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Influence of Orchard Management Systems on Spur Quality, Light, and Fruit within the Canopy of 'Golden Delicious' Apple Trees

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Abstract. **Trees of 'Golden Delicious' apple (*Malus domestica* Borkh.) were established in 1973 in the following orchard management systems: slender spindle (SS), trellis (TR), interstem hedgerow (IH), and pyramid hedgerow (PH). Spur quality and percent photosynthetic photon flux (PPF) transmission declined from the top to the bottom of the canopy of all systems. The three conical central leader type trees (SS, IH, PH) produced a quarter of their fruit on or close to the central leader, while the palmette-shaped TR produced 60% in the center sections along the wire trellis. There was no difference between vertical fruit distribution in trees in the more intensive systems (SS, TR), but the larger trees (IH, PH) produced twice as much fruit in the top half of the canopy as in the bottom half. Trees in the SS had a lower percentage of PPF transmission values within the canopy than trees in the TR systems. Trees in IH generally had higher PPF transmission values within the canopy than the larger PH trees. The number of leaves per spur and specific leaf weight of spur leaves generally followed the light distribution pattern, and trees in the TR and IH systems had higher-quality spurs than the SS and PH systems. The SS and TR systems appeared more responsive to the orientation of the sun, having higher light transmission values on the east side of the canopy in the morning and west side in the afternoon, than the IH or PH systems.**

Palmer (1988; 1989) has shown a close association between light interception and dry matter production of apple trees in multirow beds. The dry matter was partitioned as follows: 65% in fruit, 23% in leaves, and 12% in the wood, framework, and roots (Palmer, 1988). Computer models have been developed (Jackson, 1980; Jackson and Palmer, 1972) that demonstrate the influence of different apple tree shapes and canopy sizes on light interception. Significant reduction of the light levels in apple canopies can reduce yield by reducing flower initiation (Cain, 1971; Jackson and Palmer, 1977); fruit set (Doud and Ferree, 1980); or fruit size (Heinicke, 1966; Barritt et al., 1987). Apple fruit color, soluble solids concentration (SSC), and firmness also depended on canopy light levels (Barritt et al., 1987; Doud and Ferree, 1980; Heinicke, 1966; Robinson et al., 1983). Recent work has shown the localized importance of spurs with large leaf areas, large buds, and high specific leaf weight (SLW) for good fruit set, satisfactory size, and high fruit Ca levels (Ferree and Palmer, 1982). Long-term yields of nine apple cultivars were correlated with spur quality (Rom and Ferree, 1984). Since yield of four cultivars in an 11-year study was influenced by the orchard management system (Ferree et al., 1989b), this study was conducted to determine the influence of management systems on spur quality, light distribution, and canopy position on fruit size, quality, and location.

Materials and Methods

Trees of 'Golden Delicious' were established in 1973 in four orchard management systems with north–south rows as described by Ferree et al. (1989b). Trees in the four systems had the following average canopy dimensions at maturity: SS—height 2.3 m, spread 1.6 m; TR—height 2.2 m, spread 1.1 m; IH—height 3.1 m, spread 2.8 m; PH—height 4.5 m, spread 4.5 m. In 1979, tree height of eight interior trees of each system was divided into thirds and fruit from each third was harvested separately and graded on an FMC weight-sizer and the number of fruit in each of the following size classes was counted: ≥8.0 cm diameter (box size 80–88s); 7.9–7.3 cm (100–113s); 7.2 – 5.7 cm (125–138s). The fruit was graded according to commercial standards and culled fruit removed and counted. The data were analyzed as a split-plot with systems as the whole-plot and canopy height as the sub-plot, with eight single-tree replications.

In 1980, the same trees were used and height divided in half and each half divided into thirds in both directions, giving a total of 18 sections. At harvest, fruit in each section were counted, harvested, and weighed and a sample of 10 fruit rated for color (1 = yellow to 5 = green); russet (1 = no russet to 5 = completely russeted); firmness measured with pentrometer; and SSC measured by refractometer. Light transmission as the canopy developed was monitored in the same eight trees of each system by taking a fisheye photograph at a tagged spur at the bottom of the canopy near the trunk beginning at full bloom with four subsequent times through mid-July. Light transmission through the photographs was measured and calibrated to percent sky values generated on a false color densitometer (Lakso, 1976).

