Journal of Horticultural Science (1994) **69** (6) 1035–1041

Postharvest water stress of an early maturing plum

By R. SCOTT JOHNSON,[1] D. F. HANDLEY[1] and K. R. DAY[2]
[1]Department of Pomology, University of California Kearney Agricultural Center, Parlier, CA 93648, USA
[2]Cooperative Extension, Tulare County Civic Center Agricultural Building, Visalia, CA 93291, USA

SUMMARY

Postharvest water stress was imposed on a May harvested plum (*Prunus salicina* Lindl. cv. Red Beaut) over a three year period. Control trees were irrigated at approximately 100% ET. One stress treatment (T1) received 50% of the water applied to the control. The second stress treatment (T2) was subjected to cycles of on-and-off irrigation which varied from year to year. All treatments were fully irrigated at about 100% ET through harvest. Treatment T1 received about 30 cm less irrigation water than the control and showed no decrease in yield, fruit weight or fruit quality over all three years. Treatment T2 received about the same amount of water as T1 in the first two years of the experiment and also showed no decrease in productivity. In the third year, T2 was irrigated only for a single three week period after harvest which saved over 60 cm of applied water. The trees were extensively defoliated by the end of the season, showed some shoot and scaffold dieback, and had reduced yields in the following year. Double fruit formation was low in all treatments and was not increased by stress. Stem water potential (SWP) measurements followed a consistent seasonal pattern in the control. In the final year of the experiment, SWP during the postharvest period correlated well with yield in the following spring. This suggests SWP might be useful for monitoring stress, thus preventing a loss in productivity while saving some water.

PREVIOUS studies have demonstrated substantial water savings by imposing deficit irrigation after harvest on early season peach cultivars (Johnson *et al*., 1992; Larson *et al*., 1988). They reported no loss in productivity and no indication of declining tree vigour or loss of tree health. The major drawback to this practice has been a dramatic increase in the formation of double fruits. Although the deformed fruit can largely be thinned off, the procedure is more time consuming than normal thinning. Early maturing Japanese plums tend to produce fewer double fruits under normal cultural practices compared with peach cultivars. Therefore, double fruit formation might not be a problem with postharvest deficit irrigation of early plum cultivars.

Very little research has been conducted on the response of Japanese plum to water stress. Deprivation of irrigation water before harvest has been shown to reduce fruit growth (Veihmeyer, 1975). However, to our knowledge, there have been no studies to evaluate postharvest water stress. For early maturing cultivars in California, the postharvest period is very long and includes the hottest and driest months of the year. Therefore, water deprivation during this period might be expected to induce severe stress symptoms. It would be valuable to know how much stress plum trees can tolerate without reducing productivity. Other *Prunus* species differ from each other in both their response to severe stress and subsequent recovery (Proebsting and Middleton, 1980; Proebsting *et al*., 1981), so it is difficult to predict how Japanese plum might respond.

If moderate water stress could be imposed on plum trees without loss of productivity, the

the tertiary scaffolds had started to die. These were recorded as the number per tree.

Data from the two individual trees per plot were averaged together and subjected to ANOVA or regression analysis using the CoHort statistical package (CoHort Software, Berkeley, CA).

RESULTS

Yield, fruit size, fruit load and flowering were not sigificantly reduced by the moderate stress treatment (T1) compared with the control over the three-year period (Table I). The cyclic stress treatment (T2) imposed in 1989 and 1990 also showed no loss of production in subsequent years compared with the control. However, when more severe stress was imposed in 1991, yield was significantly reduced in 1992. During the summer of 1991, trees in treatment T2 showed extensive defoliation and eventually some shoot dieback. In 1992, the surviving shoots showed a 28% reduction in flowering compared with the control. It was visually obvious that whole-tree flowering was reduced by more than 28% and was probably due to shoot dieback and spur death. This led to a 64% reduction in the whole tree initial fruit load and the subsequent reduction in yield. By 1992, dieback in the scaffolds at the top of the tree was starting to show up in stressed trees (T2) but not the control. Standard Duncan's Multiple Range Test showed no significant differences but Fisher's Exact Test (Steel and Torrie, 1980) indicated a significant ($P = 0.03$) separation of the control and T2.

The percentage of double fruits was low both before thinning (<2%) and at harvest (<1%) and not affected by the stress treatments (data not shown). Vegetative growth as measured by pruning weights was not significantly different (data not shown).

