, 13, 18, 19) and other types of environmental stresses (2, 3, 6, 12, 15) affect the endogenous concentrations of different plant hormones. ABA concentration increased and stomata closed when leaf water potential in sorghum and maize dropped to –10 or –12 bars (19). In leaves of non-irrigated apple seedlings increases in ABA concentration were associated with changes in leaf turgor rather than water potential (4). ABA content of leaves of *Juglans* seedlings increased during waterlogging (18). In lettuce (*Lactuca sativa* L.) leaf ABA increased, while gibberellin and cytokinin declined, during desiccation (1).

Application of ABA or its esters to leaves of several species reduced water loss (1, 7, 8, 10, 11), while treatments with gibberellic acid or kinetin did not affect stomatal opening in non-stressed leaves of lettuce (1). Application of gibberellin and cytokinin retarded stomatal closure during water stress (1). Loveys (12) found that ABA synthesis in stressed broad bean leaves occurred in the chloroplasts and from there ABA migrated rapidly to other parts of the plant.

The experiments reported here on peach trees were designed to provide information on the seasonal and diurnal variations of leaf ABA, water potential, and diffusive resistance in relation to differences in soil moisture as affected by drip irrigation.

Materials and Methods

Uniform 9-year-old 'Fay Elberta' peach trees on Lovell rootstock were selected at the University of California Wolfskill Experimental Station in Winters, California. The soil is classified as Yolo loam and the trees were irrigated daily by drip irrigation at 100% ET and 50% ET and compared with a group of non-irrigated trees. Trees were hand thinned to the commercially accepted fruit load per tree. ET was estimated from a U.S. Weather Bureau Class A pan placed in a bare field nearby. A crop coefficient factor of 0.6 was used and corrected for approximately 45% ground cover of the trees. ET of the trees

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was then estimated to be about 0.27 ET_{pan} and the trees were irrigated accordingly. Water was applied through four 3.78 liters/min emitters per tree and the average amount of water applied per day during the season was 139 liters/tree in the 100% ET and 75 liters in the 50% ET. The maximum application rate occurred in mid-July when 196 liters/day was applied in the 100% ET and 106 liters/day in the 50%. Total water applied to each tree was 19.4 m^3 and 10.4 m^3, respectively, for 100% ET and 50% ET.

Soil moisture was measured weekly with a neutron probe at depths of 25, 35 and 45 cm, and at each additional 30 cm interval down to 285 cm, and at several distances from the trunk.

For measurements of ABA, leaf diffusive resistance and leaf water potential, sun-exposed leaves from the middle third of the shoots were used, as these parameters reportedly are affected by leaf position and age (9, 16). Leaf water potential measurements were taken with a Scholander pressure chamber (17) just before sunrise and in the afternoon between 1300 and 1400 hr solar time. Leaf diffusive resistance was measured on the abaxial surface of the leaves with a non-ventilated diffusion porometer (Model 6 Serial No. 15, Ennis and Associates, Riverside, CA) between 1300 and 1400 hr. Six leaves (2 from each of 3 trees) were used for each measurement.

For ABA analysis 4 leaves from each tree (3 trees per treatment) were sampled between 1300 – 1400 hr and put in a plastic bag in an ice chest for transport to the laboratory. The leaves were then weighed and homogenized in 80% methanol. The samples were prepared for gas liquid chromatography (GLC) following the procedure described by Martin et al. (14). All analyses were performed on a Hewlett-Packard Model 5736A gas chromatograph equipped with a ^{63}Ni electron capture detector. One microliter samples of methylated plant extracts equivalent to 1 mg fresh weight were separated isothermally at 200°C on a 2% OV-101 column (121.9 x 0.64 cm OD) on 100-120 mesh W.H.P. Injector port and detector temperature was 250°, with a N_2 flow rate of 30 ml/min. Sample peaks and retention times were compared with authentic ABA standards.

On September 8 measurements of leaf ABA, water potential and leaf diffusive resistance were taken at 2 to 4 hr intervals from sunrise to sunset.

Results and Discussion

After the spring rains had ended in April, soil moisture in the non-irrigated plot declined at a uniform rate during May and June (Fig. 1). By July, the average soil moisture in the top 90 cm of soil, where most of the roots were located, had decreased to 23 volume %, or 30% of available moisture. By August 1, only 20% of available moisture remained and by the end of September the soil moisture had reached the permanent wilting point (PWP). The 90 to 300 cm depth soil moisture was depleted slowly and never reached PWP.

