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Time and Severity of Summer Pruning Influences on Young Peach Tree Net Photosynthesis, Transpiration, and Dry Weight Distribution

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Abstract. **Young peach trees 1) trained to a single shoot or 2) allowed to branch, were pruned by removing 50% of current growth at either or both of 2 summer dates. Another group of trees had 0%, 25%, 50%, and 75% shoot growth removed by pruning in midseason. Net photosynthesis (Pn) and transpiration (Tr) were increased within 3 days after pruning at either date. Plants pruned twice at 30-day intervals had a 2nd cycle of increased Pn and Tr, with rates returning to levels of unpruned controls within 24 days. Distribution of water soluble carbohydrates in various plant tissues was not altered by pruning. Pruning at 60 days reduced root starch, whereas pruning again at 90 days increased total root carbohydrate content. Pruning early in the season increased lateral shoot formation, and terminal bud formation was delayed by pruning. Plant dry weight was reduced by all pruning treatments, with delayed pruning and increasing pruning severity resulting in greatest reductions. Distribution of dry weight was not altered substantially by pruning, and a balance of growth was maintained between different plant parts.**

Summer pruning of peaches has been used to contain tree size, control tree shape, and redirect tree growth. However, the responses of peaches have been inconsistent with reports of increased vegetative growth (3, 24), decreased vegetative growth (10, 13, 14), and prolonged growing period (2, 13, 14). Since peaches initiate fruit buds on current season growth, summer pruning effects on current growth is critical in maintaining production. The effects of summer pruning of apple have been reported (5, 15, 22), but detailed observation of growth and physiological responses (e.g., net photosynthesis, carbon partitioning, and growth increments) to summer pruning of peach have not been well documented and may aid in developing an understanding of the vegetative responses.

The present series of 3 studies was conducted to investigate the physiological effects of time and severity of pruning young peach trees.

Materials and Methods

Plant materials. Dormant one-year-old 'Redhaven'/'Halford' peach trees were planted in 2.9 liter pots containing a medium of 1 Wooster silt loam soil : 1 peat moss : 1 perlite (by volume). Trees received an initial 15 g of 14.0N–6.1P–11.6K Osmocote fertilizer with additional application of about 1 liter of 10 g/liter liquid fertilizer (20.0N–8.7P–16.6K) at 3 week intervals. At planting (10 May), trees were pruned at the 3rd node above the bud union. The lowest emerging shoot was selected (other shoots were removed) and trained upright as a single shoot. Plants were grown outdoors and after 60 days of growth had an average height of 60–70 cm when treatments were begun. All experiments were terminated after 125 days of growth.

Study 1. Time of pruning/unbranched plants. Trees were maintained as single-shoot, unbranched plants by removing lateral axial branches when 0.5–1.0 cm in length. Lateral branches which formed subsequent to pruning treatments were allowed to develop. Trees were staked, and the topmost regrowth was trained upright. Pruning treatments consisted of: 1) unpruned control, 2) 50% shoot growth removal at 60 days, 3) 50% total shoot growth removal at 90 days, and 4) 50% removal at 60 days and 50% regrowth growth removed at 90 days. Growth made after 60 days will hereafter be called "subsequent" growth, and new growth after a pruning treatment called "regrowth". Trees were arranged in a randomized complete block design with 9 replications of single tree treatments. Five additional replicate plants of each treatment were harvested at each pruning time for leaf number, area, and tissue dry weight determination.

Dry weight increment was calculated as weight difference between 2 dates. Plants harvested at each pruning and at the experiment termination were frozen quickly, lyophilized, and stored at $-18°C$. Soluble carbohydrates were extracted from lyopholized tissue with boiling water for 10 min, centrifuged and filtered for reducing sugar analysis by a ferricyanide method of Hoffman (7). Starch in the insoluble pellet was hydrolyzed by a modified takadiatase method (20) and subsequent ferricyanide reducing determination for glucose (7).

Pn and Tr were measured on the 3rd or 4th intact leaf below the pruning cut and on a corresponding leaf on unpruned plants at 3, 10, and 24 days after each treatment, utilizing techniques previously described (19). Pn was measured with an infrared gas analyzer (MSA-200, Lira), and Tr was measured with a dew-point hygrometer (International EG and G, Model 880). Photosynthetically active radiation of 1050 $\mu mol\ s^{1}\ m^{-2}$ inside leaf chamber was emitted by Sylvania phosphorus coated metal arc lamps. Leaf chamber temperatures of $30° \pm 2°C$ and air flow rates of 3 1 min^{-1} were maintained.

