

Relationships between Shoot Productivity and Leaf Characteristics in Peach Canopies

T.M. DeJong and K.R. Day

Department of Pomology, University of California, Davis, CA 95616

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Abstract. The relationships between shoot light exposure in one year and the flower and fruit production characteristics of those shoots the following year were indirectly investigated in summer pruned and nonsummer pruned peach [*Prunus persica* (L.) Batsch.] trees by evaluating leaf characteristics (leaf N and dry matter content per unit leaf area; N_a and W_a , respectively) on tagged shoots during one season and the flowering and fruiting characteristics during the subsequent season. There were significant positive linear relationships between leaf N_a and W_a on shoots in one year and flower and fruit production per unit shoot length during the subsequent year. Summer pruning had relatively little influence on these relationships. There was no apparent relationship between percent fruit set in the spring and light exposure of the shoots the previous summer. Following dormant pruning and commercial thinning, trees summer-pruned the previous year had higher yields than nonsummer pruned trees because of less shoot mortality and more fruit per tree.

The importance of light to cropping in fruit trees has been recognized for >100 years, and most early horticulturists recognized that one of the principal reasons for pruning is to manage light in tree canopies (Ricks and Gaston, 1935). Adequate light exposure is not only important for the development of good fruit quality and color (Erez and Flore, 1986; Heineke, 1966), but also for the maintenance of high quality fruit wood and development of flower buds. Cain (1971) reported that 30% of available sunlight was needed for flowering in apple trees in New York, and similar results have been reported from England (Jackson, 1975). More recently, these estimates were reconfirmed in a more quantitative way in apple by using fisheye photography techniques (Lakso, 1980). Although similar relationships between light exposure and fruiting are thought to exist for peach, fewer studies have attempted to quantify those relationships (Kappel and Flore, 1983). Marini and Sowers (1990) have recently reported that shade treatments imposed at different times during the season can affect flower production on peach shoots, particularly if shading is imposed relatively early in the growing season. However, artificially imposed shade does not represent the type of light regime typically experienced within tree canopies (DeJong and Doyle, 1985).

Several studies with both natural light exposure gradients within tree canopies (DeJong and Doyle, 1985; DeJong et al., 1989; Marini and Marini, 1983) and under artificial shade conditions (Kappel and Flore, 1983; Marini and Sowers, 1990) have shown good

correlations between leaf photosynthetic capacity, leaf N content per unit area (N_a) or dry weight per unit leaf area (W_a) and leaf light exposure during development. These relationships allow for a quick and simple method of using leaf characteristics to study light microclimate effects on flowering and fruiting in fruit tree canopies (Southwick et al., 1990).

The elucidation of the relationships between light exposure and flowering and fruiting is of great importance when performing various cultural operations. One of the common characteristics of mature peach and nectarine trees is the shading and dying of lower fruiting wood. Various tree manipulations have been employed to reduce this problem including various tree forms and dormant and summer pruning (Day et al.,

1989; Kappel and Flore, 1983; Marini, 1985). Each of these methods attempts to solve the problem by providing greater and more uniform light penetration to the lower portions of the tree, but more specific information is needed regarding which aspects of fruiting are affected and whether certain "critical" light exposure levels can be identified under natural canopy conditions.

This study was undertaken to investigate the relationship between N_a and/or W_a of leaves sampled in the summer and flowering and fruit set on the same shoots in the subsequent spring. This study was conducted with the understanding that leaf N_a and W_a reflect the relative light exposure of the shoot they came from. A second aspect of this study was to determine if the changes in light exposure brought about by summer pruning affect these relationships.

The experiments were conducted on mature 'Flamecrest' peach trees growing at the Univ. of California, Kearney Agricultural Center in southern Fresno County. The trees were planted at a spacing of 6.1 × 6.1 m, trained to an open-vase system, and received routine horticultural care suitable for mid-season, fresh-shipping peaches.

