Preharvest Watersprout Removal Influences Canopy Light Relations, Fruit Quality, and Flower Bud Formation of 'Redskin' Peach Trees

Stephen C. Myers¹

Department of Horticulture, University of Georgia, Athens, GA 30602

Additional index words. *Prunus persica*, summer pruning, fruit size

Abstract. Three separate blocks of mature, nonirrigated trees of 'Redskin' peach [*Prunus persica* (L.) Batsch] on 'Lovell' rootstock, all uniformly dormant-pruned to an open center, were summer pruned 43, 31, and 21 days before harvest (DBH) in 1988, 1989, and 1990, respectively, and compared to unpruned controls in respect to light penetration and fruit characteristics. Summer pruning consisted of watersprout removal (WSR), selectively including all shoots more upright than 45° on scaffolds from the crotch to the top of the tree. WSR increased photosynthetic photon flux density (PPFD) in the center of the fruiting zone of the canopy to four times the level measured in unpruned trees, but only to an average of 16% of above-canopy PPFD. The greatest effect of WSR on PPFD occurred in the center of the tree, increasing light levels from <10% full sun before WSR to 90% full sun following WSR. WSR resulted in higher PPFD in the center of the tree for the remainder of the season. Fruit ground color and red pigmentation were not affected by WSR. WSR increased the percentage of fruit that exceeded 62 mm in diameter and decreased the percentage of fruit < 55 mm in diameter in 1988 and 1990. In 2 of the 3 years, WSR increased flower count per cm shoot length in the fruiting zone of the canopy.

Optimum fruit production involves maximizing distribution of photosynthates to fruit for optimum yield and quality while controlling vegetative and root growth at minimum plant level requirements (Chalmers et al., 1981). In fruit trees, control of photosynthate distribution is attempted by genetic, growth regulator, and cultural manipulation. In the absence of genetic or growth regulator control, peach trees in many production areas are characterized by an inefficient distribution of photosynthates to fruit compared to vegetative growth (Walsh et al., 1989).

The open-center tree training system, still common in many production areas, promotes the distribution of photosynthates to vegetative growth (Myers, 1988). This system involves training primary scaffolds out at various orientations, primarily with pruning. By design, the tree center is open, with no central axis above the origin of the scaffolds from the trunk. In the absence or reduction of apical control, coupled with use of severe pruning, open center peach trees tend to restore a rounded tree crown via apical response, resulting in the production of vigorous watersprouts along the upper side of scaffolds concentrated at pruning cuts and horizontal areas.

The architecture of open center peach trees influences the canopy light environment, with light levels highest at the tree periphery, intermediate in the tree center, and lowest halfway between the tree center and periphery (Marini and Marini, 1983). Peach redness has been correlated linearly with the percentage of full sun to which fruit was exposed (Rom et al., 1984). Light exposure of fruit in the final stages of fruit development increased red pigmentation, possibly due to increased fruit sink strength (Erez and Flore, 1986). The greatest negative effect on peach fruit weight and quality occurred when fruit were shaded during the

period from 44 to 0 days before harvest, corresponding to Stage III (final swell) of fruit development (Marini et al., 1991). Light levels during the latter half of Stage III were found to be the most important for fruit weight and quality.

Removal of excessive vegetative growth, particularly watersprouts, in the tree center before harvest has been advocated to improve fruit quality and flower bud formation by improving the light environment within the tree (Gerdtz, 1987; Myers, 1988). Effects of preharvest summer pruning on fruit size, red pigmentation, and yield have been inconsistent (Day et al., 1989; Marini, 1985; Walsh et al., 1989). Differences between preharvest summer pruning experiments may be due to differences in cultivar, environment, pruning method, pruning severity, and tree architecture.

The objective of this research was to determine the influence of selective preharvest watersprout removal in open center peach trees on canopy light relations, fruit quality, and flower bud formation under environmental conditions and cultural practices common in the eastern United States.

