Long-term Effects of Sod Competition on Peach Yield

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SUMMARY. Excessive vegetative growth in peach (*Prunus persica*) causes canopy shading that reduces fruit bud initiation in the canopy interior and increases pruning costs and time. Sod competition can reduce pruning but may also reduce yield. The objective of the present study was to measure the effects of increased sod competition [2- vs. 8-ft-wide vegetation-free areas (VFA)] on yield and quality of irrigated peach. Total pruning weight was reduced by sod competition in the first 4 of 7 cropping years. Subsequent years indicated no effect on vegetative growth due to sod competition. Annual increase in trunk cross-sectional area was reduced by sod competition in the first year of cropping and unaffected in subsequent years. Canopy development was reduced by sod competition in the first 2 years of cropping, which increased photosynthetically active radiation transmission through the canopy and increased fruit red color in the first year. The width of the VFA did not alter the relationship between total fruit number and total yield in any year; however, the total number of fruit per tree was reduced in all years and total yield was reduced in 6 of 7 years. Results suggest that dormant season pruning was removing a higher percentage of the crop bearing wood from the 2-ft VFA compared with the 8-ft VFA treatment, resulting in reduced yield per unit of dormant pruning. This indicates that pruning practices must be modified to leave more bearing wood in mature trees to maintain yield potential when sod competition is used to control vegetative growth.

Excessive vegetative growth in peach causes canopy shading that reduces fruit bud initiation in the canopy interior and increases pruning costs and time (Chalmers et al., 1981; Guilivo et al., 1984; Hayden and Emerson, 1973). Sod in the drive middles does not limit peach tree growth (Belding et al., 2004; Liverani et al., 1992), but weed interference of summer annuals in the tree row will reduce yield (Belding et al., 2004). Similarly, establishing sod or other plant species in the tree row to compete with the peach tree has reduced vegetative growth (Glenn et al., 1996; Glenn and Welker, 1996; Tworkoski, 2000; Tworkoski and Glenn 2001). The proximity of sod to peach tree root systems likely limited nitrogen (N) uptake and reduced fruit number and yield (Tworkoski et al., 1997) while increasing branch angle (Welker and Glenn, 1995). Long-term studies in rain-fed peach production demon-

strated that sod competition, while reducing pruning weights and sucker weights in most years, reduced yield in 5 of 18 study years but only reduced yield of large fruit in 1 of 18 study years (Glenn and Welker, 1996). The objective of the present study was to determine the effect of increased sod competition on yield and quality of peach in an irrigated orchard.

Materials and methods

‘Autumnango’ on Lovell seedling rootstock were planted in augered holes in 1997. All trees were cut back to a 3-ft height after planting. Trees were planted in rows spaced 20 ft apart and oriented north to south with 8-ft spacing within rows. A

randomized complete block design with six replications was used. Each plot was 10 ft wide and contained seven trees with a guard tree between plots in each row. Data were collected from the center five trees. The trees were dormant pruned in all years and were summer pruned in 5 of 7 years.

Trees were trained and dormant pruned to a modified central leader with four permanent lower scaffolds and the central leader. Central leader side limbs were dormant pruned to remove any limbs that were two-thirds the diameter or larger of the leaders diameter. Smaller diameter limbs were pruned to one or two buds to promote annual fruiting wood. One-year-old wood and the shoots growing from the leader were spaced and thinned along the leader for fruiting. The leader was dormant topped at an 8 ft height to a weak competing leader. When pruning the trees, no attempt was made to keep the two treatment canopies of similar dimensions—that is, the trees were allowed to grow outward until they filled the space allotted. Therefore, with 20 ft between rows, the 0.6 vegetation-free areas (VFA) took longer to fill the area and required less pruning. Summer pruning was generally done in late July. All shoots of current summer growth that were vigorously growing upright were removed. Flowers were thinned with 5 qt/acre Wilthin (sulfocarbamide 79% a.i.; Entek Corp. Brea, CA) and 1 pt/acre Regulaid (2-butoxyethanol + poloxalene + mono-propylene 90.6% a.i.; Kalo, Inc., Overland Park, KS) each year at 80% to 90% bloom. Supplemental hand thinning commenced after June drop. Final fruit spacing was 6 to 8 inches along the shoot. There was no attempt to equalize the crop load between treatments other than the fruit spacing at 6 to 8 inches.

