J. Amer. Soc. Hort. Sci. 108(1):102–105. 1983.

Characterization of the Light Microclimate in Four Peach Hedgerow Canopies[1]

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Additional index words. summer tipping, *Prunus persica*

Abstract. **Light levels were estimated by hemispherical photography at 4 different times during the growing season, in 4 different peach [*Prunus persica* (L.) Batsch] hedgerow canopies: oblique fan, canted oblique fan, modified central leader, and open center. Greatest percentage of sky levels occurred in the area from above to 25 cm below the top of the canopy. There was little difference between canopy training systems except 1 m above the ground. Hedging improved the light microclimate in the canopies, but only within the top 25 cm. Spectral distribution determined in an open-center tree did not follow the general trend of total radiation. As shading increased, not all wavelengths were absorbed equally, resulting in a decrease of the visible to infrared ratio.**

Several tree fruit morphogenic and reproductive responses are affected by solar radiation. Shading reduces flower-bud development and fruit size, decreases quality and color, and reduces the number of new shoots and the fresh weight of the plant (1, 2, 7, 8, 18, 19).

Interception of light has been investigated in apple canopies for several years, but little research has been done with peaches. A wide range of cultural practices—such as spacing, pruning, training, and size control—can greatly modify light interception and the light regime in the canopy (11).

Increased yields have been associated with increased planting density (3, 17) and with increased light interception (10, 16). With judicious pruning and summer tipping to train and restrict growth, tree walls can be formed and plant density can be increased to permit efficient management of the orchard. Although commercial growers are increasing the number of trees per hectare by adopting the tree-wall system, data concerning light interception and light distribution in high-density tree-wall plantings are needed so that the most ideal balance of light interception and exposure in a training system can be utilized.

The objectives of this study were: a) to characterize the light microclimate in the bearing surface of 4 training systems of peaches (oblique fan, canted oblique fan, modified central leader, and open center); and b) to determine the spectral distribution of solar radiation within the canopy of an open-center tree.

Materials and Methods

Culture, training system, and percentage of sky determinations. 'Olinda' peach trees on 'Siberian C' rootstock were planted in 1969 in four hedgerow systems: oblique fan (OF); canted oblique fan (COF); modified central leader (MCL); and open center (OC). Each training system was represented by a single row of trees oriented north to south, with in-row spacing of 4.9 m (OF), 2.4 m (COF), 3.0 m (MCL), and 4.3 m (OC) and row spacing of 3.6 m between OF and COF, 5.5 m between COF and MCL, and 6.1 m between MCL and OC. From 1974 to 1979, tree walls were maintained to a uniform height of 3 m and tree-wall widths of 1.5 m (OF), 2.0 m (COF), 3.0 m (MCL), and 3.0 m (OC) by mechanical hedging using a Durand Wayland Tree Topper and Hedger in mid-July. In 1979, dormant pruning consisted of removing only the dead wood, and trees were summer-hedged on July 12. Vegetative growth was permitted to fill the available space within the row.

Fisheye, or hemispherical, photography was used to estimate the radiation microclimate in 1979 within tree canopies using a technique similar to that of Lakso (13), except that percentage of sky was determined by measuring transmission of light through the negative. In 1978, the radiation determinations were taken with a Lambda PAR meter. Full sun readings were taken above the tree canopies, and percentage of full sun determined as follows:

$$\%\text{ full sun} = \frac{\text{PAR reading (in canopy)}}{\text{PAR reading (full sun)}} \times 100.$$

Determinations were taken at about solar noon throughout the 1978 and 1979 seasons on bright, sunny days. Since 1978 and 1979 data were similar, only the more detailed 1979 observations will be reported in depth. Unless otherwise indicated, data are expressed as:

$$\%\text{ sky} = \frac{\text{Sky (in canopy)}}{\text{Sky (full sun)}} \times 100.$$

Three trees in each treatment were selected in 1978 and 3 different trees in 1979. Nine positions were selected in 1978 and 15 in 1979 in each tree as illustrated (Fig. 1). The same positions were used throughout the season—i.e., the peripheral positions did not move with the expanding canopy. Care was taken to avoid biasing the results due to sunflecks, but they were not accounted for when readings were taken.