Study 2. Time of pruning/branched plants. Time of pruning also was studied on a 2nd group of plants which developed lateral branches throughout the growing period. Pruning treatments were similar to Study 1, but pruned at 70 and 100 days of shoot growth. Lateral branches as well as the main shoot were pruned. Plants were arranged by height in a randomized complete block with 7 replications of single tree treatments.

Study 3. Pruning severity. Pruning severity was studied on

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unbranched plants (similar to Study 1) until treatment, when subsequent lateral growth was permitted to develop. Pruning treatments consisted of: 1) unpruned control, 2) 25%, 3) 50%, and 4) 75% shoot removal at 80 days after growth had started. Trees were arranged by height in a randomized complete block with 6 replications of single tree treatments.

Leaf area removed by pruning and at termination of the experiment was measured with a Lambda portable leaf area meter. All tissue removed by pruning and at termination was dried at 70°C for 72 hr for dry weight measurement.

Results

Study 1. Net photosynthesis and transpiration. Pn and Tr of intact leaves of the main shoot were increased (14% and 23%, respectively) within 3 days after pruning, compared to unpruned plants (Table 1). The effect appeared to be transient and was negligible after 33 days. Likewise, plants pruned 30 days later (90 day treatment) showed increased Pn and Tr rates 10 days after treatment. When subsequent regrowth after the 60 day pruning again was headed 50% 30 days later (60 + 90 treatment), a 2nd cycle of increased Pn and Tr was apparent after 10 days and maintained at 24 days, whereas leaves of unpruned plants had decreasing Pn during the 54 day period. After pruning at 90 days (90 and 60 + 90 treatments), Pn of leaves 3 nodes below the cut (which were on subsequent growth) and 7 nodes below the cut (which were on main shoot) had similar responses.

The Tr of leaves of pruned shoots was increased after pruning at 60 and/or 90 days (Table 1). The Tr of unpruned shoots generally remained constant and did not show a substantial decline during the 54 day experimental period, indicating no change in stomatal function.

Study 1. Soluble and insoluble carbohydrates. Analyses of the water soluble sugar and starch carbohydrate fractions of young peach tree leaves, shoots, and roots generally show an increase during the season (Table 2). The greatest increases were observed in starch fractions of shoots (1200%) and roots (260%), whereas soluble carbohydrate fractions had relatively small increases (10% to 87%). There was no difference in water soluble carbohydrate levels between pruned and control plants in any tissue sampled at the time of the second pruning (90 days). For the same period, however, starch levels of shoots pruned at 60 days were significantly less than unpruned shoots, and root starch levels also were reduced 23%. Leaf sugar and starch levels of plants pruned at 90 days were 10% to 19% lower than unpruned trees at the end of the experiment (125 days). At the end of the experiment, shoot starch levels of plants pruned at 60 days and 60 + 90 days were greater than levels of unpruned shoots. Soluble sugar levels in roots were similar, but starch contents of plants pruned at 60 days were 48% lower than controls. Plants pruned twice had 33% higher starch levels than unpruned plants.

Studies 1 and 2. Shoot growth and development. Summer pruning reduced shoot diameter increase, but pruning date had no effect at the end of the experiment (Fig. 1). When unbranched plants were pruned twice, diameter increase was reduced more than pruning at either date alone. This effect was not observed on branched trees pruned twice.

Pruning early in the season resulted in increased shoot number compared to unpruned trees or trees pruned only late in the season (Table 3). Main shoot length (plant height) was reduced by all pruning treatments. Delayed pruning reduced length more than in early pruning because of less regrowth. Pruning generally reduced total shoot length (laterals + all regrowth). However, total shoot length of plants pruned at 60 days was increased compared to controls. The average lateral shoot length of trees pruned at 60 days (24.1 cm) was significantly shorter than those of controls (30.1 cm), but total length was greater due to increased number of lateral shoots.

At the conclusion of the experiment, unpruned controls had formed terminal buds, but trees pruned twice during the season still had active growing points (Table 3). However, pruning only once during the season (at 60 or 90 days) had little effect on unbranched trees and no effect on terminal bud formation of branched trees.

Leaf number, size, area/tree, and specific leaf weight (SLW) generally were reduced by pruning treatments; however, unbranched trees pruned at 60 days had increased leaf number, corresponding to total shoot length (Table 3). Pruning later in the season reduced leaf area to a greater extent than pruning early or not pruning. Average leaf size of plants pruned late was reduced 26% to 55% compared to unpruned plants, but leaf number per cm shoot was increased 16% to 35%. When unbranched plants were pruned at 90 days, little regrowth occurred, and thus, SLW was greater than of other treatments.