Materials and Methods

Summer pruning was performed in 1988, 1989, and 1990 on mature trees of 'Redskin' peach on 'Lovell' rootstock in Byron, Ga. Different orchard sites were used for each year; therefore, the cumulative effects of summer pruning were not studied. Nonirrigated trees, planted at standard spacing (267 trees/ha), were trained similarly to the open center system and managed using standard cultural practices. Vegetative growth and climatic conditions varied from year to year. Crop load in 1988 and 1989 was average and virtually equal, while crop load in 1990 was slightly above average.

Within each year, trees were selected for uniformity based on tree size, trunk circumference, and total fruit count. Trees were ≈ 2.2 to 2.5 m high and 4.5 to 5.0 m wide. All trees had been uniformly pruned during the previous dormant season. Treatments were imposed 43, 31, and 21 DBH in 1988, 1989, and 1990.

Received for publication 15 June 1992. Accepted for publication 13 Feb. 1993. A contribution of the Univ. of Georgia Agricultural Experiment Station, College Station, Athens. This research was supported by State and Hatch funds allocated to the Georgia Agricultural Experiment Stations. Appreciation to Donna Warnock and Amy Savelle for technical assistance and to Glenn Ware for assistance with statistical analysis. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

¹Associate Professor of Horticulture.

Abbreviations: DAH, days after harvest; DBH, days before harvest; PPFD, photosynthetic photon flux density; WSR, watersprout removal.

respectively, with the objective of pruning as close as possible to the predicted onset of Stage III. Variation in WSR timing between years resulted, in part, from yearly variation in maturity date. Treatments included: a) no summer pruning (control) and; b) summer pruning consisting of thinning cuts (complete removal) of all watersprout growth more upright than 45° in orientation (WSR). WSR included removal of growth from the proximal area of scaffolds (origin of scaffolds at crotch) distally along the scaffolds to the tree top (end of scaffolds). Trees were arranged in a randomized complete-block design with six single-tree replications per treatment in 1988 and 10 in 1989 and 1990.

Canopy PPFD measurements were taken at solar noon in 1988 and 1989 using a LI-COR LI-188B integrating quantum radiometer/photometer with a LI-COR LI-1915 line quantum sensor (LI-COR, Lincoln, Neb.). Light intensities were measured three days after treatment, during the harvest period, and ≈ 2 months thereafter. PPFD was measured at three positions in each tree: a) center of the fruiting zone on the north side of the tree. b) center of the fruiting zone on the south side of the tree, and c) in the center of the tree. For positions a and b, the quantum sensor was placed horizontally in an east-west orientation in the respective fruiting zone of the tree, 2 m from the row center at a height of 1.2 m. For position c, PPFD was measured by positioning the sensor in an east-west orientation in the crotch of the tree at a height of 0.5 to 0.7 m. Full sun was measured at each tree. Each reading was integrated for a period of 10 sec.

During the harvest period each year, fruit samples were randomly selected from throughout the fruiting zone in which the light sensor had been centered, as previously described. A random 40-fruit sample was taken from the south and north side of each tree for a total sample of 80 fruit per treatment tree. Individual fruit from each tree position were measured to determine weight, diameter, percentage of the fruit surface that was red, green ground color, and flesh firmness in 1988 and 1989. Individual fruit diameter was determined with an electronic caliper by making lateral transverse measurements with the suture facing middle of the caliper. Each fruit was visually rated for percent surface redness. Ground color of each fruit was measured using a 1 to 6 green color chip system, with 1 being most green and 6 least green (Delwiche and Baumgardner, 1983). Flesh firmness was determined on the cheek of each fruit with an Effegi FT 327 penetrometer with a 9-mm tip (Effegi; Alfonsine, Italy). In all years, fruit were segregated into three size categories based on fruit diameter: ≤ 55 mm, >55 to <62 mm, and ≥ 62 mm. The percentage of fruit in each size category was determined, and distribution analysis was performed using the Pearson χ^2 test of homogeneity (Fienberg, 1977).

During late March of each year following the year of WSR treatment, representative shoots 50 to 60 cm long were sampled from throughout the tree canopy from the center to the periphery. In 1989, shoot samples were taken from the inside and outside regions of the canopy. Shoot diameter was measured at 2 cm from the base. Status of buds, i.e., vegetative vs. reproductive, was discernible at sampling time as flower buds were all at least at the pink bud stage. Number of flower buds per centimeter shoot length was calculated.