On 11 July 1988, 5 days after fruit harvest, eight uniform, well-shaped trees were selected. Light measurements at solar noon ±30 min were made under these trees at ground level (0 m) and at a height of 2 m using a Decagon Ceptometer (Decagon Devices, Pullman, Wash.), integrating total photosynthetically active radiation over its 1-m length. Eight measurements were taken at each height, one at each cardinal compass point and intermediate point, and then averaged for each tree and height.

Four of the eight trees were randomly selected for summer pruning on 12 July 1988. All interior watersprouts originating below 2.5 m were removed. Additional summer pruning on the tree periphery was performed by removing about one-half of the fruit-bearing

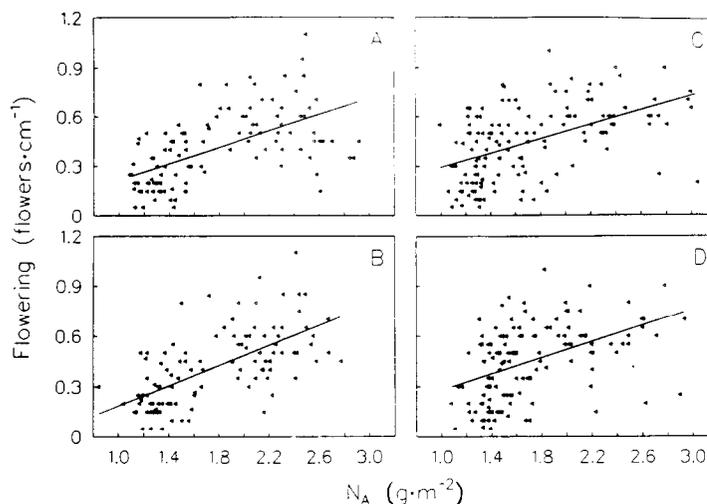


Fig. 1. Relationship between flowers per unit shoot length in spring and leaf N_a on shoots the previous July (A, C) and October (B, D) in nonsummer pruned (A, B) and summer pruned (C, D) trees. Regression equations: (A) $y = 0.246x - 0.028$, $r^2 = 0.38$; (B) $y = 0.298x - 0.111$, $r^2 = 0.41$; (C) $y = 0.216x + 0.077$, $r^2 = 0.26$; (D) $y = 0.240x + 0.041$, $r^2 = 0.21$.

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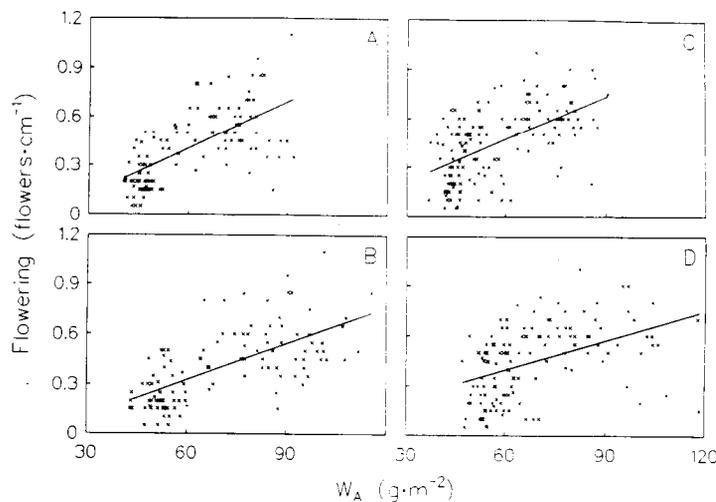


Fig. 2. Relationship between flowers per unit shoot length in spring and leaf W_a on shoots the previous July (A, C) and October (B, D) in both nonsummer pruned (A, B) and summer pruned (C, D) trees. Regression equations: (A) $y = 0.009x - 0.165$, $r^2 = 0.42$; (B) $y = 0.007x - 0.109$, $r^2 = 0.43$; (C) $0.009x - 0.051$, $r^2 = 0.32$; (D) $y = 0.010x + 0.040$, $r^2 = 0.20$.

Table 1. Mean light flux density readings under and within the canopies before and after summer pruning on 11 and 12 July.