Plant dry weight. All pruning treatments reduced dry weight of shoots and roots (Table 3) and total season's growth [plus

Table 1. The influence of time of summer pruning on net photosynthesis (Pn) and transpiration (Tr) of leaves on basal and subsequent shoots of young unbranched 'Redhaven' peach trees.

Time of pruning treatment	Pn ($mg\ CO_2 dm^{-2} hr^{-1}$) Days after 60 day pruning treatment: 3	10	24	33	40	54	Tr ($gm\ H_2O dm^{-2} hr^{-1}$) Days after 60 day pruning treatment: 3	10	24	33	40	54
Main shoot												
Control	22.9 b[z]	24.2 b	24.3 a	19.6 a	22.8 b	19.6 b	1.7 b	2.0 b	2.1 a	1.6 a	2.1 b	1.8 b
60	26.1 a	26.3 a	27.3 a	22.3 a	22.6 b	19.2 b	2.1 a	2.3 a	2.5 a	2.0 a	2.1 b	1.7 b
90	22.9 b	24.2 b	24.3 a	20.0 a	26.7 a	27.0 a	1.7 b	2.0 b	2.1 a	1.8 a	2.5 a	2.6 a
60 + 90	26.1 a	26.3 a	27.3 a	20.8 a	26.2 a	25.5 a	2.1 a	2.3 a	2.5 a	1.8 a	2.5 a	2.6 a
Subsequent shoot growth												
Control				22.8 ab	24.8 b	18.2 b				2.2 ab	2.1 b	1.9 b
60				19.9 b	21.6 b	17.3 b				1.9 b	1.8 b	1.8 b
90				25.5 a	30.0 a	27.9 a				2.4 a	2.5 a	2.8 a
60 + 90				24.0 a	30.6 a	27.7 a				2.4 a	2.5 a	2.8 a

[z]Mean separation within dates and by shoot type by LSD, 5% level.
[y]Days of shoot growth at time of pruning.

Table 2. Effect of time of summer pruning on water soluble reducing sugars and insoluble hydrolyzable carbohydrate fractions of leaf, shoot, and root tissue of peach sampled at 3 dates.

	Carbohydrates by dry weight (%)								
	Leaf			Shoot			Root		
Time of pruning treatment[y]	Water soluble sugars	Hydrolyzed starch	Total extracted CHO	Water soluble sugar	Hydrolyzed starch	Total extracted CHO	Water soluble sugars	Hydrolyzed starch	Total extracted CHO
Time of 1st pruning (60 days)									
Control	3.2	1.6	4.8	3.1	0.3	3.5	2.6	0.1	2.6
Time of 2nd pruning (90 days)									
Control	6.4 a[z]	3.3 a	9.7 a	2.4 a	5.1 a	7.5 a	2.7 a	1.5 a	4.2 a
60 days	6.3 a	3.2 a	9.5 a	2.4 a	3.7 b	6.1 b	2.3 a	1.2 a	3.5 a
End of experiment (125 days)									
Control	6.0 a	4.5 a	10.5 a	4.5 a	3.8 b	8.2 b	2.8 a	3.8 ab	6.6 ab
60	6.2 a	4.3 ab	10.5 a	4.4 a	5.8 a	10.2 a	3.2 a	2.0 b	5.1 a
90	5.4 a	3.7 ab	9.1 ab	3.7 a	4.8 ab	8.5 ab	2.3 a	3.2 ab	5.4 b
60+90	4.9 a	3.6 b	8.5 b	3.7 a	5.8 a	9.5 ab	3.4 a	5.0 a	8.0 a

[z]Mean separation within columns and period by LSD, 5% level.
[y]Days of shoot growth at time of pruning.

Table 3. The influence of time of pruning of unbranched and branched trees and severity of pruning of unbranched trees of young 'Redhaven' peach on dry weight, leaf growth, and shoot development.