[1]Received for publication April 21, 1982. Michigan Agricultural Experiment Station Journal Article No. 10302.

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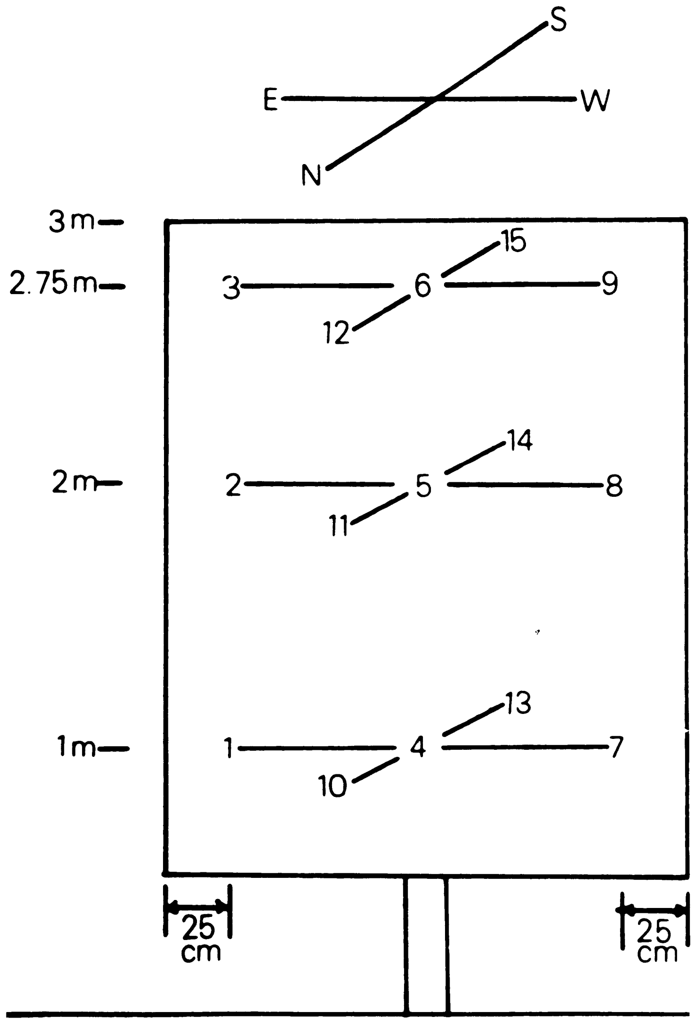

Fig. 1. Location of percentage of sky readings in trees. Positions 1 to 9, 1978; positions 1 to 15, 1979.

Spectral distribution. Spectral distribution of global radiation was determined between 1300 and 1500 HR on Aug. 30, 1979, with a spectroradiometer (ISCO Model SR, Lincoln) at 1, 2, and 2.8 m above ground in the center of three 'Harken' trees (6 yrs old, 3 m high) on Siberian C rootstock and trained to an open center.

Results

Effect of time, training system, and hedging on percentage values within canopies. Shading increased with foliage development (Table 1, 2, Fig. 2). Before hedging (June 3–4 and June 27) the area with the greatest percentage of sky values for all treatments was the upper 25 cm (Fig. 2). On June 3 and 4 more light was recorded at the 1-m level than at the 2-m level in all treatments except COF. The only treatments on June 27 with more light at 1 m than at 2 m were MCL and OC. On June 3, 5% less light was recorded at the 1-m than at the 2-m level in COF; this was significantly less (P = 5%) than the other 3 treatments—differences between training systems were not significant at 2 or 2.75 m. On June 27, percentage of sky values were lower in each training system at all levels; the OC treatment had significantly more (P = 1%) light than the other 3 treatments at the 1-m level, but differences between training systems at other levels were nonsignificant.

Six days (July 18) after hedging, no regrowth had started. The percentage of sky values did not differ significantly at the 2.75-m and 2-m levels for all treatments, but at the 1-m level MCL and OC had significantly higher (P = 5%) percentage of sky values than did OF (Fig. 2, July 18). Only the MCL treatment had higher percentage of sky values at the 1-m level than the 2-m level.