Time of measurement	Light flux density ($\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$)	
	Measurement ht (m)	
	0	2
Before pruning	28	196
After pruning	726	1672
Control (not pruned)	21	165
LSD (0.05)	320	306

Table 2. Summary of yield data for summer-pruned and nonsummer pruned trees harvested July 1989.

Summer pruning	Fruit/tree		\bar{X} Fruit wt (g)
	kg	No.	
Yes	127	729	175
No	82	421	194
LSD (0.05)	14.5	131	21.0

ing shoots below 2 m. Post-pruning light measurements were made again on 12 July using the method described above.

Following summer pruning, 40 shoots were tagged in each tree by selecting 10 evenly spaced shoots from the bottom to the top of each of four scaffolds. The scaffolds were selected from the four quadrants of each tree.

Leaf samples consisting of two leaves from the middle section of each tagged shoot were collected on 14 July and 31 Oct. Leaf area of each sample was determined using a LICOR LI-3000 (LI-COR, Lincoln, Neb.) electronic area meter. After drying for 48+ hat 75C, the samples were weighed and total leaf N was determined using a modified Kjeldahl procedure (Carlson, 1978).

A normal dormant pruning was performed on each tree in Jan. 1989. On 27 Feb. 1989, at $\approx 5\%$ to 10% bloom, flower buds on the tagged shoots were counted. On 25 Apr., fruit on tagged shoots were counted to determine set. Immediately after they were counted, the trees were hand-thinned so that

fruits were spaced 12 to 15 cm apart on the shoots. No attempt was made to equalize fruit loads per tree. The trees were harvested according to industry maturity standards on 1, 5, and 10 July 1989. On each picking date the fruit from each tree was counted and weighed.

Light flux and fruit yield data from summer-pruned and control trees were statistically treated as a completely random design.

Summer pruning significantly increased the amount of light penetrating to the lower fruit wood of the open-vase peach trees during midday (Table 1). The increased light exposure in the summer-pruned trees apparently decreased fruiting shoot mortality in these canopies. Only one of the tagged shoots in the summer-pruned trees died during the course of the experiment, whereas 13% died in the nonsummer pruned trees. Since the shoots were purposely tagged to represent the whole range of light exposures and only the shoots in the most shaded end of the range died (mean $N_a = 1.38 \text{ g N/m}^2$), the actual mortality rate of shoots in the heavily shaded areas of the tree canopy was substantially higher than 13%.

There were weak linear correlations between flower production per unit shoot length and N_a and W_a for leaves borne on those shoots during the previous season (Figs. 1 and 2). The coefficients of determination (r^2) were slightly higher for unpruned than summer-pruned trees, which may be a result of the elimination of heavily shaded areas in the summer-pruned trees' canopies. However, there were still significant correlations between July N_a and W_a and flower production the following spring, in the summer-pruned trees. Apparently, flower induction was determined before mid-July and, thus, summer pruning had little effect on flower production of surviving shoots. Tufts and Morrow (1925) reported flower bud differentiation of 'Elberta' peach occurring as early as June in California.

The relationship between N_a and flower

production for each pruning treatment was essentially the same for leaves sampled in July and in October (Fig. 1). The coefficients of determination were slightly greater in the nonpruned treatment. However, the slopes and intercepts were similar within each pruning treatment.

Although leaf W_a was significantly correlated with flower production the following spring, the range of W_a changed substantially depending on when the leaves were sampled (Fig. 2). The range of leaf W_a increased by $\approx 50\%$ from July to October. In July, the maximum W_a was $\approx 90 \text{ g}\cdot\text{m}^{-2}$, but in October it was nearly $120 \text{ g}\cdot\text{m}^{-2}$. The minimum W_a encountered in July was also somewhat lower than in October. Similar differences in the variability of W_a compared with N_a were reported by Castagnoli et al. (1990).

There was no correlation between N_a or W_a (data not shown) sampled in July or October and percent fruit set on those same shoots the following spring in either the summer-pruned or unpruned trees. Mean fruit set of buds on trees in both treatments was $\approx 50\%$. Therefore, although there was substantial variability in percent fruit set between shoots, the variability was apparently unrelated to the light environment of those shoots the previous summer.