	Shoot growth				Leaf growth				Dry wt (g)			
Time of pruning treatment[y]	No.	Main shoot length (cm)	Total length (cm)	Active growing points	No.	Total area (dm^2)	Average size (cm^2)	Specific leaf wt. (mg/cm^2)	Leaves	Shoots	Roots	Total
Unbranched plants												
Control	2.6 b[z]	126.9 a	201.3 b	0.0 b	107.6 b	43.9 a	45.9 a	7.6 ab	35.5 a	44.8 a	56.2 a	136.5 a
60	9.3 a	74.8 b	263.9 a	0.3 b	150.1 a	45.5 a	31.2 b	6.7 c	30.5 b	27.3 b	46.2 ab	104.1 b
90	3.5 b	61.1 c	101.8 d	1.2 ab	56.3 c	14.9 b	27.9 b	8.0 b	11.8 c	22.4 c	42.4 bc	76.6 c
60 + 90	10.2 a	54.0 c	158.6 c	1.9 a	68.1 c	14.9 b	20.7 c	6.9 bc	10.3 c	16.0 d	34.2 c	60.5 d
Branched plants												
Control	17.3 c	96.3 a	528.3 a	0.0 b	302.0 a	85.6 a	28.4 a	7.0 a	59.0 a	59.8 a	99.3 a	218.1 a
70	22.1 b	72.9 b	394.4 b	0.0 b	219.6 b	55.2 b	25.2 a	6.1 b	33.6 b	33.2 b	53.9 b	120.7 b
100	12.3 d	58.0 d	228.3 d	0.0 b	106.1 d	20.8 d	19.6 b	5.9 b	12.1 d	28.3 b	69.8 b	110.1 c
70 + 100	25.9 a	65.3 c	317.7 c	5.0 a	166.6 c	34.2 c	20.5 a	6.0 b	20.4 c	30.1 b	60.0 b	110.5 c

[z]Mean separation within columns and within studies by LSD, 5% level.
[y]Days of shoot growth at time of pruning.

tissue removed by pruning (13)]. Pruning plants early in the season (60 or 70 days) resulted in the greatest shoot dry weight reduction (34% to 45% of unpruned control) compared to other tissue fractions (roots or leaves), but when pruning was delayed leaves had the greatest dry weight reduction (66% to 80%). Roots had less reduction in dry weight than either the leaf or shoot fractions. Pruning late or twice during the season resulted in the greatest reductions in total dry weight accumulation. Pruning late removed a similar proportion of total plant dry weight at the time of pruning as did pruning early, but due to minimal compensatory regrowth as indicated by no increase in shoot number, total plant dry weight was low.

It was interesting to note the difference in general growth between unpruned plants, which were not allowed to branch by continuously removing young axillary laterals, unbranched plants, and unpruned branched plants (Table 3, Fig. 1). Although not compared experimentally, it is obvious that removing the young laterals well in advance of leaf expansion and development greatly reduced total tree growth. Unbranched and branched control trees had similar diameters (Fig. 1) and growth rates as indicated by regression analysis (diameter in cm × time: slope = 0.089, 0.098, intercept = 0.58, 0.59, R^2 = 0.88, 0.89, respectively). Branched trees were shorter than unbranched but had increased shoot number and total shoot length. Branched trees had a 2-fold increase in leaf number, but average leaf size was 12% to 20% smaller than unbranched trees. Removing the axillary shoots very early reduced root dry weight similar to the 50% pruning at 70 days. Total dry weight accumulation of unbranched trees was 37% less than branched trees. However, leaf efficiency (mg dry wt/cm^2 leaf area) was 22% greater in unbranched than branched trees (31.1, 25.5, respectively). Branched trees had a 17% lower shoot to root ratio (data not presented).

Dry weight increment. During the period between the 1st and 2nd pruning (60–90 days), unpruned plants had 36% of dry weight in the leaf fraction, whereas between the 2nd and the end of the experiment (90–125 days), 45% of dry weight was in the shoot fraction (Table 4). During both periods, roots comprised one-third of dry weight increase, and shoot:root ratios were similar. Pruning unbranched trees reduced leaf, shoot, and root dry weight fractions during the 30-day period following