Light transmission pattern was also measured in the same trees of each systems used above by placing a pole halfway between the trunk and branch tip on both the north and south sides of the tree. Tree height was divided in thirds and LI-COR quantum sensors were placed on the poles at the midpoint of each level for a total of six measuring points per tree. The sensors were connected to integrators (LI-COR 11-510) and left at each location for 24 hr. Since only 13 integrators were available, sensor placement was at random within each tree and it required 15 days to take all measurements in the eight replicate trees of each system. Measurements were taken in early Sept. 1979 and 1981 and percent PPF transmission was calculated as a proportion of unobstructed above canopy values measured with a sensor and integrator placed adjacent to the planting. In

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1981, the same procedure was used, except the poles were placed on the east and west sides of the tree. Additionally, in 1982, a LI-COR line quantum sensor (LI-191'SB) was held horizontally in a north–south direction at the same locations as the integrator on four dates chosen for uniform sunny light conditions in August, with spot readings taken in the morning (9:00–10:00 AM) and afternoon (3:00–4:00 PM) on four replicate trees of each system.

In 1983, The same eight replicate trees of each system were divided into thirds from top to bottom and through the tree both north to south and east to west, producing 27 canopy sections. A sample of three single, nonfruiting spurs were taken in August in the 15 sections in the four compass sides and center of each tree at each level. Terminal bud diameter, number of leaves, and leaf area were determined for each spur. The leaves were then dried and specific leaf weight determined.

The data involving divisions of the canopy were analyzed as a split-plot with systems as whole-plots and canopy position and level as the splits and, unless otherwise noted, with eight single-tree replications. Data presented as percentages were checked for normality and subjected to square root transformation before analysis.

Results

Results over the first 11 years (Ferree et al., 1989b) indicated that orchard systems had very little effect on fruit size compared to the effect of crop load. In 1979, trees in their 7th year on TR had a very large crop relative to tree size and tended to have a higher proportion of fruit in the smaller grades (Table 1). There was no interaction between management system and canopy level. The middle and bottom thirds had a higher proportion of fruit in size 2 and less in the smaller size 3. In total production, the top third had a higher total yield than either of the two lower levels.

An effort was made in 1980 to determine whether these trees with very different canopy sizes and shapes differed in the location where the fruit was produced. The three conical- (SS, IH, PH) shaped trees produced a quarter of their fruit on or close to the central leader when viewed from above the trees (Fig. 1). The palmette shape of the trellis resulted in nearly 60% of the fruit being produced in the center of the north–south rows along the wire on the main branches that were trained to it. A slight trend seemed to exist for more fruit on the east side, compared to the west, but no difference appeared between the north and south quadrants.

For fruit distribution, the interaction between systems and canopy height was significant (Fig. 2). There was no difference between vertical fruit distribution in trees in the more intensive systems (SS, TR), but the larger trees (IH, PH) produced twice as much fruit in the top half of the canopy as in the bottom half.

Generally, the apples were more yellow in the top half of the tree of all systems, with the greatest difference occurring in the IH (Table 2). Except for SS, fruit were less russeted in the top half of the tree. SSC was higher in apples from the top half of all the systems. Firmness was similar among systems in the bottom half, but fruit in the top half from the TR were firmer than those from PH trees.

Fisheye photographs were used in a attempt to characterize the amount of light transmitted by these canopies as they developed early in the season (Fig. 3). Very soon after bloom, the large PH trees transmitted less light than trees in the other systems, but, 2 weeks after bloom, these trees had relatively low percent sky values. Although trees in the TR and SS systems did not differ in size (Ferree et al., 1989b), SS trees transmitted significantly less light and, by the middle of July, were transmitting less than the larger IH trees.

Light integrators placed at six positions in the canopy in early September were used to determine if the systems influenced light distribution within the canopy. Of the supported systems, TR permitted higher light transmission than the SS trees and, in the free-standing systems, the open spreading canopy of the IH trees resulted in higher transmission values than in the larger PH trees (Table 3). As expected, light transmission was highest in the top third of the canopy and it decreased with increasing canopy depth. There was little influence of the systems on the pattern of light transmission in the north and south halves of the canopy. In 1979, the measurements were repeated in early July just as terminal growth stopped and the pattern of transmission and actual photosynthetic photon flux density (PPFD) values were similiar (data not presented). Fisheye photographs taken at bloom and later, after terminal buds formed, show the expected decline in percent sky with the increased canopy development. The large PH trees had lower percent sky values than the other systems after 22 May and the SS values were below the TR values in July.