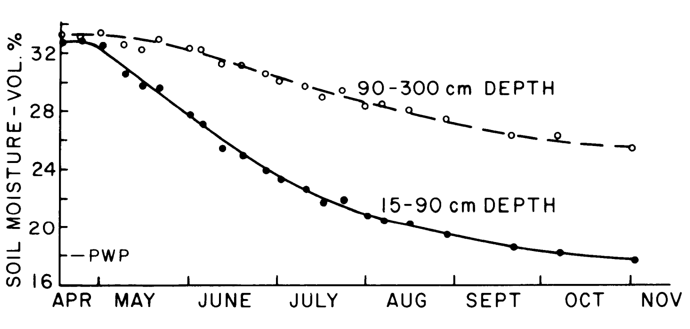

Fig. 1. Seasonal changes in soil moisture in non-irrigated plot (average of 15 sites).

Leaf water potentials taken before sunrise (Fig. 2A) were between –5 and –8 bars during the entire season in the irrigated trees, with little difference between trees irrigated at

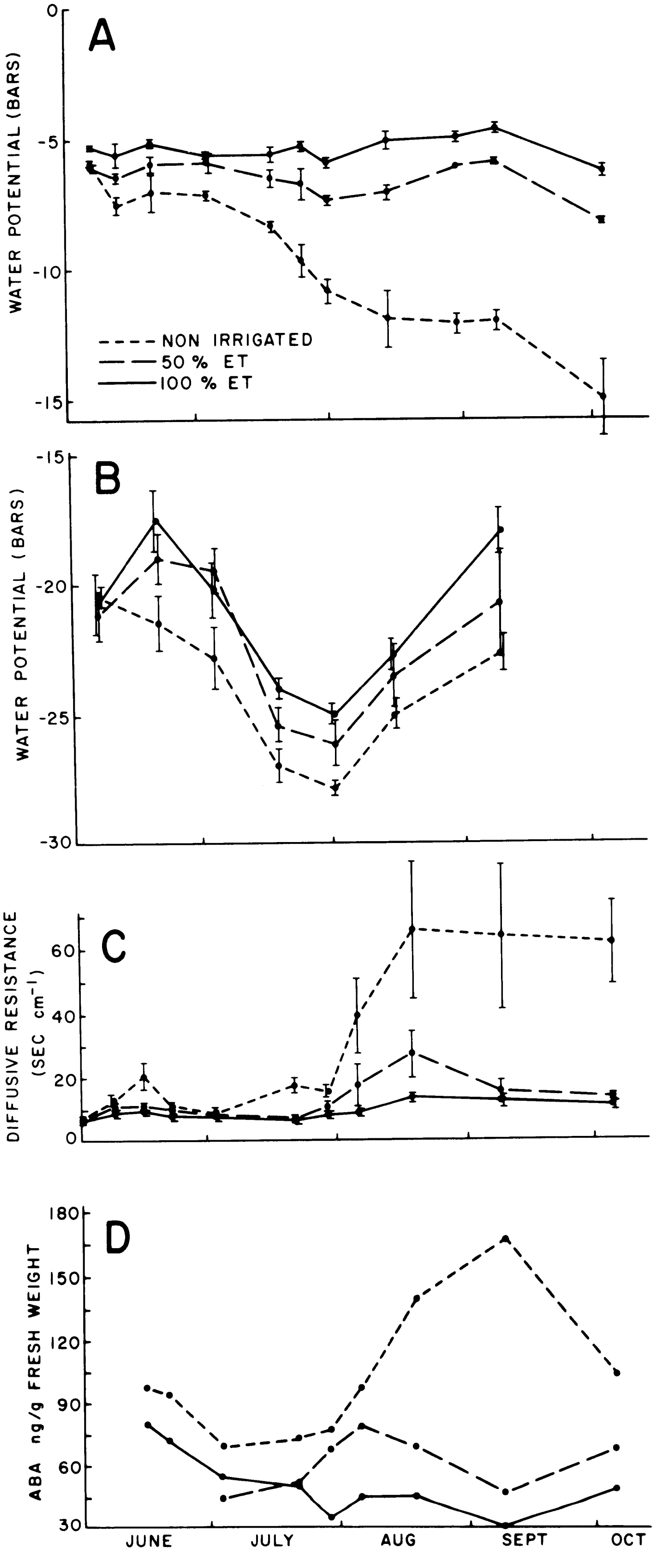

Fig. 2. Seasonal changes in (A) leaf water potential before sunrise, (B) leaf water potential during 1300 and 1400 hr, (C) leaf diffusive resistance during 1300 and 1400 hr, and (D) ABA concentration in peach leaves during 1300 and 1400 hr. Vertical bars indicate SE.

Table 1. Orchard temperature, relative humidity, solar radiation and vapor pressure deficit at time of diffusive resistance measurements (1300-1400 hr).