Stem water potential (SWP) in the control treatment declined steadily over the postharvest season reaching a low of −1.6 MPa in 1990 (Figure 1). The SWP of T1 also declined steadily over the season but faster than in the control. In 1990, the separation was quite large (ca. 0.7 MPa) by the end of the season. In 1991, the differences were much less (Figure 2). The pattern of SWP in treatment T2 reflected the cycles of irrigation and stress. With each stress cycle SWP dropped progressively lower, reaching −3.7 MPa by the end of the year in 1991. However, upon re-irrigation, the SWP value

TABLE I

Effect of postharvest irrigation treatments on yield and related variables for 'Red Beaut' plums over a three year period

Factor	Year	Treatments: Control	T1	T2	Significance
Yield	1990	51.8	51.6	49.3	n.s.
(kg/tree)	1991	51.8	44.1	48.6	n.s.
	1992	52.2 a	44.8 a	30.2 b	**
Fruit load	1990	810	779	732	n.s.
(no. fruit/tree)	1991	1067	846	859	n.s.
	1992	969 a	770 a	476 b	**
Fruit weight	1990	62.3	66.0	67.5	n.s.
(g/fruit)	1991	49.1	52.7	56.9	n.s.
	1992	54.5 a	58.0 ab	65.1 b	*
Flower density	1990	2.07	2.07	2.43	n.s.
(no./cm)	1991	1.05	1.05	1.08	n.s.
	1992	1.97 a	2.00 a	1.41 b	**
Sunfleck penetration[z]					
July 23	1991	12.5 a	14.5 a	23.9 b	*
October 9	1991	6.6 a	9.5 a	19.6 b	***
Thinning weights (kg/tree)	1992	17.0 a	12.4 a	5.3 b	*
Initial fruit load (no. fruit/tree)	1992	2686 a	1944 a	960 b	**
Scaffold dieback (no./tree)	1992	0	0.3	0.5	n.s.

[z]Relative amount of sunflecks above a threshold of ~1000 μmol m^{-2} sec^{-1} penetrating the canopy to the orchard floor.
Values within rows followed by different letters are significantly different by Duncan's Multiple Range Test ($P = 0.05$).
*, **, ***, n.s. Significant at $P = 0.05$, 0.01, 0.001, or non-significant, respectively.

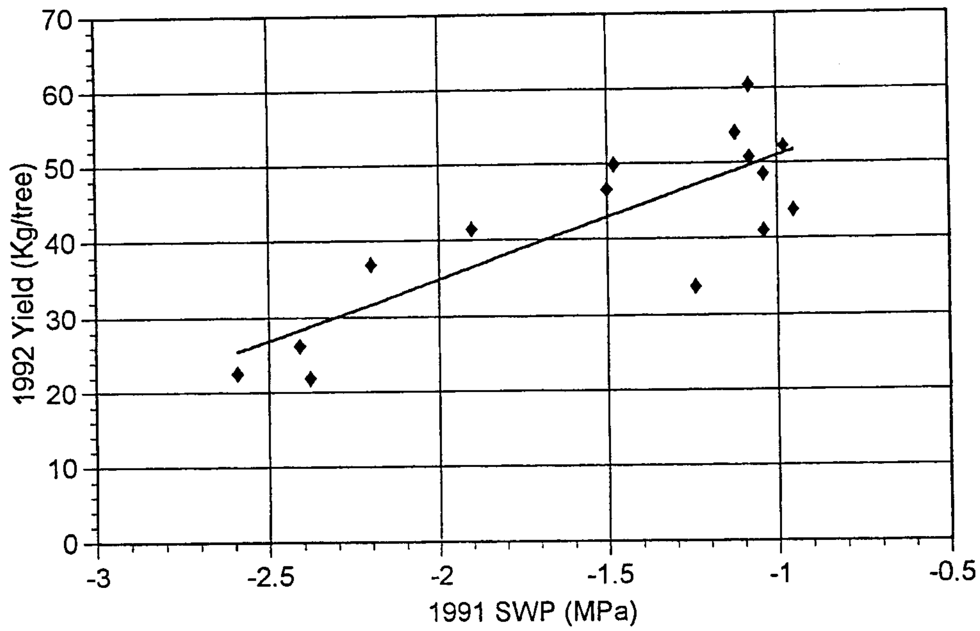

FIG. 3
Relationship between average postharvest (1 June–10 October) stem water potential (SWP) in 1991 and total yield in 1992. Line is the least squares regression line (R^2 = 0.67).