Earlier studies (Rom et al., 1984) indicated north–south peach

Table 1. Fruit size distribution of 'Golden Delicious' apple trees in four orchard management systems at three canopy levels in 1979, the 7th year after planting.

Management systems	Fruit size category and distribution[z,y]										Yield per tree (kg)
	Percent					kg/tree					
	1	2	3	4	Cull	1	2	3	4	Cull	
Slender spindle (SS)	13.5 a	42.9	33.2	1.8	8.6 b	1.4 b	3.0	2.9 b	0.1	0.8 c	8.2 b
Trellis (TR)	4.7 b	37.7	40.9	6.5	13.5 a	1.1 b	19.1	9.9 ab	0.3	1.7 b	32.1 a
Interstem hedgerow (IH)	10.5 a	42.8	32.3	2.6	12.6 ab	3.3 a	7.2	4.4 ab	0.1	1.7 b	16.7 b
Pyramid hedgerow (PH)	9.3 ab	45.2	35.2	0.9	9.2 ab	3.7 a	18.8	12.1 a	0.1	2.8 a	37.5 a
Canopy level											
Top	8.4	34.3 b	44.5 a	2.6	10.1	3.9 a	15.1	12.5 a	0.3 a	2.9 a	34.7 a
Middle	8.6	44.5 a	34.8 b	2.6	10.4	1.8 b	9.5	7.6 ab	0.1 b	1.3 b	20.3 b
Bottom	11.6	47.1 a	26.9 b	3.6	12.4	1.5 b	14.9	1.9 b	0.1 b	1.1 b	19.5 b

[z]Size 1 = 8 cm and larger in diameter (80–88); size 2 = 7.9–7.3 cm (100–113); size 3 = 7.2–5.7 cm (125–138); size 4 = <72 cm.

[y]Mean separation within main effect columns by Duncan's multiple range test $P = 0.05$. Systems data are means of eight observations and canopy level are means of 32 observations.

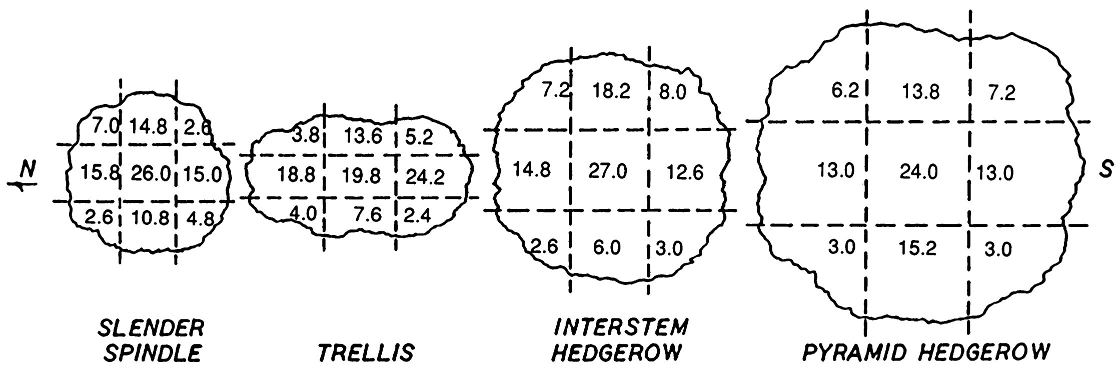

Fig. 1. Percentage of 'Golden Delicious' fruit in each canopy section of four orchard management systems viewed from above the canopy (1980). Systems × position interaction significant at P = 0.01. Each value is a mean of 16 observations.