	June				July			August		Sept.	Oct.
Variable	1	8	15	20	3	21	29	5	18	8	5
Temp (^{o}C)	25.7	34.5	26.2	26.2	29.5	35.6	31.7	39.4	34.5	27.9	30.6
R.H. (%)	42	30	31	40	37	37	34	38	24	38	36
V.P.D. (g m^{-3})	13.9	27.0	17.0	14.8	18.6	25.8	27.0	30.8	29.3	16.8	20.1
Solar radiation (langley min^{-1})	1.17	1.17	1.30	1.22	1.27	1.34	1.19	1.22	1.27	1.24	.89

100% ET and 50% ET. Leaf water potentials in non-irrigated trees decreased steadily from –6 bars in early June to –15 bars in October. The decrease became evident when about half of the available water in the top 90 cm of the soil was depleted (mid-June). Subsequent decreases in soil moisture were accompanied by further decreases in pre-dawn leaf water potential.

Afternoon leaf water potential values (Fig. 2B) did not parallel the level of soil moisture, but did reflect the hot, dry conditions in the afternoon. As expected, however, the differences in leaf water potential between irrigated and non-irrigated trees remained similar during much of the season. Even after July 29, when soil moisture approached the permanent wilting point (PWP), leaf water potential in non-irrigated trees was nearly the same as that in the irrigated trees for the stomates in the non-irrigated were closed (Fig. 2C). The ability of stressed trees to maintain leaf turgor by reducing transpiration is an important mechanism to protect the plants against drought (1, 6).

Leaf diffusive resistance (Fig. 2C) in irrigated trees was maintained between 6 and 20 sec cm^{-1} except on August 18 in trees irrigated at 50% ET. On this date the temperature was 35^{o}C and the relative humidity 24% (Table 1). Only during August, when temperatures were very high or relative humidity very low, did differences in leaf diffusive resistance become evident between 50% and 100% ET treatments.

Mid-day leaf diffusive resistances in non-irrigated trees were slightly greater than in irrigated trees, but remained below 20 sec cm^{-1} until July 29. Until then soil moisture was sufficient and leaf water potential before sunrise was between –5 and –10 bars (Fig. 2A). After July 29 early morning leaf water potential was lower than –10 bars and over 80% of the available soil moisture in the top 90 cm of soil had been depleted (Fig. 1). Leaf diffusive resistance then increased very rapidly, reached >60 sec cm^{-1} on August 18, and remained high for the rest of the season (Fig. 2C). We propose that leaf diffusive resistance at mid-day is dependent upon the interaction of several factors including soil moisture, temperature, solar radiation, and relative humidity.

Abscisic acid concentration in leaves sampled from irrigated trees was consistently between 30 and 80 ng/g fresh wt during the season (Fig. 2D). Leaves of trees irrigated at 50% ET contained higher levels of ABA than did those of irrigated trees at 100% ET. The concentration of ABA in leaves from non-irrigated trees was always higher than that in leaves from irrigated trees, but the differences were small until July 29. Thereafter the concentration in leaves from non-irrigated trees increased sharply, reaching 166 ng/g on September 9, then decreased to 105 ng/g on October 5. In most cases ABA concentration in leaves was positively correlated with leaf diffusive resistance (compare Fig. 2C and 2D). Several authors (2, 13, 19) have observed a negative correlation between leaf ABA and leaf water potential, although Davies and Lakso (4) reported that leaf ABA was associated with leaf turgor, rather than with water potential.

Abscisic acid and its esters acted as antitranspirants in young barley plants (8) and in turgid lettuce leaves (1), and induced stomatal closure in a manner similar to stress induced by water shortage (10, 13, 19), water logging (18), or other environmental conditions (2, 3, 6, 12, 15). Loveys (12) found that isolated broad bean epidermis appeared unable to synthesize ABA in response to stress, but elevated levels were detected in epidermis isolated from previously stressed plants and in intact leaves. Evidently ABA synthesized in the mesophyll chloroplasts (12) is transported to the epidermis where it affects stomatal closure.

On September 8 the leaf water potential before sunrise (Fig. 3A) was –4.5, –5.9 and –12.2, respectively, for trees irrigated at 100% ET, 50% ET and non-irrigated. These values decreased rapidly until 1000 hr, reflecting increased stress, in all treatments, then changed little until 1400 hr. Thereafter a gradual increase in leaf water potential occurred as stress decreased in both irrigated plots; however, leaf water potential remained low in the non-irrigated plot until 1800 hr. Late in the afternoon leaves on irrigated trees regained water rapidly, since there was enough water in the soil, while leaves on stressed trees regained water slowly (Fig. 3A).

Leaf diffusive resistance (Fig. 3B) was measured before sunrise first on the non-irrigated plot, then 50% ET and lastly, 100% ET. The resistance in the non-irrigated treatment was very high due to light limitation and insufficient soil moisture. By the time the 100% ET treatment was measured 45 min later, the light intensity was sufficient to open stomates, resulting in a much lower resistance. By 0800 hr values for all treatments were equally low and remained so until 1100 hr. However, by 1400 hr leaf diffusive resistance was 12, 15.6 and >60 sec cm^{-1}, respectively, for the leaves sampled from trees irrigated at 100% ET, 50% ET and non-irrigated. The low soil moisture level (Fig. 1) and the low leaf water potential (Fig. 2A, 3A) in non-irrigated trees induced stomatal closure, thus reducing further water loss by transpiration. Leaf diffusive resistance values obtained during the day were also affected by increased air temperature and lower relative humidity (Fig. 3C).