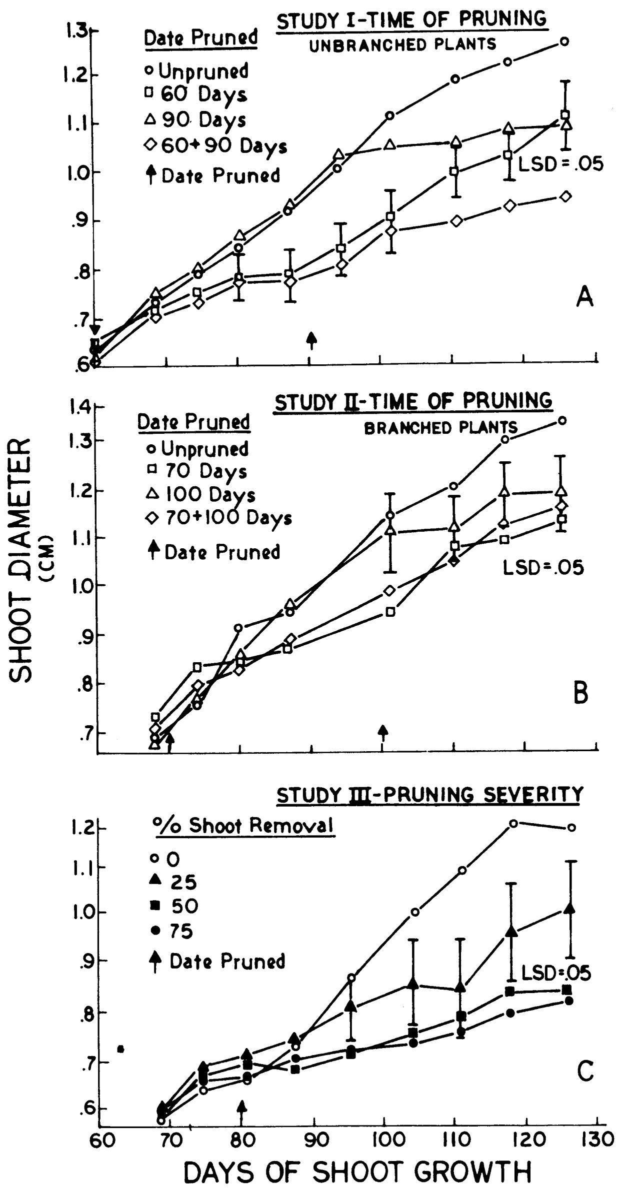

Fig. 1. The influence of time of pruning of unbranched plants (**A**), branched plants (**B**), and pruning severity (**C**) on main shoot diameter of young 'Redhaven' peach trees.

treatments. However, plants pruned at 60 days had a higher percentage of dry weight go to formation of leaves than did unpruned controls during the period after pruning (45% and 36%, respectively), and plants pruned at 90 days (90 and 60 + 90 treatments) had a higher percentage dry weight in shoot fractions than controls (51% to 59% and 45%, respectively) during the 30-day period following the respective pruning treatment. Plants pruned at 60 days had a 12% increase in dry weight allocated to leaf fractions, compared to unpruned plants, during the time between the 2nd pruning and the end of the experiment. In the 30-day period following 60-day pruning, the increase in total plant dry weight was 29% less than that of unpruned plants, whereas after the 90-day pruning treatment, total dry weight increase was 64% less. Regardless of treatment, root growth was about one-third of total increment for a given time period.

Study 3. Severity of pruning. Pruning 25%, 50%, or 75% shoot length after 80 days growth significantly reduced shoot diameter (Fig. 1) and length (Table 5). Pruning severity did not affect shoot number significantly, but all treatments resulted in an average 60% to 80% increase. Pruning tended to decrease leaf number; however, no significant trend occurred. Total leaf area and SLW were reduced by pruning. Increasing pruning severity reduced leaf, shoot, root and total dry weight and increased plant root:shoot ratio. Trees pruned 50% and 75% had considerable regrowth, whereas trees pruned only 25% had less. Therefore, shoot length, leaf dry weight and shoot dry weight were similar 45 days after pruning and thus showed a quadratic response. Pruning 75% resulted in a similar reduction as pruning 50% for every variable, but a significant reduction in shoot diameter, leaf area, root dry weight and total plant dry weight compared to 25% pruning.

Discussion

An increase in Pn after summer pruning has been reported for apple (5, 11, 22) and mulberry (18). However, 39 days after young apple trees were pruned, Pn rates were similar to controls (22). Pn rates of basal mulberry leaves were maintained after pruning when combined with subsequent bud removal (18). In our study, Pn rates were increased after pruning at either 60, 90, days or 60 days and subsequently again at 90 days (Table 1). The response tended to be prevalent close to the pruning cut as previously indicated (22). Although pruning at 90 days removed a greater percentage of total leaf area and plant tissue than pruning for the 2nd time at 90 days (60 + 90 treatment), the response was similar. Therefore, it appears that the Pn response is not linked to the amount of tissue removed by pruning, but is related to an alteration in plant size, removal of shoot apex or apical meristem (1, 18), and the proximity of the measurement to the pruning cut.