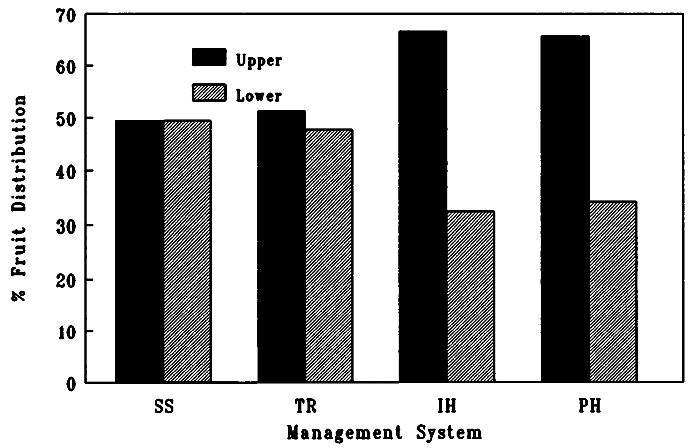

Fig. 2. Percent of 'Golden Delicious' fruit in the upper or lower half of the canopies in four orchard management systems (1980). Systems × level interaction significant at P = 0.01. Each value is a mean of 72 observations. SS = slender spindle, TR = trellis, IH = interstem hedgerow, PH = pyramid hedgerow.

hedgerows had more fruit on the east side, and there appeared to be a slight difference in this study (Fig. 1). Therefore, the light integrators were changed in 1982 to the east and west sides and additional spot readings taken to determine whether morning and afternoon differences existed (Table 4). Results from the integrated values indicate that the percent PPF transmission in the TR and IH systems were higher than in the SS system (Table 3). As found in other years, percent PPF transmission values declined in all systems from the top third of the tree to the bottom third (Table 3). Spot readings averaged over 4 days with uniform light conditions showed generally the same pattern as the integrated values among systems and canopy levels (Table 4). Generally, percent PPF transmission was higher in the afternoon than in the morning, with the exception of the IH and SS systems on the east side (Table 4). Light penetration in the SS and TR systems in this study appeared more sensitive to the orientation of the sun, being higher on the east side of the canopy in the morning and west side in the afternoon. The open canopy of the IH trees resulted in higher values of percent PPF transmission on the west side in both the morning and afternoon. The increase in afternoon values declined as the measurement descended through the canopy, especially in the large PH trees (Table 4).

Spur quality has been closely associated with fruit set, size, and Ca at harvest (Ferree and Palmer, 1982). One of the most important factors in the development of high-quality spurs is canopy light level (Barritt et al., 1987; Ferree and Forshey, 1988), and this study provided the opportunity to evaluate spur

Table 2. Fruit quality in the top and bottom canopy halves of 'Golden Delicious' apples trees in four orchard management systems, 1980.

Management system	Color[z]		Russet[z]		Soluble solids concn (%)		Firmness (N)	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Slender spindle (SS)	4.3	3.8	1.9	1.9	12.9	13.9	57.0	55.5
Trellis (TR)	4.6	3.8	2.2	1.9	12.0	12.7	56.3	57.8
Interstem hedgerow (IH)	4.7	3.1	1.9	1.3	12.5	13.5	56.7	55.9
Pyramid hedgerow (PH)	4.7	3.9	2.0	1.7	12.7	13.8	56.2	54.4
F tst of significance								
System	*		**		**		*	
Level	**		**		**		NS	
Position[y]	*		NS		**		NS	
System × level	*		*		NS		*	
System × position	NS		NS		NS		NS	

[z]Rating systems: Color 1 = yellow, 5 = green; Russet: 1 = no russet, 5 = completely russeted.
[y]Position: divisions into thirds in a north–south or east–west direction.
NS,*,**Nonsignificant and significant at P = 0.05 or 0.01, respectively.