On September 8 ABA concentration in leaves from irrigated trees between 0600 and 1800 hr varied with leaf diffusive resistance (compare Fig. 3B with 3D). At 0600 hr diffusive resistance and ABA content were elevated in both irrigated plots. While diffusive resistance had decreased by 0800 hr, ABA content remained elevated and did not decrease until about 1100 hr. Because ABA content was not evaluated between 0800-1100 hr, the exact timing remains unknown. However, diffusive resistance probably decreased prior to the decrease in ABA content (compare Fig. 3B with 3D). Similarly, between 1400 and 1800 hr both diffusive resistance and ABA content increased, but cause and effect cannot be established without intermediate measurements.

Contrasts were notable in the non-irrigated plot on September 8, where both diffusive resistance and ABA content

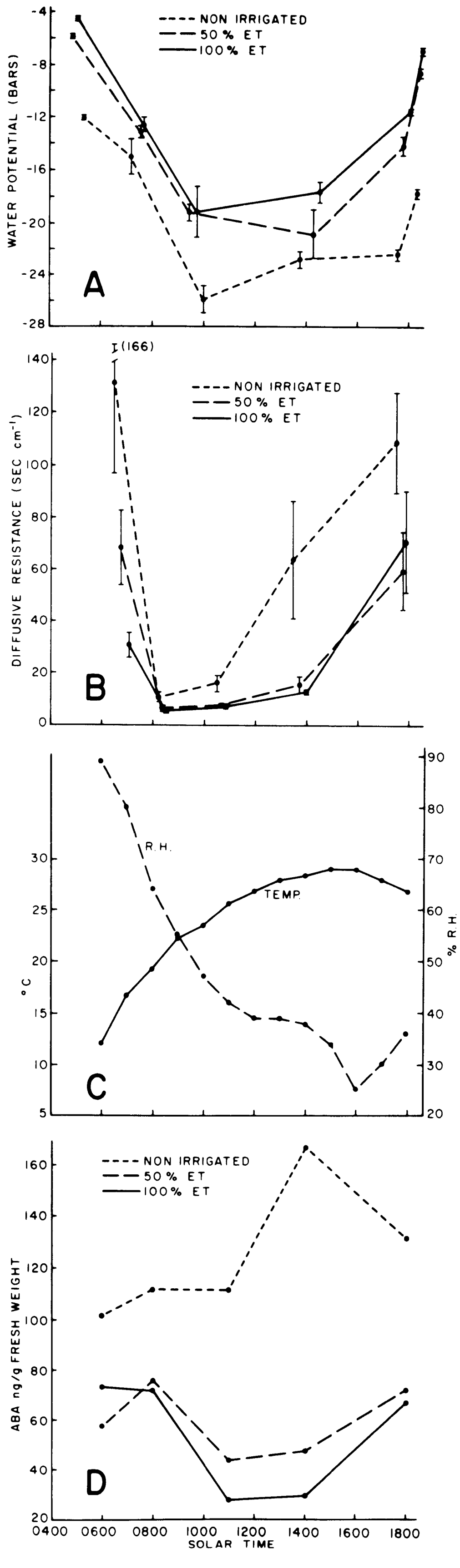

Fig. 3. Variations on September 8 in (A) leaf water potential, (B) leaf diffusive resistance, (C) temperature and relative humidity of the air, and (D) ABA concentration in peach leaves. Vertical bars indicate SE.

were elevated at 0600 hr (Fig. 3B and 3D). Although diffusive resistance plummeted by 0800 hr, ABA remained elevated at both 0800 and 1100 hr. Further, although both diffusive resistance and ABA content rose sharply between 1100 and 1400 hr, between 1400 and 1800 hr diffusive resistance continued to increase while ABA content declined. These uncoordinated changes do not suggest cause and effect. In a number of herbaceous plants similar relationships between ABA and diffusive resistance have led to similar confusion regarding regulation (1, 2, 3, 6, 7, 8, 10, 19).

Raschke and Zeevaart (16) reported that high ABA content did not decrease stomatal aperture in leaves of *Xanthium strumarium*. They proposed that either the guard cells are insensitive to ABA, or that large changes in ABA stored in leaves do not reflect levels in the guard cell. Even where ABA formation occurs at a high rate, such as in water-stressed bean leaves (approximately 0.15 ng/hr/g fresh wt) (5), these reactions may be secondary responses rather than controlling ones.

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