The response of Pn to summer pruning was similar on leaves of varying age (Table 1). Sams and Flore (16) reported that Pn of sour cherry increased to a maximum 30 days after unfolding, but had decreased to about 65% of maximum by 65 days after unfolding. The response to pruning at 90 days and 60 days was similar; however, the leaves were 30 days older. In both instances, the decline in leaf Pn with age was interrupted by pruning, and Pn rates increased to presumably maximal levels. Likewise, after the 90-day pruning, Pn of the subsequent growth was similar for the 60 + 90 and 90 treatments, even though leaves were on different age shoots (regrowth and mainshoot, respectively) and thus of different age (<30 days for regrowth, >30 days for mainshoot subsequent growth).

Pn increase after pruning was reported to be simultaneous with the breaking of dormant lateral buds (1, 18, 22) and attributed to increase auxin (1) or decreased abscissic acid levels (9). Likewise, shortly after peach trees were pruned at 60 days, lateral axial buds broke and grew for about 40 days, at which time terminal buds had formed (Table 3). However, there was no lateral bud break or further shoot growth after pruning at 90 days, but Pn was increased (Table 1).

Satoh et al. (18) reported that stomatal resistance (R_s), the major transpirational control, was not affected by pruning, but residual resistance (R_r) was decreased. Kriedeman (8) reported that water vapor loss from citrus leaves is under stronger stomatal control than CO_2 assimilation, but R_r may be rate-limiting to CO_2 assimilation. Since, in the present study, Tr of control trees was constant during the experimental period but was increased after pruning (Table 1), it appears that R_s, i.e., stomatal aperture, was not the controlling mechanism in Tr and Pn response to pruning, but internal R_r likely was reduced. However, since R_s of young apples was reduced after summer pruning

Table 4. Effects of time of summer pruning on dry weight increment increase of leaves, shoots, roots, shoot to root ratio, and percentage of roots of total growth.

Treatment	Dry weight (g) increase			Shoot:Root	Roots (%)
	Leaves	Shoots	Roots		
Between 1st and 2nd pruning (60–90 days)					
Unpruned control	14.7 a[z]	13.2 a	13.4 a	2.1 a	0.32 a
Pruned at 60[y]	13.4 b	6.8 b	9.3 b	2.8 a	0.31 a
Between 2nd pruning and end of experiment (90–125 days)					
Unpruned control	12.9 b	28.0 a	21.3 a	2.2 a	0.33 a
Pruned at 60	14.4 a	17.7 b	15.1 ab	2.4 a	0.32 a
90	3.5 c	11.4 c	7.6 bc	2.0 a	0.32 a
60 + 90	2.4 c	8.5 d	3.5 c	3.1 a	0.24 a
Total: 1st pruning to end of experiment (60–125 days)					
Unpruned control	27.6 a	41.1 a	34.7 a	2.1 a	0.32 a
Pruned at 60	27.6 a	24.5 b	24.4 b	2.1 a	0.32 a
90	18.3 b	24.5 b	21.0 b	2.3 a	0.32 a
60 + 90	15.7 c	15.2 c	12.8 c	2.7 a	0.28 a

[z]Mean separation within columns and period by Duncan's new multiple range test, 5% level. Shoot:Root = shoot + leaf dry weight/root dry weight. Percentage of roots = root dry weight/total dry weight.
[y]Days of current season shoot growth at time of pruning.

Table 5. Regression analysis of effects of summer pruning severity on shoot growth, leaf growth, and dry weight accumulation of young 'Redhaven' peach trees.[z]

Variable	Shape of regression	Coefficients			R^2	P(f)
		Intercept	X	X^2		
Shoot growth						
Diameter	Linear	1.16	−.005	---	0.602	0.000
Length	Quadratic	123.3	−253	−0.024	0.780	0.003
No. of laterals	NS	---	0.037	---	0.134	0.080
Leaf growth						
Number	NS	114.5	−0.276	---	0.051	0.324
Area	Linear	4569	−26.0	---	0.303	0.026
Specific leaf weight	Quadratic	6.99	0.005	0.0003	0.392	0.000
Tissue dry weight						
Leaves	Quadratic	33.8	−0.65	0.01	0.563	0.011
Shoots	Quadratic	42.1	−1.05	0.01	0.821	0.000
Roots	Linear	43.0	−0.18	---	0.268	0.002
Total	Quadratic	132.9	−2.06	0.02	0.647	0.001
Root:Shoot	Linear	1.14	0.03	---	0.300	0.005

[z]Pruning treatment levels: 0%, 25%, 50%, and 75% shoot removal after 80 days of growth.

when measured below light saturation (11), changes in stomatal responsiveness should not be discounted.