DISCUSSION

Substantial water savings were achieved by the stress treatments in this experiment. Based on average emitter discharge rates, the control trees received approximately 90 cm of irrigation water each year. Treatment T1 received about 60 cm as did treatment T2 in 1989 and 1990. In 1991, T2 only received about 25 cm of applied water. This latter, severe treatment, substantially reduced yield but the less severe treatments did not decrease production while saving as much as 30 cm of applied water.

The response of plum trees to postharvest water stress is quite different from that reported for peaches. A dramatic increase in double-fruit formation has been reported for early season peaches (Handley, 1991; Johnson *et al.*, 1992), but did not occur in this early season plum. Data on double-fruit formation before thinning were also collected on the two early cultivars ('Ambra' and 'Durado') bordering the 'Red Beaut' trees in this experiment. Although the level of fruit doubling was slightly higher than measured in 'Red Beaut' (2–5%), it was unaffected by the water stress treatments. This suggests that early plum cultivars in general do not have the problem with double-fruit formation as reported for peaches. The response of flowering to water stress also differs between these two species. Water stress has been shown to increase flowering in peach (Garcia, 1980 and Johnson *et al.*, 1992). The plum cultivar in this study showed no such effect under moderate stress and a decrease in flowering under severe stress. Research on apricots has also shown decreased flowering under water stress (Brown, 1953 and Jackson, 1969).

The data suggested an increase in fruit weight induced by the stress treatments. In 1992, there was a significant separation and the other two years showed a similar trend. However, the 1992 results could be explained almost entirely on the basis of fruit load differences. Using the strong correlation between fruit weight and fruit number (r = −0.83) it can be estimated that each additional fruit on the tree decreases the average fruit weight by about 0.02 g. Consequently, when the fruit load for each treatment is mathematically adjusted to the same level, the differences in fruit weight disappear. A similar analysis of the 1990 and 1991 data erases any apparent trends in fruit weight differences. Therefore, it appears very

REFERENCES

BROWN, D. S. (1953). The effects of irrigation on flower bud development and fruiting in the apricot. *Proceedings of the American Society for Horticultural Sciences*, **110,** 662–7.

GARCIA, M. A. (1980). *Influence of different irrigation regimes on flower bud formation and development in peach trees.* Thesis, University of California, Davis, USA.

GARNIER, E. and BERGER, A. (1985). Testing water potential in peach trees as an indicator of water stress. *Journal of Horticultural Science*, **60,** 47–56.

HANDLEY, D. F. (1991). *The formation of double fruit in peaches in response to postharvest deficit irrigation.* Thesis, California State University, Fresno, USA.

JACKSON, D. I. (1969). Effects of water, light, and nutrition on flower-bud initiation in apricots. *Australian Journal of Biological Science*, **22,** 69–75.

JOHNSON, R. S., HANDLEY, D. F. and DEJONG, T. M. (1992). Long-term response of early maturing peach trees to postharvest water deficits. *Journal of the American Society for Horticultural Science*, **117,** 881–6.

LARSON, K. D., DEJONG, T. M. and JOHNSON, R. S. (1988). Physiological and growth responses of mature peach trees to postharvest water stress. *Journal of the American Society for Horticultural Science*, **113,** 296–300.

MEDAWAR, C. (1991). *Size and growth of O'Henry peach related to water status of the tree evaluated as stem water potential and crop water stress index.* Thesis, California State University, Fresno, USA.

MCCUTCHAN, H. and SHACKEL, K. A. (1992). Stem-water potential as a sensitive indicator of water stress in prune trees (*Prunus domestica* L. cv. French). *Journal of the American Society for Horticultural Science*, **117,** 607–11.

PIERCE, L. L. and RUNNING, S. W. (1988). Rapid estimation of coniferous forest leaf area index using a portable integrating radiometer. *Ecology*, **69,** 1762–67.

PROEBSTING, E. L., JR. and MIDDLETON, J. E. (1980). The behaviour of peach and pear trees under extreme drought stress. *Journal of the American Society for Horticultural Science*, **105,** 380–5.

PROEBSTING, E. L., JR., MIDDLETON, J. E. and MAHAN, M. O. (1981). Performance of bearing cherry and prune trees under very low irrigation rates. *Journal of the American Society for Horticultural Science*, **106:** 243–6.

STEEL, R. G. D. and TORRIE, J. H. (1980). *Principles and procedures of statistics. A biometrical approach.* McGraw-Hill, New York.

VEIHMEYER, F. J. (1975). Effect of soil moisture on the size of plums. *California Agriculture*, **29 (1),** 12–13.

(Accepted 16 June 1994)