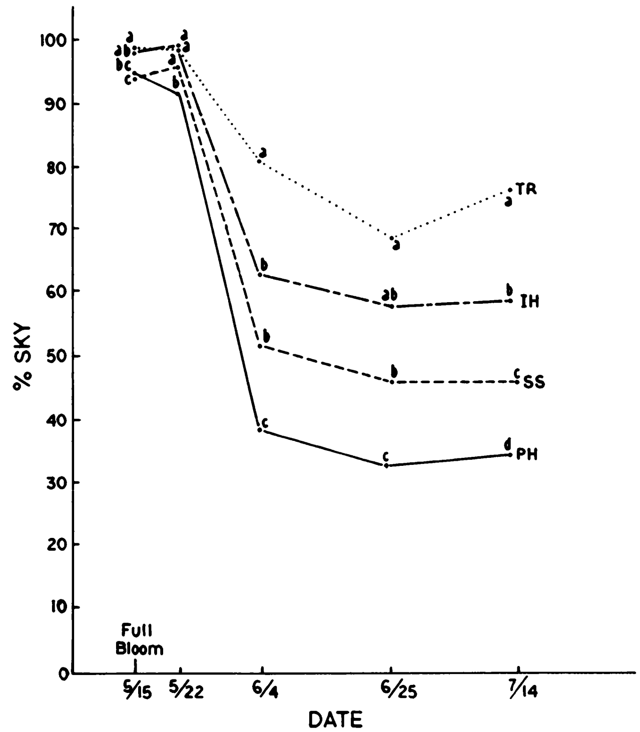

Fig. 3. Percent sky values from fisheye photographs during the first half of the season taken adjacent to a spur in the lower canopy of 'Golden Delicious' trees in four orchard management systems. Means of each date separated by Duncan's multiple range test, $P = 0.05$. Each value is a mean of eight observations. SS = slender spindle, TR = trellis, IH = interstem hedgerow, PH = pyramid hedgerow.

quality in different canopy positions of the four orchard systems. The number of leaves per spur declined slightly or did not change with increased depth of canopy in the SS or TR systems, but tended to increase lower in the canopy of the IH or PH systems (Table 5). Leaf area per spur was highest in trees in the PH systems and was not influenced by height of canopy. Specific leaf weight (SLW, $mg \cdot cm^{-2}$) declined with increased depth of canopy in all orchard systems and was particularly low in the bottom of the SS and PH systems, having a 29% and 35% decrease from top to bottom, respectively. Trees in the IH system tended to have the highest SLW, followed closely by the TR system and having only 20% and 21% drop in SLW values from top to bottom, respectively. Canopy position had less influence than canopy height on spur quality (Table 6). SLW tended to be lowest in the center of the canopy of all systems.

Discussion

The decrease in fruit size and quality from the top of the tree to the bottom found in this study (Tables 1 and 2) supports similar findings in other studies (Barritt, et al., 1987; Jackson et al., 1971; Jacyna, 1980) with trees that were 3 to 4 m tall and round or conical in canopy shape. Trees in this study ranged in height from 2.0 m (SS and TR) to 4.5 m (PH), and varied in shape from small cone (SS) to a medium (IH) and large cone (PH) or a narrow canopy palmette (TR). The interaction of tree height and orchard system was not significant. Thus, the relationship of declining fruit size through the canopy appears to be consistent through a range of tree sizes and shapes.

Apple fruit size, quality, and yield have been closely associated with the level of light in the canopy (Barritt et al., 1987; Cain, 1971; Doud and Ferree, 1980; Heinicke, 1966; Jackson and Palmer, 1977; Robinson et al., 1983). Results from this study (Tables 1, 3, and 4) support the principle that areas of canopy that receive the most light are the most productive. More flowers (Cain, 1971; Jackson and Palmer, 1977), improved fruit set (Doud and Ferree, 1980), and improved spur quality (Tables 5 and 6 Barritt et al., 1987) are characteristically found in canopy areas with higher light levels and likely are related to improved fruit size, yield, and quality.

The rapid reduction of light penetration through apple canopies has been reported previously for hedgerows of central leader trees (Cain, 1973). The data in Fig. 3 indicate that, by 3 weeks after bloom and before terminal buds were formed, light levels are dramatically reduced and leveled off until at least mid-July, when the canopy was complete and terminal buds formed. The narrow canopy spread of the trellis trees and comparatively wide between row spacing may have artificially inflated the percent sky values for this system. Trees in the SS and TR systems did not differ in trunk cross-sectional area (Ferree et al., 1989b) but the TR and IH trees had 40% and 48% larger canopy volume per tree, respectively, than the SS. The SS trees received annual containment pruning after the 3rd year because of the close spacing; this pruning resulted in vigorous shoot growth at the

Table 3. Influence of four orchard management systems on canopy light distribution in September and percent sky in May and July of 'Golden Delicious' apple trees

