THE EFFECT OF ROW ORIENTATION ON LIGHT DISTRIBUTION IN HEDGEROW PEACH TREE CANOPIES

T.M. DeJong
Pomology Department
University of California
Davis, California, U.S.A. 95616

J.F. Doyle
Pomology Department
University of California
Davis, California, U.S.A. 95616

Abstract

An electronic micro-datalogger coupled with light sensors designed to measure photosynthetic photon flux density (PPFD) was used to investigate the effect of row orientation on canopy light distribution in commercial hedgerow peach orchards planted in central California. Sensors were placed at specific levels along the vertical face of the hedgerow canopies and data were recorded every ten seconds over 24-hour periods. The amount of light intercepted by sensors on the east and west sides of the north-south-oriented hedgerows was similar. The sensors on the north side of the east-west-oriented hedgerows intercepted less than half the light that was intercepted by the sensors on the south side. However, the total amount of light intercepted by all the sensors on the east-west-oriented hedgerows was not significantly different from the amount intercepted by sensors on the north-south hedgerows. The distribution of fruit appeared to be more closely related to measurements of light distribution in the north-south-oriented hedgerows than in the east-west-oriented hedgerows.

1. Introduction

Several research groups have investigated the subject of optimum hedgerow orientation for orchard systems with differing results. Using theoretical computer simulations, Cain (1972) and Jackson and Palmer (1972) showed that in most cases light would be distributed more evenly and absorbed more efficiently in north-south compared to east-west-oriented hedgerows at latitudes between 34 and 51.3°N. Using tree models and photographic methods, Ferguson (1960) indicated that for late-harvested apples at relatively high latitudes the east-west row orientation would be preferable. Jackson (1980) suggests that the differences between Ferguson's conclusions and those of Cain (1972) and Jackson and Palmer (1972) are due to differences in the model tree heights, row widths, and apple varieties the researchers were considering. Russian workers have also indicated that east-west-oriented hedgerows would be more efficient than north-south hedgerows (Devyatov and Gorny, 1978, 1980).

Because of the problems involved in making continuous light measurements at numerous locations over extended periods of time, there is very little actual field data available on light distribution characteristics in hedgerow orchard canopies and there is virtually no field data available for peach hedgerow canopies. The purpose of this research was to conduct a comparative study of mid-summer canopy light distribution characteristics in commercial, mature peach tree canopies in a major California fruit growing district.

2. Materials and methods

The commercial orchards used for this study were located approximately 15 km south-east of Fresno, California (36° 40'N, 119° 40'W). In 1982, measurements were made on adjacent, Autumn Gem peach and Fairlane nectarine orchards that were under the same management. Both orchards were planted on Nemaguard rootstock, had row spacings of 4.2 m with 2.4 m between trees in the row, and were vertically and horizontally pruned so that the height of the hedgerows was approximately 4.5 m and the width was approximately 1.5 m. Both orchards were mature, drip-irrigated and receiving routine commercial horticultural care. Both fruit varieties are relatively late maturing, with Fairlane nectarine being harvested in late August and Autumn Gem peach in mid-September.

In 1983, light distribution measurements were made in a single O'Henry peach orchard that had part of its rows oriented in a north-south direction and another part in an east-west direction. The trees in this orchard were also on Nemaguard rootstock and were planted and maintained in a manner similar to those trees used in the 1982 study. O'Henry peach is harvested in early to mid-August.

Canopy light distribution measurements were made using custom-built, cosine-corrected light sensors similar to those described by Biggs et al. (1971) for measuring photosynthetically active radiation at wavelengths between 400-700 nm. Each sensor was individually calibrated with a LI-COR LI-190S quantum sensor and LI-185 quantum meter. In 1982, 12 light sensors were simultaneously monitored with two micro-dataloggers (CR-21 Microloggers, Campbell Scientific, Inc.). The microloggers were programmed to scan each sensor every ten seconds and log the data as a frequency distribution to determine the amount of time each sensor was exposed to sunlight within a specific range of quantum flux densities. For the field measurements the specified ranges of quantum flux densities were, <100, 101-300, 301-500, 501-700, 701-900, 901-1100, 1101-1300, and >1301 µmol m^{-2} s^{-1}. However, for the purposes of this report the data have been summarized into four ranges: <100, 101-700, 701-1300 and >1301 µmol m^{-2} s^{-1}.