Units

To convert U.S. to SI, multiply by	U.S unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
6.4516	inch ²	cm ²	0.1550
0.4536	lb	kg	2.2046
1.1209	lb/acre	kg·ha ⁻¹	0.8922
0.1198	lb/gal	kg·L ⁻¹	8.3454
28.3495	oz	g	0.0353
70.0532	oz/acre	g·ha ⁻¹	0.0143
0.001	ppm	mg·g ⁻¹	1000
1.1692	pt/acre	L·ha ⁻¹	0.8553
2.3385	qt/acre	L·ha ⁻¹	0.4276

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Table 1. Fertilizer materials and amounts applied to 'Autumn-glo' peach and the leaf nitrogen (N) content from 1997 to 2005. Trees were planted in 1997.

Year	March fertilizer ^z		July fertilizer ^z		Leaf N (mg·g ⁻¹) ^y	
	Material	N rate (g/tree) ^y	Material	N rate (g/tree)	2-ft-wide VFA ^x	8-ft-wide VFA
1997	16N-0P-0K	40	16N-0P-0K	0	nd ^w	nd
1998	16N-0P-0K	40	16N-0P-0K	0	nd	nd
1999	16N-0P-0K	40	16N-0P-0K	0	2.7	3.1*
2000	16N-0P-0K	40 ^v	16N-0P-0K	0	2.6	2.4
2001	10N-4.4P-8.3K	54	16N-0P-0K	0	2.2	2.2
2002	16N-0P-0K	44	16N-0P-0K	82	2.4	2.3
2003	16N-3.5P-6.6K	54	16N-0P-0K	35	2.6	2.5
2004	16N-3.5P-6.6K	108	16N-0P-0K	82	3.4	3.1
2005	16N-3.5P-6.6K	54	10N-4.4P-8.3K	29	nd	nd

^zFertilizer materials are: 16N-0P-0K (calcium nitrate), 10N-4.4P-8.3K (ammonium nitrate), and 16N-3.5P-6.6K (a blended fertilizer).

^y1 g = 0.0353 oz, 1 mg·g⁻¹ = 1000 ppm.

^xVegetation-free area, 1 ft = 0.3048 m.

^wNo data collected.

^vThe 2-ft-wide VFA received an additional 20 g/tree N.

*Indicates significant difference within 1 year ($P = 0.05$).

Sod of 'Kentucky-31' tall fescue (*K-31*; *Festuca arundinacea*) was established in the drive middle. After planting, the tree row strip was maintained with an 8- or 2-ft vegetation-free strip. Fruit were harvested two to three times in late August in all years, and there were no severe frosts that limited cropping. Fruit load was annually thinned by hand. Fertilization and weed control varied each year and were not constant across both treatments (Tables 1 and 2).

Canopy light interception was measured in July of 1999 through 2001 before summer pruning. Light transmission through the canopy was measured at 25-, 50-, 75-, and 100-cm distances from the tree at ground level on the north and south sides of

the tree. Data were collected on clear days 1 h before to 1 h after solar noon. A 1-m line quantum sensor (model LQA; LI-COR, Lincoln, NE,) measured transmitted photosynthetically active radiation (*PAR*). Incoming *PAR* levels were measured after each eight data points beneath the canopy. Transmission was calculated as the percentage of *PAR* beneath the canopy at a specific distance, relative to the average incoming *PAR* before and after the eight readings.

Pruning fresh weights of each five-tree plot were collected in dormant seasons from 1999 to 2005 and for summer prunings in all years except 2003 and 2005. Data are expressed on a single-tree basis.