Management system	Photosynthetic photon flux transmission (%) 1979 North Top	Middle	Bottom	1979 South Top	Middle	Bottom	1981 North Top	Middle	Bottom	1981 South Top	Middle	Bottom	Percent sky (1981) 14 May	13 July
Slender spindle (SS)	35.1	20.5	13.2	49.6	23.2	15.9	19.9	9.3	10.8	27.7	13.0	4.6	56.5 a	12.8 b
Trellis (TR)	54.2	27.9	21.6	59.9	32.2	22.9	22.5	28.7	13.6	40.8	13.9	19.1	62.6 a	30.8 a
Interstem hedgerow (IH)	40.1	25.0	21.4	47.0	32.9	33.3	55.7	28.8	9.4	56.8	44.1	21.6	57.3 a	20.6 ab
Pyramid hedgerow (PH)	35.9	24.2	17.5	42.6	31.0	15.8	29.1	12.6	10.3	32.7	15.3	4.4	42.3 b	10.6 b
F test significance														
System			**						**					
Canopy height			**						**					
North vs. south			NS						*					
System × height			*						NS					
System × north–south			NS						NS					

[z]Duncan's multiple range test, $P = 0.05$. Each value is a means of eight observations.
[NS,*,**]Nonsignificant and significant at $P = 0.05$ or 0.01, respectively.

Table 4. Influence of time of day on percent full sun values of selected canopy levels and positions in 'Golden Delicious' trees grown in four orchard management systems.

Management system	Canopy level						Canopy position			
	Top		Middle		Bottom		East		West	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
Slender spindle (SS)	59.9	70.2	25.4	42.1	12.5	7.9	36.3	35.7	28.9	51.2
Trellis (TR)	58.0	70.8	37.1	50.3	22.4	31.9	51.5	36.9	26.8	65.1
Interstem hedgerow (IH)	54.4	85.1	34.4	62.8	22.8	31.3	42.2	50.0	32.2	69.5
Pyramid hedgerow (PH)	37.9	58.1	14.2	21.2	8.1	8.7	22.7	25.3	17.4	33.4
F test of significance										
System	**									
Level	**									
Time	**									
Position	*									
System × level	NS									
System × time	**									
System × position	NS									
Level × time	**									
Level × position	NS									
Time × position	**									
System × level × time	**									
System × level × position	NS									
System × position × time	**									
Level × time × position	NS									

NS,*,**Nonsignificant and significant at P = 0.05 or 0.01, respectively. Each value is a mean of 32 observations for levels and 48 observations for position.

Table 5. Influence of four orchard management systems and canopy height on non-fruiting spur quality of 'Golden Delicious' apple trees in 1983.

Management system	Leaves/spur			Leaf area/ spur (cm^2)			specific leaf wt. ($mg \cdot cm^{-2}$)		
	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom
Slender spindle (SS)	7.3	7.6	7.1	90	92	81	9.7	7.9	6.9
Trellis (TR)	8.6	8.6	8.3	86	86	89	10.3	8.8	8.2
Interstm hedgerow (IH)	8.0	8.5	8.4	92	100	96	10.8	10.4	8.7
Pyramid hedgerow (PH)	6.0	7.6	7.9	113	125	132	9.8	7.7	6.4
F test significance									
System		**			**			**	
Canopy height		**			NS			**	
System × height		**			*			**	

NS,*,**Nonsignificant and significant at P = 0.05 or 0.01, respectively. Each value is a means of 40 observations.

Table 6. Influence of four orchard management systems and canopy position on spur quality of 'Golden Delicious' apple trees in 1984.