Because there was a significant positive correlation between N_a and/or W_a with flowers per unit shoot length (Figs. 1 and 2) and no relationship between N_a and/or W_a with percent fruit set, there was also a positive relationship between N_a and/or W_a and fruit set per unit shoot length (data not shown). However, the coefficients of determination for these relationships were lower than for flower production per unit shoot length because of the apparent random variability of percent fruit set.

In the year after summer pruning, the yield of the summer-pruned trees was $>50\%$ higher than that of nonsummer pruned trees (Table 2). The difference in yield per tree was due to more fruits per tree. The low fruit count per tree in the nonsummer pruned trees is probably a result of shoot death in the intensely shaded portions of these trees. The trees were dormant-pruned and hand-thinned by commercial crews who treated the nonsummer pruned trees like the remainder of the orchard. While dormant pruning, they thinned out the fruiting wood in the tops of the trees in a similar manner for both treatments. Following set, the fruits on the remaining shoots were hand-thinned and spaced 12 to 15 cm apart irrespective of the total fruiting shoots on the tree. Therefore, the trees with fewer total shoots bore fewer fruits. The mean weight of the fruit on the nonsummer pruned trees tended to be higher than that of fruit on the summer-pruned trees (Table 2), suggesting that the former may have been undercropped relative to the latter, although the difference was not significant. The question regarding the relationship between yield and dormant pruning and fruit thinning remains open because we did not adjust the treatments to maintain constant fruit loads.

The primary objectives of this study were to investigate the relationships between N_a and/or W_a of shoot leaf samples in the summer and fall with shoot flowering characteristics the following spring, and to determine if July summer pruning affects these relationships. Our data indicate that flower production per unit shoot length is related to shoot leaf N_a and W_a the previous summer. Since differences in N_a and W_a reflect light exposure gradients within canopies (DeJong and Doyle, 1985; DeJong et al., 1989), we can infer that these relationships reflect flowering responses to light exposure gradients in the tree canopies. This result was expected and is in agreement with reports by Marini and Sowers (1990) for peach, and Cain (1971), Jackson and Palmer (1977), and Lakso (1980) for apples. However, the lack of any correlation between the previous year's shoot light exposure (by inference from N_a and W_a) and percent fruit set was unexpected. Jackson and Palmer (1977) reported that heavy artificial shading in previous years significantly reduced percent fruit set in the subsequent year in 'Cox's Orange Pippin' apples. Similarly, Barritt and Rom (1987) have reported lower percent fruit set of fruiting spurs in low canopy positions than in top canopy positions in spur 'Delicious' apple trees. They also reported that percent fruit set was correlated with leaf dry weight per unit area. The lack of any such correlation in the present study with peach may be related to differences in fruiting habit of apple and peach; apple bears primarily on long-lived spurs and peach bears almost exclusively on annual extension shoots. Apparently, if a peach shoot growing in the shade receives enough light to survive and develop flower buds, those flower buds have the same probability of setting fruit as buds on shoots growing in more exposed areas of the canopy. However, the quality of the fruit can be expected to be affected by the light exposure in the same season as fruit growth occurs (Day et al., 1989; Marini et al., 1991).

In this study the relationships obtained using W_a were very similar to N_a for describing flowering characteristics of different shoots in the canopy. However, the range in W_a was more variable than in N_a during the season, and one has to be careful not to attribute some significance to changes in a W_a /shade-

induced relationship that may simply be caused by seasonal changes in W_a .

The lack of much effect of summer pruning on flower production or percent fruit set was unexpected, especially in light of the difference in yield between summer-pruned and unpruned trees. Apparently, the primary effect of July summer pruning in these trees was to permit the survival of more fruit wood in a greater volume of the tree canopy. The July pruning was too late to significantly affect induction of new flower buds on previously shaded shoots and percent set was unrelated to shading the previous year. In this study no attempt was made to measure bud or fruit size as potentially affected by shoot shading the previous year. Bud size (Barritt et al., 1987) and consequently fruit size (Blanpied and Wilde, 1968; Blasburg, 1943) have been reported to vary along canopy light gradients in apple, but no information of this type is available for peach.

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