Results and Discussion

Light intensities in the unpruned trees, in the center of the tree and within the fruiting zone of the canopy, were extremely low, averaging 5% of above-canopy PPFD during the preharvest period in 1988 and 1989 (Tables 1 and 2). WSR increased PPFD in the

fruiting zone of the canopy during the same period, but only to an average level equal to 16% of above-canopy PPFD. This increase in light intensity in the fruiting zone as a result of WSR persisted throughout the remainder of the season. WSR produced the greatest change in light penetration in the center of the canopy, increasing PPFD to levels near that above the canopy immediately following the treatment. Light intensity appeared to decline over time in the center of the pruned trees, possibly due to regrowth in the center of the tree, but remained at relatively high levels at harvest and until the end of the growing season.

A similar study in California (Day et al., 1989) reported increased PPFD following WSR and at 45 days after pruning, but not at 90 days after treatment compared to the unpruned control.

Table 1. Photosynthetic photon flux density [PPFD ($\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$)] within the canopy of 'Redskin' peach trees at solar noon as affected by canopy position and preharvest watersprout removal (WSR) in 1988.^c

Treatment	PPFD ^y		
	40 DBH	0 DBH	60 DAH
Control-north	170	138	---
Control-center	---	---	40
Control-south	61	87	---
WSR-north	235	173	---
WSR-center	---	---	933
WSR-south	237	119	---
<i>Observed significance level (P value)</i>			
Contrasts			
Pruning	0.0093	0.1637	0.0001
Position	0.1879	0.0423	---
Pruning $\times$ position	0.1694	0.9380	---

²Average above-canopy PPFD at solar noon of 1513, 1584, and 1543 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ for 40 days before harvest (DBH), 0 DBH, and 60 days after harvest (DAH), respectively.

^yPPFD measured 20 June (40 DBH, 3 days after watersprout removal) and 4 Aug. (0 DBH, during harvest period) in fruiting zone of tree (2 m from row center) at a height of 1.2 m. PPFD measured 4 Oct. (60 DAH) in center of tree at a height of 0.5 to 0.7 m.

Table 2. Photosynthetic photon flux density [PPFD ($\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$)] within the canopy of 'Redskin' peach trees at solar noon as affected by canopy position and preharvest watersprout removal (WSR) in 1989.^z

Treatment	PPFD ^y		
	28 DBH	0 DBH	58 DAH
Control-north	26	26	66
Control-center	7	16	74
Control-south	37	65	138
WSR-north	437	200	374
WSR-center	1468	699	640
WSR-south	117	449	430
<i>Observed significance level (P value)</i>			
Contrasts			
Pruning	0.0002	0.0001	0.0002
Position	0.0001	0.0320	0.2214
Pruning $\times$ position	0.0001	0.0251	0.1541

²Average above-canopy PPFD at solar noon of 1611, 1496, and 1546 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ for 28 days before harvest (DBH), 0 DBH, and 58 days after harvest (DAH), respectively.

^yPPFD measured 26 June (28 DBH, 3 days after watersprout removal), 24 July (0 DBH, during harvest period), and 20 Sept. (58 DAH) in fruiting zone of tree (2 m from row center) at a height of 1.2 m and in center of tree at a height of 0.5 to 0.7 m.

Table 3. Percentage of fruit surface pigmented red, ground color², and flesh firmness of fruit as affected by preharvest watersprout removal (WSR) during Stage III fruit development of 'Redskin' peach trees, 1988–89.

Treatment	1988			1989		
	Red surface (%)	Ground color	Firmness (N)	Red surface (%)	Ground color	Firmness (N)
Control	23.8	2.4	70	44.8	2.3	55
WSR	25.9	2.5	71	49.2	2.1	63
P value	0.48	0.75	0.85	0.50	0.59	0.01

²1 = most green, 6 = least green.