Management system	Leaves/spur					Leaf area/spur (cm^2)					Specific leaf weight ($mg \cdot cm^{-2}$)				
	North	South	Center	East	West	North	South	Center	East	West	North	South	Center	East	West
Slender spindle (SS)	7.4	8.1	7.7	7.3	6.3	80	104	92	81	74	7.0	7.4	7.0	7.7	7.9
Trellis (TR)	8.4	9.1	8.5	8.4	7.9	82	94	90	92	78	8.4	8.4	8.0	8.9	8.9
Interstem hedgerow (IH)	8.6	7.7	9.1	8.5	8.5	104	85	100	99	100	9.5	11.2	8.2	9.2	9.2
Pyramid hedgerow (PH)	7.6	7.7	7.7	8.0	8.1	133	122	126	133	126	7.0	7.5	6.4	7.2	7.1
F test significance															
System			**					**					**		
Canopy position			NS					NS					*		
System × position			**					**					NS		

NS,*,**Nonsignificant and significant at P = 0.05 or 0.01, respectively. Each value is a mean of 16 observations.

canopy periphery, which reduced light penetration through the canopy (Tables 3 and 4). Trees in the IH system had an open spreading canopy that allowed good light penetration into the lower areas of the canopy, which was contrasted with the relatively low PPF transmission values, particularly in the lower third of the canopy, for SS (Tables 3 and 4). These differences in light interception and distribution most were due primarily to the effect of the rootstock and interstem on tree growth and not to differences in pruning and training.

Reports on the early results of this trial (Ferree, 1980; Ferree and Hall, 1989) showed that trees had a high leaf area per unit of canopy height coupled with the largest number of fruit per 100 cm^2 of leaf area and the greatest yield per trunk cross-sectional area. Yields per hectare over the first 7 years did not differ between the TR and SS systems, even though the TR system had 48% fewer trees/ha (Ferree et al., 1989b). Certainly some of this efficiency was due to the improved light relations (Tables 3 and 4) and improved spur quality in the TR system (Tables 5 and 6).

When the physiological efficiency of trees in the free-standing systems in this trial was compared after the first 6 years of this study (Ferree, 1980), IH trees had more fruit per 100 cm^2 of leaf area, higher yield per trunk cross-sectional area, and higher cumulative yield than PH trees. The yields over 11 years were not different between IH and PH systems and the IH trees had a 43% greater production per unit trunk area than the PH (Ferree et al., 1989b). Light at various canopy locations was slightly higher in IH compared to PH trees, but the differences were marked in the south bottom area of the canopy (Table 3). Leaf area per spur and SLW were higher in nearly all canopy locations (Tables 5 and 6); the difference was particularly evident with the SLW in the south section of the IH system trees. Barritt et al. (1987) found that spur specific leaf weight had the highest correlation with apple fruit size and quality of all characteristics of spur quality they measured.

Rom et al. (1984) reported more fruit on the east side of north–south peach hedgerow and spur quality was higher on the east side of the large 'Starkrimson' apples on seedling rootstocks (Ferree and Forshey, 1988). In one year, but not another, 'Golden Delicious' had higher spur quality on the east side in several management systems (Ferree et al., 1989a). Jacyna and Soczek (1980b) reported that the east sides of hedgerows with alleyways up to 2.5 m wide receive more full sunlight than the west sides. They found that the differences in light intensity between the two sides of a hedgerow decreased with an increase in width of the alleyway. However, fruit quality was higher in fruit from the west side of the hedgerow (Jacyna and Soczek, 1980a). In the present study, although there was a slight trend toward more fruit on the east than on the west side (Fig. 1), no differences were obvious in percent PPF transmission values, spur quality, (data not presented). Generally, the difference from the top to the bottom of the canopy in light levels, spur quality, fruit distribution, or fruit quality. Mika and Antoszewski (1974) found no differences in photosynthetic efficiency expressed relative to fruit set or foliage area between the east and west side of north–south apple hedgerows.

Mike and Antoszewski (1974) found the highest photosynthetic rate on the east side of apple hedgerows at 8:00 AM and at 12:00 noon on the west side. They concluded that daily photosynthetic rate reaches its maximum before the maximum illumination, probably due to water deficit in the leaves. Ferree et al. (1989a) made measurements on 2 days in July and found a greater correlation of afternoon compared to morning light values with apple fruit size in several orchard systems in West Virginia. The higher light values recorded in the afternoon in the present study may have been due partially to the afternoon readings being taken 1.5 hr closer to solar noon, which occurs at ≈1:30 PM EST at Wooster, Ohio. A summation of hourly light values over the past 7 years from the OARDC weather station indicates that the hours before solar noon over the growing season received 5.3% more light than the hours after noon. In August, when measurements in this study were taken, morning averages were only 0.92% higher than those for afternoons over the 7 years. The SS and TR systems in this study and in the previous study (Ferree el., 1989a) seemed to be more sensitive to the orientation of the sun, the percent sun values being higher on the east side in the morning and the west side in the afternoon (Table 4). The open canopy of the IH trees resulted in higher values of percent PPF transmission on the west side in both the morning and afternoon.