In 1983, light distribution measurements were made using a total of 14 sensors simultaneously and the microloggers were programmed to log the mean PPFD that each sensor was exposed to for two-hour intervals throughout the day.

In 1982, the six light sensors were mounted on each of two vertical frameworks so that light sensors were spaced at 0.7 m intervals up the two opposite vertical surfaces of a hedgerow canopy. Light measurements were made on six clear sunny days in late July in each row orientation and the frameworks holding the sensors were moved approximately 1.2 m down the hedgerow between each measurement day. In 1983, measurements were made using frameworks similar to 1983 except that seven sensors were placed at 0.6 m intervals up the two vertical faces of the hedgerow canopies. Due to problems with cloudy weather, light measurements were made at five locations along the east-west hedgerows and three locations along the north-south hedgerows. In 1983, measurements were also made in late July and early August.

3. Results and discussion

Figure 1 shows the frequency light distribution data for the 1982 measurements in the north-south and east-west-oriented hedgerows, respectively. These data indicate that the lower sensors are exposed to PPFD above 100 $\mu mol\ m^{-2}\ s^{-1}$ for only short periods of time in both hedgerow systems. The south side of the east-west-oriented hedgerow appears to be exposed to PPFD above 700 $\mu mol\ m^{-2}\ s^{-1}$ for greater amounts of time than the north side. However, the upper sensors on the north side are exposed to greater amounts of time at PPFD between 100 and 1300 $\mu mol\ m^{-2}\ s^{-1}$. The lowest sensors in the east-west hedgerow were exposed to PPFD >100 $\mu mol\ m^{-2}\ s^{-1}$ for substantially less time than in the north-south planting. The variations in light exposure between the two sides of the north-south hedgerow are inconsistent and are probably due to the placement of the sensors into the vertical walls of the canopies relative to surrounding leaves and branches.

Figure 2 contains the two-hour mean light distribution data from the O'Henry peach trees in 1983. These orchards and methods of expressing the data more clearly show expected differences between the south and north side of the east-west-oriented hedgerows. Although the north side of the east-west hedgerow receives slightly more light than the south side in the early and late part of the day, the south side is exposed to substantially more light during mid-day at all sensor levels. The total amount of light received by each side of the north-south oriented hedgerows is much more similar than in the east-west hedgerows. The main differences between the two sides is the time during the day that either side is exposed to the direct light. The differences in amount of light received by two sensors at a given level in the north-south hedgerow may be primarily due to variations in the distribution of leaves along the vertical hedgerow surface that cause intra-canopy shading.

The data shown in figure 2 can be used to calculate the mean total daily PPFD for each sensor at each canopy location (figure 3). The total amount of light received by sensors on the north side of the east-west hedgerow was always less than that received by sensors on the south side. This was true even for the highest sensors because they were vigorously growing shoots that extended above these sensors. By comparing the total length of the horizontal bars in figure 3, it is clear that in the 1983 experiments, there were relatively small differences in the combined total amount of light received by a pair of sensors at a given level in either hedgerow orientation. The main difference is in how evenly the light is distributed between both sides of a given hedgerow. The daily sum of the total PPFD received by all sensors was 224.7 moles m^{-2} day^{-1} in the north-south hedgerow and 237.7 moles m^{-2} day^{-1} in the east-west hedgerow. This again indicates that for this hedgerow system and time of year the major difference in light distribution between the two hedgerow types was not the total amount of light intercepted but the differences in uniformity of distribution.

This research is essentially in agreement with the modelling work of Jackson and Palmer (1972). For the time of the year and latitude that the present measurements were made, one could predict from their work that the total interception of direct light by the east-west oriented hedgerows would be very similar to the north-south hedgerows. Earlier in the season the east-west systems would be expected to intercept somewhat less light than the north-south systems and later in the season the situation would be reversed. The primary difference between the two orientations is apparently the uniformity of light distribution and not the total amount of light intercepted.

Fruit harvest data were obtained from the orchards of different row orientation in 1982 but not 1983. Since the 1982 study involved orchards with two different varieties, yield comparisons are irrelevant but there were some interesting differences between the two systems regarding fruit distribution. In the east-west hedgerow system the fruit were distributed almost equally between the top and bottom halves of the trees but the south side of the hedgerow bore substantially more fruit than the north side (table 1). In the north-south oriented hedgerows more than two-thirds of the fruit were in the upper half of the tree and substantially more fruit were located on the east side of the hedgerow than the west side. Although these fruit distribution data should be considered preliminary, they do indicate that in spite of the more uniform distribution of light over the north-south-oriented hedgerows the fruit is distributed less evenly than the east-west hedgerows. Further research needs to be done to verify these results and gain a better understanding of the factors controlling fruit distribution characteristics in these hedgerow systems.

