12.5.1?Sunlight interception

An upper limit on dry matter production by crops is set by the amount of visible radiation (400–700nm) intercepted (Monteith 1977). Horticultural crops, however, can rarely achieve 100% interception of sunlight because physical access is required year round for routine management operations such as spraying, pruning and picking. This is especially so for perennial fruit crops and vines, but is also the case for many annual greenhouse and vegetable crops that are repeatedly hand harvested. With a closed agronomic canopy such as a ?eld of wheat, light interception is largely determined by LAI. With discontinuous canopies such as an apple orchard, a ?xed LAI can intercept different amounts of light depending upon the display in space of discrete canopy units, namely individual trees or vines. (LAI for discontinuous canopies is calculated from the total area of leaves on the plant divided by the area allocated to the plant.)

Table 12.2 Effect of hedge height, row spacing and row orientation on calculated percentage light interception for a sunny day at Riwaka (Lat. 41° 6′S) for hedgerow apple orchards with an LAI of 2 on 31 January. Each hedgerow is 1.5 m thick at the base and 0.5 m thick at the top. All orchards have the same LAI, but they differ markedly in light interception

Hedge height (m)	Row spacing (m)	Row orientation	Interception (% sunlight)
1	3	NS	44
2	3	NS	50
4	3	NS	55
1	5	NS	32
2	5	NS	38
4	5	NS	47
1	3	EW	39
2	3	EW	42
4	3	EW	49
1	5	EW	27
2	5	EW	31
4	5	EW	38

(Original data courtesy J.W. Palmer)

[1]

Table 12.2 Effect of hedge height, row spacing and row orientation on calculated percentage light interception for a sunny day at Riwaka (Lat. 41° 6'S) for hedgerow apple orchards with an LAI of 2 on 31 January. Each hedgerow is 1.5m thick at the base of 0.5 thich at the top. All orchards have the same LAI, but they differ markedly in light interception

Light interception can be altered by changing spacing, tree height, tree shape and/or row orientation. An

illustration of this is given in Table 12.2 using a computer simulation model of light interception (Palmer 1989a). The model calculates light interception over a whole day and allows for change in incident radiation, sun angle (both elevation and azimuth) and sky light. The model was used to calculate light interception under sunny conditions by apple trees arranged in continuous rows, of truncated conical cross-section, in midsummer at Riwaka, Nelson, New Zealand. For a constant LAI, light interception increased by increasing hedge height, closer row spacings and planting in a north–south rather than an east–west orientation (Table 12.2). Light interception varied by a factor of two, from 27% by short wide-spaced hedges in east–west (EW) rows to 55% by tall close spacings in north–south (NS) rows. Differences due to row orientation will be smaller in cloudy regions where more of the incoming light is diffuse.

In Table 12.2 the density of leaves within the tree volume changes with height and row spacing to maintain a constant LAI. Differences in light interception would be much larger if leaf area density rather than LAI was maintained at a constant. Nevertheless, data given in Table 12.2 for discontinuous canopies show that the relationship between LAI and light interception depends on the physical arrangement of foliage in space. Calculations for Table 12.2 assume an extinction coef?cient suitable for apples. Light interception would have to be recalculated for other crops such as peach and cherry that have lower extinction coef?cients (Flore 1994).

As discussed in Section 12.3, the relationship between light interception (F) and LAI of a continuous canopy follows the Beer–Lambert Law, and can be approximated by Equation 12.8. Again, k (the extinction coef?cient) is dependent upon leaf angle distribution, leaf transmission to sunlight and whether the foliage is random, regular or clumped. k varies between about 0.3 for erect foliage and 1.0 for canopies comprising horizontally disposed leaves. In general terms,

$$F = 1 - e^{-k\text{LAI}} \quad (12.8)$$

Unlike closed canopy forests or a continuous crop cover, sunlight interception by discontinuous canopies consists of two parts, a fraction determined by the overall form and extent of the canopy (F_{max}) and a leaf area part that deter-mines how close a particular orchard approaches the maximum interception attainable. F_{max} would be reached if LAI was in?nite. Accordingly, Equation 12.8 can be rewritten for discontinuous canopies as Equation 12.9, where $L' = \text{LAI}/F_{max}$ (Jackson and Palmer 1979).