Differences in PPFD at the end of the season between the two studies can be partially explained by positioning of the light sensor and tree architecture. The California measurements were all made in the center of the tree at the crotch, where maximum effect on PPFD due to WSR in open center trees might be expected. The Georgia measurements were made within the fruiting zone of the canopy, about halfway between the center and the periphery of the tree. Subsequent growth, particularly at the distal end of scaffold, would potentially influence PPFD measurements more where the sensor was positioned underneath that area. When PPFD was measured in the center of the tree in this study 158 to 60 days after harvest (DAH)], PPFD for the control trees was very similar to PPFD measured for pruned and control trees in the California study (7 Oct.). Canopy architecture of a California tree differs significantly from a typical tree in the eastern United States, the former having more upright scaffolds. Thus, subsequent growth along the scaffold and at the distal end of scaffolds may have had a much greater influence on PPFD in the center of summer-pruned trees in the California study by the end of the season compared to the more spreading type of canopy common in the eastern United States. In the Georgia study, October PPFD in the WSR trees averaged 51% of full sun in 1988 and 1989.

Measurements at harvest indicated that WSR had no effect on mean fruit weight or diameter in any year (data not presented) or on ground color in 1988 or 1989, although WSR increased fruit firmness in 1989 (Table 3). WSR had no effect on red pigment

development in 1988 or 1989, even though PPFD was increased by WSR. There were no differences in weight, diameter, redness, ground color, or flesh firmness between fruit taken from the north and south sides of the tree in 1988 and 1989 (data not presented). In the California study, in which WSR 23 to 28 DBH increased fruit diameter, weight, and redness, fruit samples were taken relatively close to the tree center in the bottom 1.3 m of the tree, an area in which WSR caused a 6- to 7-fold increase in PPFD. In our study, WSR doubled PPFD in the zone from which fruit were sampled, although the net effect on preharvest light intensities, which averaged an increase to only 16% of above-canopy PPFD, was relatively marginal and may not have been enough to affect fruit quality. Marini et al. (1991) reported that light intensities $\leq 23\%$ that of incident PPFD may reduce fruit redness and soluble solids concentration, as well as slow ground color changes.

Market value of peaches is not determined by average fruit weight or size; value is based primarily on the segregation of fruit into various size categories. Analysis of fruit distribution into selected representative commercial size categories revealed that, in 1988 and 1990, WSR increased the percentage of fruit in the largest size category while decreasing the percentage of peaches in the smallest size group (Table 4). Similarly, WSR decreased the percentage of undersize fruit in nectarine trees (Day et al., 1989). The fruit size distribution effect of WSR may be the result of a decrease in total leaf area and, as a result, a decrease in the total transpirational loss by the tree. Such trees would use less water and be less susceptible to water stress, thereby improving fruit water

Table 4. Percent distribution of fruit by diameter based on the Pearson χ^2 test of homogeneity² as influenced by preharvest watersprout removal (WSR) during Stage III fruit development of 'Redskin' peach tree, 1988–90.

Treatment ²	Percent distribution (%)—1988		
	≤ 55 mm	>55 mm <62 mm	≥ 62 mm
Control	18.7	48.0	33.3
WSR	4.4	45.1	50.5
P value	<0.0001		
Treatment ²	Percent distribution (%)—1989		
	≤ 55 mm	>55 mm <62 mm	≥ 62 mm
Control	5.3	23.5	71.2
WSR	4.9	26.8	68.3
P value	0.7830		
Treatment ²	Percent distribution (%)—1990		
	≤ 55 mm	>55 mm <62 mm	≥ 62 mm
Control	27.8	51.7	20.6
WSR	22.6	45.9	31.6
P value	<0.0001		

²Fienberg, S.E. 1977. The analysis of cross-classified data. MIT Press, Cambridge, Mass.

²WSR performed 43, 31, and 21 days before harvest in 1988, 1989, and 1990, respectively.

Table 5. Flower count per unit shoot length as influenced by preharvest watersprout removal (WSR) during Stage III fruit development of 'Redskin' peach trees in 1988–90.

Treatment ²	Flowers per centimeter shoot length ²		
	Year of measurement		
	1989	1990	1991
Control	0.28	---	0.29
Outside	---	0.35	---
Inside	---	0.31	---
WSR	0.42	---	0.30
Outside	---	0.44	---
Inside	---	0.26	---
Observed significance level (P value)			
Contrasts			
Pruning	0.0011	0.3240	0.4186
Position	---	0.0011	---
Pruning $\times$ position	---	0.0268	---

²One-year-old shoots ≈ 50 to 60 cm in length sampled at pink bud flower stage in spring of the year following WSR treatment.