Total sugar levels of 1-year-old peach trees increased during the growing season (Table 2), corroborating previous reports (21). Although Pn levels of pruned plants were increased between 60 and 90 days (Table 1), there was no increase in soluble sugar levels and in fact, starch levels of shoots and roots decreased (Table 2). This decrease probably was due to allocation of these carbohydrate fractions to new growth resulting from pruning (Table 3). Newly formed leaves have high dark respiration (Rd) rates before attaining maximum Pn (4). Thus, pruning treatments causing lateral bud break with a proliferation of leaves may have large respiratory carbohydrate loss. Also, increases in Rd respiration after summer pruning (11) may utilize leaf carbohydrates and allow less to be transported to storage tissues. This fact, coupled with the immediate reduction in leaf area after pruning (−53%) would account for the reduction in dry weight in pruned plants in the 30-day period following pruning.

Starch content of all tissues appeared to be more affected by pruning treatments, compared to the soluble fractions (Table 2), thus indicating changes in carbohydrate storage or utilization. Likewise, starch content of mulberry roots decreased to a minimum at 30 days after pruning before increasing above initial levels, whereas soluble sugar content was little changed after pruning but increased as new shoots began to grow (17). In the present study, root starch levels of plants pruned to 60 days did not increase as did the content of unpruned plants during the 65 day period after planting. However, when plants were repruned at 90 days (60 + 90 treatment), roots appeared to become a prominent sink for storage carbohydrates, even though there was proportionately less root dry weight accumulation (Table 4). Hansen (6), using$^{14}CO_2$ assimilated by leaves of young apple trees, determined that carbon distribution was dependent upon the growing intensity of various plant parts. A similar trend was seen in our data. When plants were pruned early in the season, starch levels of shoots and roots were depressed while leaf carbohydrate fractions were unaffected, and leaf dry weight comprised the greatest proportion (45%) of new growth in the 60–90 day period. This response then was followed by a period when shoot growth comprised the greatest proportion of dry weight accumulation, and root starch levels were depressed.

Pruning late in the season (90 days) resulted in a general decrease in growth rate and did not alter carbohydrate allocation substantially.

Summer pruning young peach trees reduced current season growth as observed by the depression in shoot diameter increase (Fig. 1) and dry weight accumulation (Tables 3, 4, 5). Diameter of current season shoots of mature peach trees was reduced when headed in July (14), but there was less effect when pruned later in the season. In the present study, this response was not observed. The difference in results may be attributed to the fact that the present treatments were applied prior to terminal bud formation. Pruning severity also affected diameter growth (Fig. 1C, Table 5) and may account for the significant reduction in shoot diameter increase by pruning twice (60 and 90 days). Pruning twice removed the greatest proportion of total dry weight accumulation and, thus, gave a response additive of either individual pruning date (Study 1) or similar to the severe (75% removal) pruning treatment (Study 3).

Although pruning depressed rate of growth (Fig. 1, Tables 3, 4) pruning early in the season resulted in lateral bud break and regrowth. As pruning was delayed, regrowth was reduced. Similarly, when shoots of mature peach trees were pruned after terminal bud formation, there was no regrowth (14). Young peach trees pruned 50% and 75% had considerable regrowth, whereas those pruned 25% had less. Therefore, all treatments resulted in similar shoot lengths (Table 5). Taylor (22) has reported that regrowth length of 1-year-old apples was inversely proportional to pruning severity. Total shoot length of plants pruned 50% at 60 days was greater than controls (Table 3). It may, therefore, appear that summer pruning is invigorating. However, average shoot length of pruned plants (24.1 cm) was significantly shorter than controls (30.1 cm), and total shoot dry weight increment increase was reduced after a pruning treatment (Tables 3, 4). Therefore, early summer pruning may increase the number of growing points; however, the vigor of individual growing points is reduced. Regrowth and increased physiological activity does not appear to compensate for tissue removed by pruning. This effect is increased as pruning is delayed or pruning severity is increased above 25%.

Growth and dry weight accumulation of the various plant organs seems to be balanced and, when interrupted, tends to reestablish the balance. This balance of growth has been described previously as a functional equilibrium (5, 12). Roots generally comprised one-third of the total plant dry weight accumulation in unbranched plants (Table 4). Pruning young peach trees tended to increase the shoot:root ratio in the 30-day period after treatment and have a reduced percentage of dry weight as roots. However, a growth balance was re-established in the subsequent 30-days with shoot:root ratio and the percentage of roots similar to controls. Although not as evident with late pruning, this probably is due to the termination of the experiment prior to establishing the equilibrium.