Forty days after hedging (Fig. 2, Aug. 21), the zone with the greatest percentage of sky values was again the upper 25 cm. When compared with July 18 determinations, considerable regrowth had occurred, and percentage of sky values were lower in all areas of the canopy regardless of training system. Significantly less (P = 5%) light was recorded at the 2-m and 1-m levels in the OF system than in the other 3 treatments. When compared with prehedging determination, percentage of sky values were higher 40 days after hedging in the upper 25 cm than on June 27. For all dates, at the 1-m and 2-m levels for all training systems, there was very little difference between percentage of sky values in the outside 25 cm of the canopy and values in the center of the tree (Table 1).

Spectral distribution of light. As canopy depth increased, absorption of radiation of all wavelengths decreased but not equally (Table 2). Light of 400 nm penetrated least and near-infrared

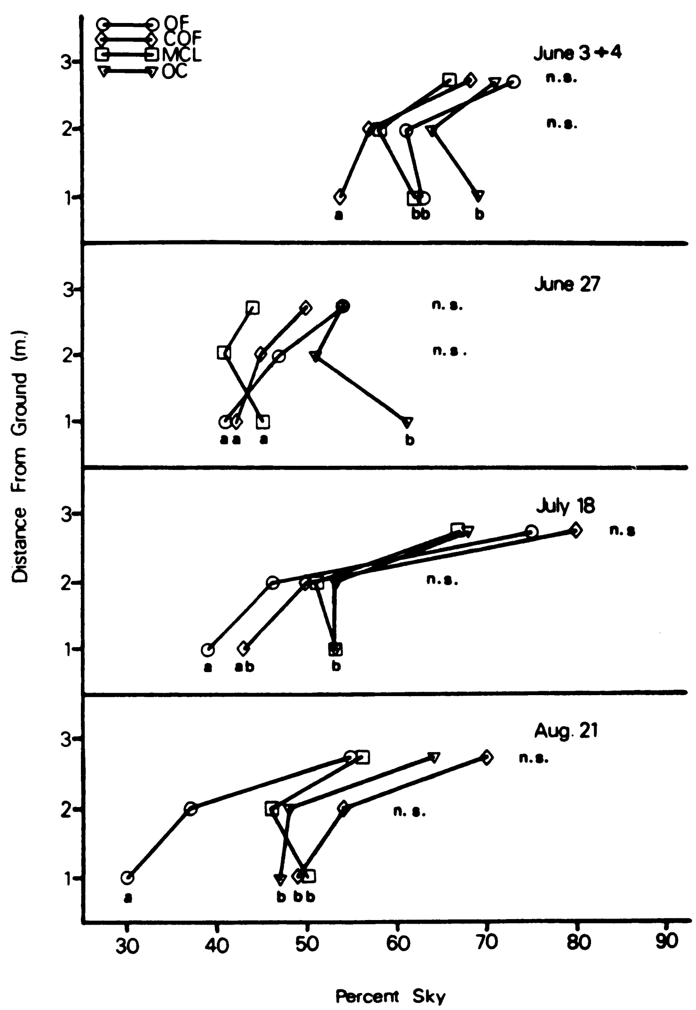

Fig. 2. The effect of hedgerow training system—oblique fan (OF), canted oblique fan (COF), modified central leader (MCL), and open center (OC)—on mean percentage of sky values at different heights from the ground for 4 different dates during the 1979 growing season. Trees were summer-hedged July 12, 1979. Mean separation within a date by Duncan's multiple range test, 5% level.

Table 1. Percentage of sky determinations at different locations[z] within 4 peach training systems at 4 different dates.