²Outside = outside half of canopy, inside = center of tree.

status and fruit growth rate during Stage III (final swell) when the fruit have a large demand for photosynthates and water (Chalmers and van den Ende, 1975; Chalmers et al., 1975; Walsh et al., 1989). In 1989, cumulative rainfall for the 4 weeks before harvest was 137% of the 30-year average. Rainfall for the same period was 94% and 99% of normal during 1988 and 1990, respectively. In all 3 years, the frequency of rainfall during these 4 weeks was uniform, with no extended dry periods occurring in any year. The above-average amount of rainfall in 1989, however, may have reduced the potential for water stress in the tree, thereby negating any potential fruit size effect following WSR.

Measurements of shoots in the spring of the year following WSR indicated no difference in shoot diameter between treatments (data not presented). However, WSR in 1988 and 1989 but not 1990 increased flower count on a shoot length basis the following year (Table 5). Segregation of sampling in 1990 indicated that WSR increased flower bud formation in the outside half of the canopy but not inside the tree. Summer pruning of peach trees after harvest (Brown and Harris, 1958), in severity similar to dormant pruning, increased shoot diameter, flower bud count, and fruit set the following spring compared to dormant pruned trees. Day et al. (1989) found no difference in either flower or fruit count the spring following WSR. Flower counts in the latter study were made on shoots on the periphery of the tree, a location in which light or other associated factors may not have been limiting. Shoots were sampled throughout the tree canopy in our study.

Responses to changes in the canopy light environment during the preharvest period may have been due to a direct or indirect light-mediated response (Day et al., 1989; Erez and Flore, 1986; Marini et al., 1991) increasing available photosynthates to fruit or increased fruit sink strength. Girdling experiments with peach suggest that an increase in weight of shaded peach fruit can occur as a result of photosynthates being translocated from unshaded areas of the tree (Chalmers et al., 1975; Marini et al., 1991). Although, in this study, WSR did not increase PPFD in the middle of the fruiting zone where light penetration was measured, increased PPFD in the tree center would have increased light available to leaves closer in proximity to fruit and, theoretically, increased photosynthates available for translocation to those fruit. Thus, removal of watersprouts might favor the availability of light, water, and photosynthates to remaining shoots and fruit (Brown and Harris, 1958) during the time when fruit size and quality would be most influenced (Chalmers et al., 1975; Erez and Flore, 1986; Marini et al., 1991).

In other preharvest summer pruning studies (Chalmers et al., 1981; Marini, 1985; Walsh et al., 1989), lack of consistent effects and/or reduction in fruit size may be due to the relative severity or method of summer pruning, possibly limiting photosynthate availability (Day et al., 1989). In those studies, removal of large amounts of leaf area may have reduced the number of leaves below the threshold required for optimum growth for a given number of fruit. Alternatively, summer hedging or topping would not be expected to reduce shading problems caused by within-canopy watersprouts (Day et al., 1989). In addition, severe pruning, including nonselective hedging, may actually reduce the availability of light and/or photosynthates to fruit as a result of the vegetative regrowth following pruning (Chalmers et al., 1981; Marini, 1985; Walsh et al., 1989).

Preharvest removal of superfluous vegetative growth, i.e., watersprouts, using selective thinning cuts may be a useful technique for increasing light penetration within open center peach trees. The overall effect of WSR on within-canopy light relations,

however, was limited by specific conditions in this study. More significant improvements in the within-canopy light environment will likely require changes in canopy shape, size, scaffold orientation, or within-canopy density of structural limbs and shoots. Removal of superfluous growth during final swell, however, has the potential for increasing the value of marketable fruit via an improvement in marketable packout based on fruit size. In addition, our results suggest that WSR can have a positive effect on flower bud formation on fruiting wood within the canopy.