Leaf samples were collected in July of 1999 to 2004 for leaf N analysis. Samples in 1999 to 2001 were collected and analyzed by plot for statistical analysis. Samples from 2002 to 2004 were collected by plot but were pooled for N analysis.

In all years, fruit were graded into four diameter categories: <2¼ inches, 2¼ to 2½ inches, 2½ to 2¾ inches, and ≥ 2¾ inches. Fruit number was counted for 1999 to 2002. Fruit number was estimated for 2003 to 2005 by a regression of fruit weight with fruit number for the specific grade using data from 1999 to 2002. The coefficients of determination for the regressions were 0.99. Data are expressed on a single-tree basis.

When fruit were harvested (five trees per plot), a subsample of 20 fruit per plot were randomly collected for color analysis for 1999 to 2001. Hue angle was calculated from measurements on four sides of each fruit with a color meter (Chromameter 400; Minolta, Osaka, Japan).

Data were analyzed in a randomized complete block design with six replications. Fruit weight was analyzed using analysis of covariance in a randomized complete block design using SAS (version 8; SAS Institute, Cary, NC). Dormant season pruning weight per tree or fruit number per tree were the independent covariates. Adjusted treatment means were compared using PDIF, which compares least squares means from the analysis of covariance.

Table 2. Herbicide materials and amounts applied to 'Autumn-glo' peach from 1997 to 2005. Trees were planted in 1997.

Year	Contact herbicide		Residual herbicide	
	Material	Rate a.i. (oz/acre) ^z	Material	Rate a.i. (lb/acre) ^z
1997	Paraquat ^y	9.5		
1998	Paraquat	9.5	Oryzalin ^x	3.75
1999	Paraquat	9.5	Norflurazon ^w + simazine ^v	3.5 + 2.5
2000	Paraquat	9.5	Norflurazon + diuron ^u	3.75 + 1.5
2001	Paraquat	9.5	Norflurazon + diuron	3.5 + 1
2002	Paraquat	9.5	Oryzalin	3.75
2003	Paraquat	9.5	Oryzalin	3.75
2004	Paraquat	9.5	Terbacil ^t + diuron	1.7 + 1.5
2005	Paraquat	9.5	Norflurazon + oxyfluorfen ^s	3.5 + 1.5

^z1 oz/acre = 70.0532 g·ha⁻¹, 1 lb/acre = 1.1209 kg·ha⁻¹.

^yGramoxone Extra [2.5 lb/gal (0.30 kg·L⁻¹) a.i.]; Zeneca Ag Products, Wilmington, DE.

^wSurflan AS (40% a.i. w/w); Dow AgroSciences, Indianapolis.

^vSolicam df (79% a.i. w/w); Syngenta, Greensboro, NC.

^uPrincep (90% a.i. wettable powder); Syngenta.

^tKarmex (80% a.i. wettable powder); Dupont Ag Products, Wilmington, DE.

^sSinbar (80% a.i. wettable powder); Dupont Ag Products.

^xGoal 2XL (25% a.i.); Dow AgroSciences.

Table 3. Effect of vegetation-free area (VFA) width on pruning weight and annual increase in trunk cross-sectional area (TCSA) from 1999 to 2005 in 'Autumnnglo' peach planted in 1997 and the results of analysis of covariance relating total fruit yield to dormant season pruning weights.