Height[y] (m)	Oblique fan					Canted oblique fan					Modified central leader					Open center				
	N	S	C	E	W	N	S	C	E	W	N	S	C	E	W	N	S	C	E	W
June 3 & 4																				
2.75	87	86	60	60	72	65	66	71	72	65	66	77	58	75	54	68	74	77	65	70
2.00	60	66	56	57	64	55	60	57	57	56	65	60	56	45	62	62	72	63	57	67
1.00	55	76	56	59	70	55	51	56	56	51	60	70	54	59	67	68	74	72	62	70
June 27																				
2.75	58	64	52	38	57	58	55	48	53	34	44	54	37	44	42	37	67	54	54	56
2.00	38	53	45	42	55	49	48	42	39	46	43	47	34	28	55	48	60	49	44	56
1.00	37	48	33	39	46	48	54	41	34	31	51	50	38	37	47	56	67	61	57	64
July 18[x]																				
2.75	69	73	71	78	86	90	85	98	78	49	70	66	64	69	68	59	63	76	91	49
2.00	38	45	55	39	54	62	51	46	43	50	55	47	45	37	72	41	50	54	53	67
1.00	37	48	33	32	43	43	47	44	53	30	56	59	42	50	60	44	56	61	43	62
Aug. 21																				
2.75	67	53	42	40	75	89	68	88	56	51	41	52	43	74	68	43	66	86	64	61
2.00	34	40	36	36	40	55	49	46	65	54	42	46	38	40	62	44	53	47	46	51
1.00	26	38	27	27	34	39	67	37	48	54	52	54	41	44	60	41	45	48	47	35

[z]Percentage of sky determinations were 25 cm from the edge of tree, except the center. North (N), south (S), center (C), east (E), and west (W) locations are the mean of 3 trees.
[y]Height from ground. Tree height was 3 m.
[x]Trees were summer-hedged July 12.

(750 nm) most. The area of greatest absorption occurred between 2 and 2.8 m above the ground.

Discussion

Proctor et al. (18) observed that little absorption of light occurred on the periphery of apple trees and that the zone of greatest absorption occurred between 1 m and 2 m from the tree top. This differs from our findings with peach tree walls, where the greatest absorption occurred in the outer 25 cm (Fig. 2, Table 1). Continual hedging resulted in the formation of dense growth at the top of the tree which absorbed a high percentage of light. This would normally be thinned out during dormant pruning, but in 1979 only dead wood was removed. This emphasizes the importance of careful dormant pruning, or the use of a hedging practice that removes wood at different levels to permit proper light penetration into the hedge. In 1978, the trees were properly thinned out during dormant pruning.

Table 2. The effect of peach vegetation at different canopy heights on the spectral distribution of global radiation under sunny conditions.[z]

Wavelength (nm)	Global radiation above tree (μW cm^{-2} nm^{-1})	Spectral distribution of global radiation (% of radiation above tree) Distance from ground: 1 m	2 m	2.8 m
400	48.3	23.4	25.9	68.4
450	62.0	38.7	31.0	83.8
500	75.5	32.0	34.1	78.7
550	71.0	33.5	38.9	88.6
660	64.5	39.3	35.9	87.2
675	70.5	25.4	39.0	77.7
730	52.9	38.7	42.6	82.0
750	55.8	60.7	60.2	88.4

[z]Determined between 1300 and 1500 HR, Aug. 30, 1979, in the center of 3 'Harken' trees (6 yr old, 3-m high) on 'Siberian C' rootstock trained to an open center. Mean for 3 trees.

The hemispherical lens used is an equidistant projection lens, and can give higher percentage of sky than percentage of full sun values because of the canopy gaps near the horizon (13). However, in this study there was good agreement (r = 0.88) between percentage of sky and PAR values for sunny cloudless days.

In some cases, the 1-m level had higher light values than the 2-m level. Similar results have not been reported for apples or other crops. Increased light at these lower levels could be attributed to the formation of few new branches at this level, which when present are usually removed during dormant pruning. Increased diffused light or opening of the canopy due to branch bending from fruit load could account for some of the increase in light values.

In the COF treatment the lowest readings occurred on June 27. The reading increased after hedging and even continued to increase at the 2-m and 1-m levels on Aug. 21. The tree architecture, combined with the fruit load later in the season, opened the canopy and increased light penetration late in the season at the middle and bottom of the canopy.