The fruit size effect would have greatest potential economic benefit, as the number of peaches required to fill a given size container is inversely proportional to size and market value of peaches is directly proportional to the fruit size category (Byers, 1989). Based on an average crop load of 650 peaches per tree and an average price of \$5 per package (0.026 m³) containing 220 fruit of ≤ 55 mm diameter, \$10 per such package containing 161 fruit of >55 and <62 mm diameter, and \$12 per such package containing 119 fruit of ≥ 62 mm diameter; the fruit size effect of WSR averaged over 3 years would have resulted in an increase in return of \$3.50 per tree per year, assuming \$0.30 per tree cost for WSR (W.H. Davidson III and A. Pearson, personal communication). As such, judicious preharvest summer pruning, designed to complement tree architecture, vegetative characteristics of the tree, and the physiological stage of fruit growth, may be a useful management practice. Additional research is needed to determine the exact nature of tree and fruit response to preharvest WSR, particularly as influenced by differences in cultivar, location, management practices, and environmental conditions.

Literature Cited

- Brown, C.S. and R.W. Harris. 1958. Summer pruning trees of early maturing peach varieties. *Proc. Amer. Soc. Hort. Sci.* 72:79-84.
- Byers, R.E. 1989. Thinning, p. 70-72. In S.C. Myers (ed.). *Peach production handbook*, Univ. of Georgia. GES Hdbk. 1. Univ. of Georgia Press, Athens.
- Chalmers, D.J., R.L. Canterford, P.H. Jerie, T.R. Jones, and T.D. Ugalde. 1975. Photosynthesis in relation to growth and distribution of fruit in peach trees. *Austral. J. Plant Physiol.* 2:635-645.
- Chalmers, D.J., P.D. Mitchell, and L. van Heek. 1981. Control of peach tree growth and productivity by regulated water supply, tree density and summer pruning. *J. Amer. Soc. Hort. Sci.* 106:307-312.
- Chalmers, D.J. and B. van den Ende. 1975. A reappraisal of the growth and development of peach fruit. *Austral. J. Plant Physiol.* 2:623-634.
- Day, K.R., T.M. DeJong, and A.A. Hewitt. 1989. Postharvest and preharvest summer pruning of 'Firebrite' nectarine trees. *HortScience* 24:238-240.
- Delwiche, M.J. and R.A. Baumgardner. 1983. Ground color measurements of peach. *J. Amer. Soc. Hort. Sci.* 108:1012-1016.
- Erez, A. and J.A. Flore. 1986. The quantitative effect of solar radiation on 'Redhaven' peach fruit skin color. *HortScience* 21:1424-1426.
- Fienberg, S.E. 1977. *The analysis of cross-classified data*. MIT Press, Cambridge, Mass.
- Gerdt, M. 1987. Training and pruning for maximum production and quality. *Proc. Natl. Peach Council Conv.* 49: 122-124.
- Marini, R.P. 1985. Vegetative growth, yield and fruit quality of peach as influenced by dormant pruning, summer pruning, and summer topping. *J. Amer. Soc. Hort. Sci.* 110: 133-139.
- Marini, R.P. and M.C. Marini. 1983. Seasonal changes in specific leaf weight, net photosynthesis, and chlorophyll content of peach leaves as affected by light penetration and canopy position. *J. Amer. Soc. Hort. Sci.* 108:609-613.
- Marini, R.P., D. Sowers, and M.C. Marini. 1991. Peach fruit quality is affected by shade during final swell of fruit growth. *J. Amer. Soc. Hort. Sci.* 116:383-389.
- Myers, S.C. 1988. Basics in open-center peach tree training, p. 389-403. In: N.F. Childers and W.B. Sherman (eds.). *The peach*. Somerset Press, Somerville, N.J.
- Rom, C.R., D.C. Ferree, and G.A. Cahoon. 1984. The influence of three training systems within hedgerows on light distribution, cropping, and efficiency of 'Redhaven' and 'Redskin' peaches. *The Ohio State Univ. Res. Circ.* 283:49-53.
- Walsh, C.S., F.J. Allnutt, A.N. Miller, and A.H. Thomson. 1989. Nitrogen level and time of mechanized summer shearing influence long-term performance of a high-density 'Redskin' peach orchard. *J. Amer. Soc. Hort. Sci.* 114:373-377.