Results of these studies confirm the importance of high levels of light in the fruiting zone for efficient apple production. The principle of declining light levels with descent through the canopy appears in trees trained as small palmette (TR) or various sizes of conical central leader trees (SS, IH, PH). Management practices, such as the containment pruning required on the SS trees, can have significant influence on canopy light levels and dramatically decrease early tree efficiency. Future orchard systems must incorporate rootstock and management practices that result in canopies that allow good light penetration and have a balance of moderate extension growth and strong spurs.

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Rootstock and Scion Influence Growth, Productivity, Survival, and Short Life-related Performance of Peach Trees

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Abstract. **Fifty-nine available combinations of 16 peach [*Prunus persica* (L.) Batsch] seedling rootstocks and four cultivars were evaluated for survival, growth, productivity, and peach tree short life (PTSL) performance of scions for 10 years (1975–1984). Rootstock influenced tree survival, cold and bacterial canker damages, root suckering, bloom date, degree of budbreak, and fruit yield. However, rootstock had little effect on bud density, fruit maturity and size, and time of autumn defoliation, and no influence on trunk circumference and bark gummosis. Cultivars differed in all characteristics except tree survival and canker damage. Tree survival was negatively correlated with budbreak, bloom date, cambial browning, *Pseudomonas* canker, suckering, and defoliation. Lovell rootstock had the best overall PTSL-related performance, while Siberian C had the worst. 'Derby' was the most desirable and 'Hamlet' the least of the four cultivars evaluated.**

Peach tree short life (PTSL) syndrome, also called peach decline or replant problem, causes rapid decline in tree survival and orchard longevity in the southeastern United States (Dozier et al., 1984; Ritchie and Clayton, 1981; Yadava and Doud, 1980a). PTSL is characterized by sudden collapse of new growth and premature death of peach trees, usually in late winter and spring. This disorder occurs most frequently on old sites with light soils and it is specific to peach (Dozier et al., 1984; Ritchie and Clayton, 1981; Weaver et al., 1974; Yadava and Doud, 1980b). The use of superior, resistant, and cold-hardy rootstock (RS) types appears to be the most economical and preferable way to reduce tree losses due to PTSL (Dozier et al., 1983, 1984; Yadava and Doud, 1978a, 1980a, 1980b; Zehr et al., 1976). Cold and bacterial canker (*Pseudomonas syringae* van Hall) are the most common factors that alone, or in combination, cause damage and PTSL death of trees (Dozier et al., 1984; Weaver et al., 1974; Yadava and Doud, 1978a; Yadava et al., 1978, 1984). Rootstock influences cold- and canker-related injuries to scions (Chaplin and Schneider, 1974; Dozier et al., 1984; Layne, 1976; Layne et al., 1977; Ormrod and Layne, 1974). This study was initiated to evaluate the influence of selected peach seedling RS on tree survival, growth, productivity, and PTSL performance of four peach cultivars in an effort to identify the desirable and hardy RS for use in the southeastern United States.

Materials and Methods

A planting of 590 peach trees was established in Mar. 1975 on a non-PTSL site at the USDA/ARS Research Station, Byron, Ga. The orchard site was prepared following local recommendations, but it was not fumigated. Peaches had not grown on the site for at least 15 years. Ten trees each of the four scion cultivars (CV) on 16 peach seedling RS were planted at a spacing of 5.5 × 3.7 m in a completely randomized design. There were actually 59 combinations because five CV/RS combinations were not available. Locally recommended cultural and management practices were followed; however, no post-plant fumigation or supplementary irrigation were provided. Data were collected at the appropriate times during each year until the end of 1984. Bud density was determined in February from counts of live buds/10 cm of wood, using terminal sections of five shoots from four sides and one from the center of trees. Degree of blossom and vegetative budbreak were rated simultaneously when the first tree in the orchard reached full bloom, using a 1 to 9 scale adopted from the S-97 Regional Peach Rootstock

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