Growth of unpruned plants was characterized by vigorous extension growth and leaf development early in the season, but as terminal buds were formed, radial growth slowed and plants increased in dry weight accumulation. This series of studies has demonstrated that the effects of summer pruning of young peach trees at different times in the season creates different responses. Pruning early in the growing season increased Pn and Tr and shifted carbohydrate fraction allocation to new regrowth. Likewise, delayed pruning increased Pn and Tr but did not cause a shift in dry weight allocation compared to controls. Although increased Pn after summer pruning has been documented for other crops (1, 5, 11, 15, 17, 18, 22), this study establishes a similar response for peach. This study also shows that the Pn stimulation response occurred on leaves of varying age and on plants in different stages of growth. Plants pruned twice had 2 cycles of increased Pn and Tr.

Evidence presented here shows that pruning early or with increasing severity on 1-year-old wood resulted in the greatest amount of regrowth; however, little regrowth occurred after a late season pruning. Pruning twice may extend the growth period. The overall effect of summer pruning was a depression in growth rate and a net reduction in dry weight accumulation. Although short-term changes in tissue dry weight accumulation patterns were observed after pruning, peach plants tended to establish a functional equilibrium of growth between plant parts.

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CORRIGENDA

- In the article "Growth Capacity of 'Valencia' Orange Buds on Different Rootstocks during Cold-hardening Temperatures" by G. Yelenosky and H.K. Wutscher [*J. Amer. Soc. Hort. Sci.* 110(1):78–83. 1985.], the figure captions for Figures 2 and 3 were reversed.

- The article "Simplified Method for Rooting Apple Cultivars in Vitro" by Richard H. Zimmerman and Ingrid Fordham [*J. Amer. Soc. Hort. Sci.* 110(1):34–38. 1985.] contained errors within Table 3. The corrected table appears below. Tables 4, 5, and 6 also are being reprinted because the previously published format was difficult to read.

Table 3. Effect of type of auxin in rooting medium on percentage of cuttings rooted after 3 weeks.

Cultivar	No. of cuttings/ treatment	Rooting (%) IBA	IAA	NAA	χ^2	No. of subcultures
Delicious[z]	40	56 ab[y]	36 b	66 a	7.492*[x]	26, 27
Redspur Delicious	40	45 a	20 b	18 b	9.279**	38
Royal Red Delicious	40	0	2	2	0	29
Gala	30	90	87	93	0.741	33
Golden Delicious	40	82	70	90	5.270	23
McIntosh[z]	40	64 a	31 b	64 a	11.305**	4, 6
Spur McIntosh	30	100	97	97	1.028	22
Mutsu[w]	30	87 a	60 b	63 b	6.302*	4
Spartan	30	80 a	40 b	73 a	12.025**	22

[z]Mean of 2 experiments, 40 cuttings per treatment in each experiment.
[y]Means for a cultivar followed by the same letter do not differ at the 5% level by χ^2 comparison of each pair of treatment means.
[x]Significant at 5% (*) or 1% (**) levels.
[w]Data after 4 weeks.

Table 4. Effect of dark treatment and temperature during first week of rooting stage on percentage of cuttings rooted after 3 weeks.

Cultivar	No. of cuttings/ treatment	Rooting (%) Light 25°	Dark 25°	Dark 30°	χ^2	No. of subcultures
Delicious	30	3 b[z]	30 a	33 a	9.387**[y]	26
Redspur Delicious	30	13 b	37 ab	47 a	8.039*	38
Vermont Spur Delicious	20	5 b	10 b	60 a	19.733**	18
Gala	30	57 b	67 ab	90 a	8.546*	32
Golden Delicious	30	50 b	87 a	53 b	10.622**	25
McIntosh[x]	40, 30	57	66	64	0.629	4, 7
Spur McIntosh	30	17 c	57 b	87 a	29.732***	16
Mutsu	40	35 b	62 a	60 a	7.418*	4
York Imperial	30	53	67	70	2.010	5

[z]Means for a cultivar followed by the same letter do not differ at the 5% level by χ^2 comparison of each pair of treatment means.
[y]Significant at 5% (*), 1% (**), or 0.1% (***) levels.
[x]Mean of 2 experiments.