References

Cain, I.C., 1972. Hedgerow orchard design for most efficient interception of solar radiation. Effects of tree size, shape, spacing and row direction. Search Agric. 2:1-14.

Devyatov, A.S. and Gorny, A.V., 1978. Effect of espalier orientation on light status and cropping of apple trees. Fruit Sci. Rep. 4:1-8.

Devyatov, A.S., and Gorny, A.V., 1980. The effect of hedgerow orientation on the rate of photosynthesis of apple leaves. Fruit Sci. Rep. 7:117-123.

Jackson, J.E., 1980. Light interception and utilization by orchard systems. Hort. Rev. 2:208-267.

Jackson, J.E., and Palmer, J.W., 1972. Interception of light by model hedgerow orchards in relation to latitude, time of year and hedgerow configuration and orientation. J. appl. Ecol. 9:341-358.

Ferguson, J.H.A., 1960. A comparison of two planting systems in orchards as regards the amount of radiation intercepted by trees. Neth. J. agri. Sci. 8:271-280.

Biggs, W.W., Edison, A.R., Eastin, J.D., Brown, K.W., Maranville, J.W., and Clegg, M.D., 1971. Photosynthesis light sensor and meter. Ecology 52:125-131.

Table 1 - Fruit distribution characteristics in the 1982 study orchards.

	East-West Hedgerows	
	North Side	South Side
% of total yield	40	60
% of yield in lower half of trees	55	51
	North-South Hedgerows	
	East Side	West Side
% of total yield	59	41
% of yield in lower half of trees	29	33

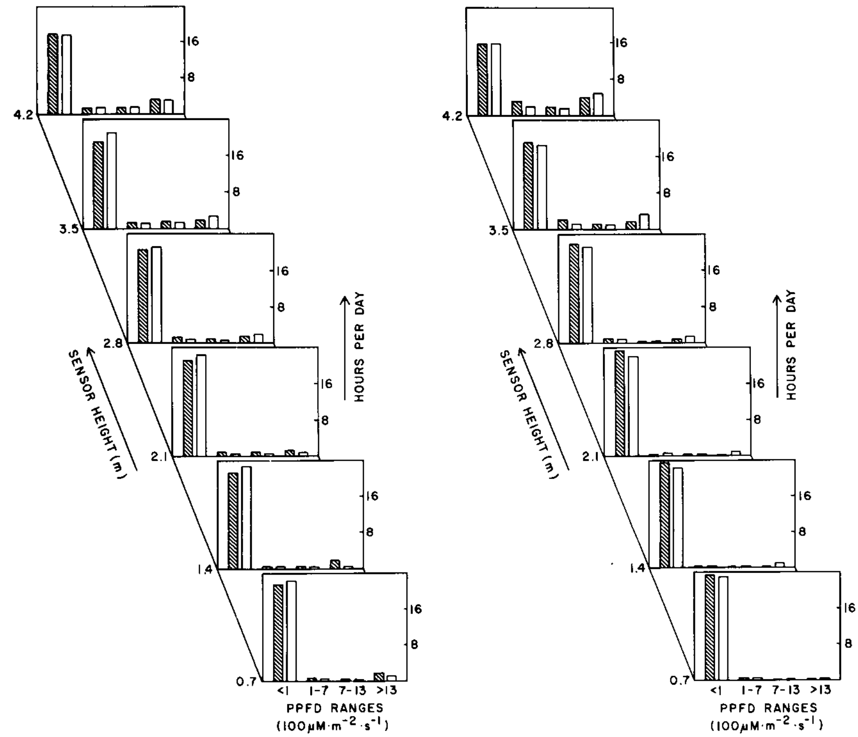

Figure 1 - Light distribution characteristics of north-south (left panel) and east-west (right panel) oriented hedgerows in the 1982 study. Vertical bars indicate the mean number of hours in a day that sensors at each height were subjected to a PPFD of a particular range during six clear days in late July. The shaded bars indicate sensors on the east and north sides of the hedgerows and the open bars indicate sensors on the west and south sides.