Year	VFA width (ft) ^z	Pruning wt (kg/tree) ^z			Annual increase in TCSA (cm ²) ^z	Total fruit yield (kg/tree) ^z	Adjusted total fruit yield ^y (kg/tree)
		Dormant season	Summer season	Total			
1999	2	1.1	0.8	1.9	12.1	10.9	9.6
1999	8	3.2*	2.2*	5.4*	19.9*	20.6*	21.8
2000	2	2.1	0.8	2.9	9.0	37.5	31.8
2000	8	2.9*	1.0	3.9*	9.8	39.5	45.4
2001	2	1.9	0.8	2.8	11.6	31.4	35.7
2001	8	2.5*	1.1*	3.6*	11.1	43.0*	41.8
2002	2	5.6	0.5	6.2	7.4	24.1	24.3
2002	8	6.7	1.0*	7.7*	9.5	34.1*	33.9*
2003	2	5.6	0.0	5.6	11.8	36.7	38.1
2003	8	6.7	0.0	6.7	12.4	46.5*	45.4*
2004	2	4.3	2.9	7.2	13.6	38.4	38.5
2004	8	4.5	3.3	7.8	12.9	42.5*	42.8*
2005	2	4.5	0.0	4.5	8.1	25.5	31.2
2005	8	5.3	0.0	5.3	9.1	38.9*	44.1*
Cumulative	2	25.1	5.8	30.9	61.6	204.5	
Cumulative	8	31.8*	8.6*	40.4*	64.8	265.1*	

^z1 ft = 0.3048 cm, 1 cm² = 0.1550 inch², 1 kg = 2.2046 lb.

^yAdjusted means are estimated fruit weight from analysis of covariance using dormant season pruning weight/tree as the covariate and mean separation (n = 6) within year uses SAS (version 8.0; SAS Institute, Cary, NC) Proc PDIF at $P \leq 0.05$.

*Indicates significant difference within 1 year ($P = 0.05$).

Results and discussion

Dormant season pruning weight was reduced by the 2-ft VFA in the first 3 years of cropping (Table 3) compared with the 8-ft VFA. Summer pruning weights were reduced by the 2-ft VFA in the first, third, and fourth year of cropping. Total pruning weight was reduced by increased sod competition in the first 4 years of cropping. Subsequent years indicated no effect on vegetative growth due to increased sod competition. Cumulative pruning weights were significantly reduced by the 2-ft VFA treatment.

Annual increase in trunk cross-sectional area (TCSA) was reduced by increased sod competition in the first year of cropping and was unaffected in subsequent years (Table 3). TCSA at the end of the study was not significantly affected by the VFA treatments.

Canopy development was reduced by increased sod competition in the first year of cropping, which increased PAR transmission through the canopy and decreased hue angle or increased fruit red color (Table 4). In the second year of cropping, PAR levels were still greater with the 2-ft treatment at 75 and 100 cm from the tree, indicating reduced canopy development, but fruit color was

Table 4. Transmitted photosynthetically active radiation (PAR) levels beneath 'Autumnnglo' peach canopy and hue angle of fruit harvested for 1999 to 2001. Trees were planted in 1997.

Year	VFA width (ft) ^z	Transmitted PAR at four distances from the tree (%)				Fruit color (hue angle)
		25 cm ^y	50 cm	75 cm	100 cm	
1999	2	24	29	40	50	64
1999	8	12*	14*	21*	27*	71*
2000	2	16	18	26	34	57
2000	8	15	15	18*	21*	49
2001	2	17	21	26	33	59
2001	8	25*	22	23	35	61

^zVegetation-free-area; 1 ft = 0.3048 m.

^y1 cm = 0.3937 inch.

*Indicates significant difference within 1 year for the indicated distance from the tree ($P = 0.05$).

unaffected. In the third cropping year, canopy development was complete. The 2-ft treatment had increased PAR transmission at the 25-cm distance likely due to a reduction of suckers (Glenn and Welker, 1996) with no effect on fruit color.

The relationship between total fruit number and total yield was not significantly different for the VFA treatments in any year (data not presented), however, the total number of fruit per tree was reduced in all years and total yield reduced in 6 of 7 years (Table 3). Cumulative yield was reduced by the 2-ft VFA treatment (Table 3). Yield of fruit >3½ inches diameter was reduced by sod competition in 2 of 8 years and increased in

one year (Table 5) and similar to the results of Glenn and Welker (1996). Yield of fruit with diameters 3 to 3½ inches and 2½ to 3 inches was reduced by sod competition in 4 of 7 years, whereas yield of fruit <2½ inches was reduced by increased sod competition in 2 of 7 years. Analysis of covariance using number of fruit per tree as the covariate indicated that there was not a significant difference ($P = 0.05$) in total yield when adjusted for the number of fruit per tree in any year (data not presented). The lack of total yield difference when adjusted for fruit per tree suggests that the sod competition treatment was consistently reducing the fruit number per tree. Tworowski et al. (1997)

Table 5. Effect of vegetation-free area (VFA) width on 'Autumnglo' peach fruit size distribution and yield from 1999 to 2005.