$$F = F_{max}(1 - e^{-kL'}) \quad (12.9)$$

[2]
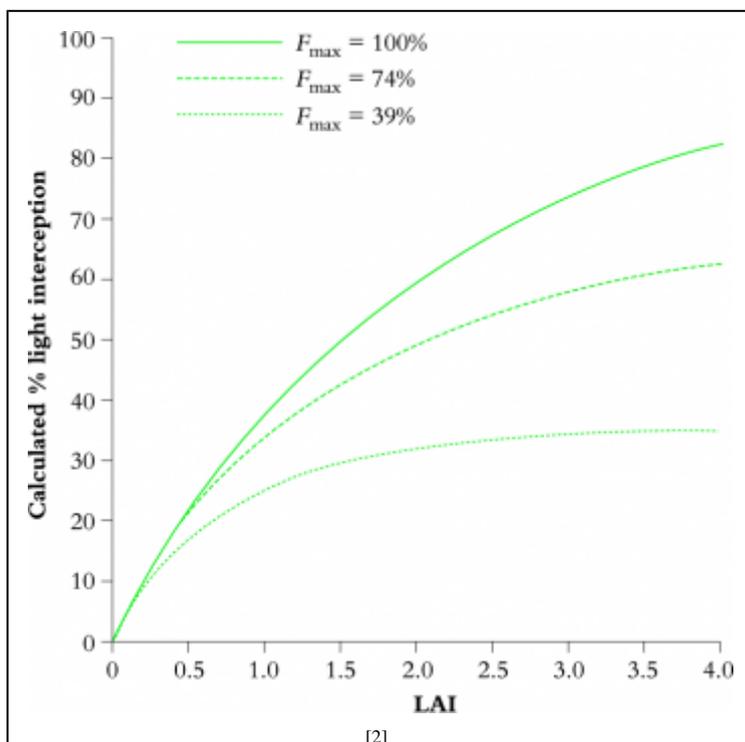
Figure 12.28 Calculated interception of sunlight as a function of LAI and canopy form. Light interception is calculated for a sunny day on 31 January at Riwaka, New Zealand (Lat. 41°6'S), for apply orchards arranged in continuous hedgerows. Orchards are either (a) a continuous canopy (F_{max} = 100%), (b) hedgerows 2 m tall, with 3 m row spacing, 1.5 m thick at the base and 0.5 m at the top (F_{max} = 74%) or (c) hedgerows 1 m tall, with 5 m row spacing, 1.5 m thick at the base and 0.5 m at the top (F_{max} = 39%). Note that light interception depends on both LAI and F_{max}, so that the same light interception can be achieved with a very different LAI or the same LAI can be rearranged to intercept a different amount of sunlight

(Original data courtesy J.W. Palmer)

This relationship for a discontinuous canopy contrasts with that for the continuous canopy (Equation 12.8) where an in?nite LAI would cause complete exclusion of light. When light interception by two of the orchards in Table 12.2 is plotted as a function of LAI (Figure 12.28) and compared with a continuous canopy with the same extinction coef?cient, light interception by either orchard approaches an asymptote well short of in?nite LAI. Light interception by discontinuous orchard canopies can be increased by increasing LAI, but a far more effective strategy is to increase canopy extent. Put another way, it is better to use orchard design to increase F_{max} and thereby intercept sunlight that would otherwise fall into clear alleyways, rather than intercept sunlight that had a good chance of being absorbed by other foliage. Knowing the physical dimensions of the canopy, F_{max} can be calculated from a mathematical model. F_{max} for complex shapes can be determined from CAD graphics.