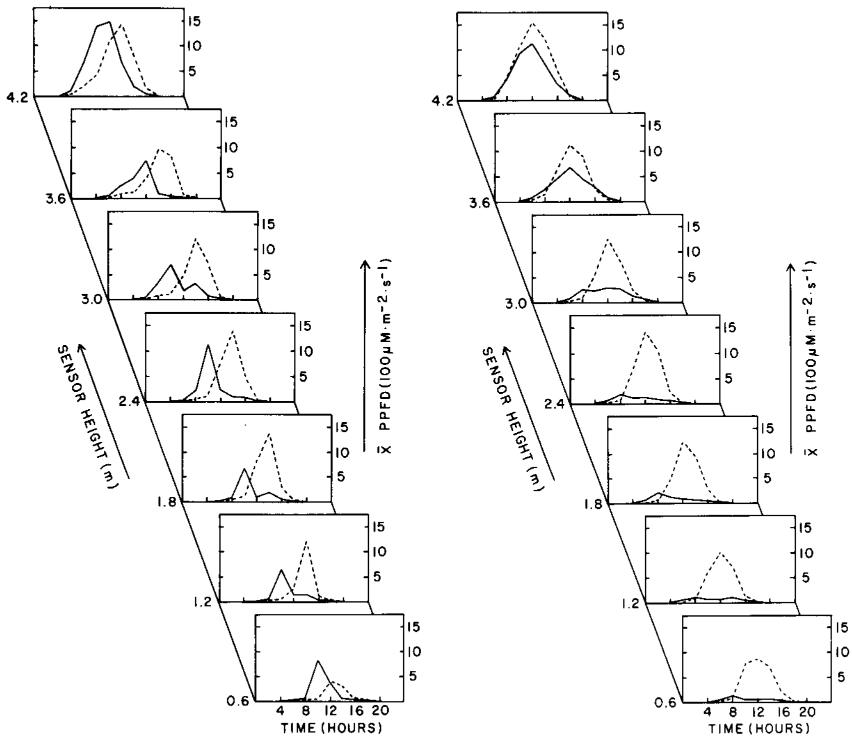

Figure 2 - Mean daily pattern of PPFD for north-south (left panel) and east-west (right panel) oriented hedgerows in the 1983 study (solid lines = east and north sides, dashed lines = west and south sides.

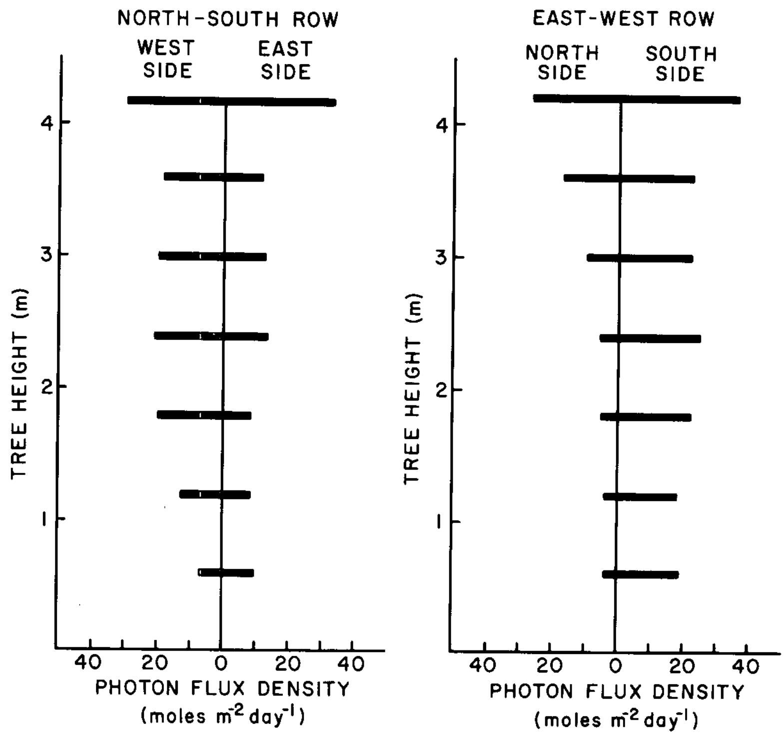

Figure 3 - Mean daily total PPFD for each sensor in the north-south (left panel) and east-west (right panel) oriented hedgerows in the 1983 study.