OF had the lower light levels in some cases, especially later in the season, and OF was the narrowest tree wall at 1.5 m. This is not so surprising when the leaf area index (LAI) is considered. Unpublished data (Gaynor, personal communication) for these training systems indicates mean LAI for 3 years (1975–77) of 4.57 for OF and 2.92, 3.30, and 2.96, respectively, for COF, MCL, and OC. Heinicke (5) determined that a LAI of about 4 to 5 was about the maximum which would allow sufficient light for the maximum photosynthetic rate to strike all foliage. In later work, he (6) reported LAI for apple trees in 4 size groups as follows: standard, 3.56; semi-standard, 3.09; semi-dwarf, 3.52; and dwarf, 2.94.

When peripheral readings are compared with center readings at all levels and in all treatments, there were no striking differences in light interception within the canopies (Table 1). The lowest reading (25%) occurred August 21 at the 1-m level on the north side in the OF treatment (Table 1). The greatest decrease in most cases occurred from outside the canopy to the peripheral zone, 25 cm inside the canopy. This would suggest that most of the growth occurs in the peripheral zone of peach trees, with very little in the center of the tree; this was supported by general observations. Thus, simple hedging alone will not completely "open" the tree to increase light penetration. The use of a slotted saw (1) or careful dormant pruning would be required to increase light levels in the center of the canopy.

The 4 training systems were relatively efficient in light interception. The light level required for flower-bud initiation in apples is about 30% of full sun (1, 5, 9). Light levels during flower-bud initiation were above this level in our study (the optimum level for peach has not been determined), except for the June 27 determination (2.0 m, E) in MCL where the reading was 28% sky (Table 1). Percentage of sky determined with an equidistant lens (13) underestimates shading. Therefore, light levels for all treatments were likely sufficient for flower-bud initiation within the primary bearing surface until late in the season.

The changes in the spectral distribution within the open-center canopy agreed with reports of others (4, 18). In addition, Lakso (14) has determined that changes in the 660/730 nm ratios in an apple tree closely correlated to fisheye percentage of sky changes. Federer and Tanner (4) suggested that varying light quality may have affected growth and photoperiod response, while Proctor et al. (18) suggested that color development in apple was dependent on a required spectral distribution. Lavee and Erez (15) concluded that light in the 600–690 nm range was needed for leaf bud burst in peach and that small amounts in the 500–600 nm range enhanced flower-bud opening. Major light quality changes in peach occur with shading, but the effect that this change has on vegetative morphology and on growth and development of the fruit has not been resolved.

Lakso (14) concluded that fisheye photography could be used to evaluate canopy densities in relation to the physical light climate and to biological resources such as flowering and fruit coloration in apple. Kappel (12) found that for 'H420' on 'Siberian C' that fruit maturity increased with percentage of sky but decreased with fruit number, and that percentage of sky and fruit number accounted for only 40.7% of the variation in maturity, indicating that factors other than percentage of sky have a very significant influence on fruit maturity.

Light interception and light levels are very important in fruit production, and determination of light interception patterns is essential in developing training systems and orchards for the future. However, training system had little effect on light distribution in the fruiting zone of peach in this study. The OF system gave the highest yields in 1979, and the highest or second highest yields in 1973 to 1978, with accumulated yields for 1973 to 1979 of 124.6 (OF), 104.2 (COF), 110.6 (MCL), and 92.2 (OC) metric tons per hectare (Layne, unpublished). In hedgerow systems, training within the row may not be as important as the relationship between rows and tree height which strongly influences total light interception per hectare (11). Recent research (10) indicates that production of apple appears to be directly proportional to the light interception; the same may be true for peach. However, in our study neither total light interception per hectare nor between-row shading was considered because of the experimental design employed. To resolve the relationship between light interception and production on a land-area basis, more extensive studies must be conducted where training and rootstock/scion combination are managed in a consistent manner while tree density is varied.

The specific percentage of sky requirement, or light requirement for flowering, fruit maturity, fruit growth, and vegetative development, have not been reported for peach. In apple, Lakso (14) found that about 15% sky was required to maintain good flowering and that fruits appeared to have "acceptable" red color at values of 25 to 30% sky or greater. The relationships between light levels and fruit-bud formation, fruit set, and fruit growth thus need to be determined carefully for peach, before they can be related to tree shape and orchard design.

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