Peach fruit size distribution											
		<2½ inches ^z diam		2½ to 3 inches diam		3 to 3½ inches diam		>3½ inches diam		Total yield	
Year	VFA width (ft) ^z	(no.)	Wt (kg) ^z	(no.)	Wt (kg)	(no.)	Wt (kg)	(no.)	Wt (kg)	(no.)	Wt (kg)
1999	2	2	0.1	11	1.5	44	8.5	3	0.8	59	10.9
1999	8	3*	0.3*	15*	2.0*	83*	16.6*	6*	1.6*	107*	20.6*
2000	2	22	2.4	101	13.9	114	21.2	1	0.1	237	37.5
2000	8	33	3.3	123*	16.1	120	20.1	0	0.1	277*	39.5
2001	2	8	0.9	27	3.9	137	26.6	7	1.9	172	31.4
2001	8	11	1.2	51*	7.2*	185*	34.5*	4*	1.2	247*	43.0*
2002	2	15	1.6	29	4.3	78	16.6	6	1.6	127	24.1
2002	8	13	1.5	25	3.9	108*	23.4*	18*	5.3*	164*	34.1*
2003	2	16	1.7	87	11.9	121	23.2	1	0.2	224	36.7
2003	8	32*	3.4*	137*	18.5*	129	24.6	0	0.1	298*	46.5*
2004	2	18	1.9	68	9.4	139	26.7	2	0.5	227	38.4
2004	8	25	2.6	76	10.5	150	28.7	2	0.7	253*	42.5*
2005	2	6	0.7	20	2.8	115	22.0	20	5.6	141	25.5
2005	8	9	1.0	35*	4.9*	174*	33.0*	19	5.4	218*	38.9*

^z1 inch = 2.54 cm, 1 ft = 0.3048 m, 1 kg = 2.2046 lb.

*Indicates significant difference within 1 year ($P = 0.05$).

demonstrated that sod proximity reduced N uptake and fruit number. However, in this study, peach leaf N levels were neither deficient nor different between treatments (Table 1) in all years except for the first year of cropping. Since trees were hand thinned after the June drop, it is likely that reduced floral shoot number in the 2-ft VFA was the source of the reduced crop load. Analysis of covariance may provide an explanation of the fruit number per tree effect. When dormant pruning weight is used as the covariate in the analysis of variance for total yield, the adjusted treatment yield, adjusted for pruning weight, is not significantly different in the first 3 years of cropping (Table 3). However, the adjusted treatment yield, adjusted for pruning weight, is significantly different in the fourth to seventh year of cropping. This pattern of differences corresponds with the significant treatment effect on dormant pruning weights and suggests that in the first 3 cropping years, dormant season pruning was removing equivalent floral shoot tissue and crop-bearing wood. However, in the subsequent years, dormant season pruning was removing a higher percentage of the crop-bearing wood from the 2-ft VFA treatment, resulting in reduced yield per unit of

dormant pruning. Canopy development of both treatments was equivalent in the third cropping year and the tree row space was filled (Table 4). This indicates that pruning practices must be modified to leave more bearing wood in mature trees to maintain yield potential when sod competition is used to control vegetative growth. In the 7 cropping years, cumulative yield and pruning weight were reduced by the 2-ft VFA treatment (Table 3). Establishing sod beneath peach trees, while an effective soil conservation practice that reduces herbicide usage, continues to increase risk of yield reduction unless traditional cultural practices are modified.

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