# Light Management during Cutting Propagation in New Zealand©

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## INTRODUCTION

Propagation of cuttings with sunlight as the sole light source is the most common situation in commercial plant nurseries. In that situation, greenhouse shading is the most important factor to manage in order to ensure that light is in an acceptable range for rapid root and shoot growth. When excess shade is applied, light is limiting to photosynthesis and growth. In contrast, excess light is likely to result in dehydration and heat stress of plants.

Studies in both commercial and research settings provide guidelines for lighting during propagation. The objective of this article is to provide light-level guidelines, and show how ambient light levels in New Zealand affect shading strategy. These guidelines must be adapted to local climate conditions, depending on whether high light leads to excessively warm air and plant temperature, and a resulting need to mist frequently or open vents and lose humidity. The greenhouse technology is also important. Movable shade can be closed during hot and sunny hours during midday, and open during morning and afternoon or cloudy weather. Movable shade therefore has greater ability than fixed shade to increase light level without resulting in heat stress. With fixed shade, the key decision is typically which month to apply or remove shade. Because of microclimates and differences in greenhouse types, growers should trial new shade levels before applying to the entire crop.

## LIGHTING GUIDELINES

Most growers are familiar with measuring instantaneous light intensity, meaning the light level that would be measured at one point in time using a light meter. One challenge in comparing measured light against recommended levels is the wide range of units used to describe light intensity.

For the photosynthetically active range of the light spectrum [400 to 700 nanometers (nm)], units are micromoles per square meter per second ($\mu mol \cdot m^{-2} \cdot s^{-1}$). For sunshine, 100 $\mu mol \cdot m^{-2} \cdot s^{-1}$ equals 520 foot candles, 5,600 lux, or 5.6 klux of visible light (380-770 nm), or 48.3 $Watts/m^2$ of light energy (280 to 2,800 nm). These conversion factors vary for different light sources such as different types of electric lamp (Both, 2002).

There is a tradeoff between having adequate sunlight intensity for maximizing photosynthesis rate versus heat stress. Typical light levels under mist during formation of callus and root initials are 200 to 300 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (11.2 to 16.8 klux). Excess light during the mist phase leads to dehydration of cuttings, and the grower may have to overcompensate with more frequent mist irrigation to keep the plants from wilting. This can create several problems. Media will become saturated, cold, and depleted of both oxygen and nutrients, making for slow rooting or plants that are nutritionally deprived.

The optimum light level may increase to 500 to 600 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (28.0 to 33.6 klux) or more after plants are well rooted, off mist, and being hardened off for transplant. Because optimum light level varies during crop growth, this can be achieved by having 2 or 3 climate zones with increasing light level, often coupled with decreasing temperature to harden off plants. For many floricultural crops during the finished phase after transplant, a light level of 500 to 1000 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (28.0 to 56.0 klux) is acceptable (Heins and Runkle, 2004). For greenhouses that are poorly vented, or are in a location with high air temperatures, light levels need to be on the lower end of these ranges.

Daily light integral (DLI) during propagation can also significantly affect adventitious rooting of cuttings. The DLI refers to the accumulated light energy in the PAR range in moles per square meter per day ($mol \cdot m^{-2} \cdot d^{-1}$). A datalogger can be used to continuously measure light level, and calculate the accumulated DLI. A suitable battery powered datalogger is the WatchDog 2475 Plant Growth Station available from <specmeters.com>. Most computerized environmental control systems can also log DLI, but this ideally requires a light meter to be placed inside the greenhouse.

When the DLI is below 4 $mol \cdot m^{-2} \cdot d^{-1}$ inside the greenhouse during mist propagation, rooting can be reduced or inhibited because leaves are unable to intercept enough light for adequate photosynthesis. When light levels are too high (above 8 to 12 $mol \cdot m^{-2} \cdot d^{-1}$) during mist propagation, transpiration is increased, and drought stress or excess misting can inhibit rooting. After plants are rooted and off mist, shade should be reduced or plants moved to a higher light zone. Finishing cuttings at a DLI of 8 to 14 $mol \cdot m^{-2} \cdot d^{-1}$ enhances rooting, branching, flowering, and post-transplant performance.

During winter months, sunlight can be limiting to plant growth. Long nights, overcast weather, and low incident angle of the sun greatly reduce the amount of light that plants receive. During this time, shading is often not necessary, particularly during cloudy days.

In the late spring and summer months, shading is applied not only to reduce light levels for unrooted cuttings, but also to lower the greenhouse temperature, reduce venting, and maintain air humidity. Beware, however, in creating very soft (poorly toned) cuttings through the combination of warm and dark conditions. Most plants that will be grown under full sun in the landscape or finished container should ideally be hardened off without shade before transplant, unless they become excessively heat-stressed.

The shoulder seasons of spring and autumn are often the most challenging, because of changeable weather. This is where fixed shade becomes most inefficient because over-shading will occur on cloudy days if the shade cloth remains closed.

## LIGHT LEVELS IN NEW ZEALAND HORTICULTURE

Table 1 shows DLI data adapted from historical climate data at 29 weather stations in New Zealand. Original data from the National Institute of Water and Atmospheric Research (NIWA) were collected using light sensors that measure total global radiation (approximately 280 to 2,800 nm). This spectral range differs from PAR light (400 to 700 nm) that is relevant for plant growth. A conversion factor was therefore applied of 2.08 $mol \cdot m^{-2} \cdot d^{-1}$ of PAR light for each $MJ/m^2$ of total radiation from sunlight, based on Both (2002).

The light levels in Table 1 represent full sun, with no shade from the greenhouse structure, covering material, or other shading materials such as shade cloth or white wash. Clean glass reduces light transmission (i.e., provides shading) by about 10%, and any areas receiving shading from the gutters, sash bars, or other overhead fixtures receive less light (Heins and Runkle, 2004). Because plastic reduces light more than clear glass, maximum light levels will be even lower in a double polyethylene-covered greenhouse. Shading by a factor of 50% is common in double-polyethylene greenhouses without additional shade during winter months because of the low incident angle of the sun. Use of whitewash, saran, aluminized, or other shade cloth provide further shading.

The amount of shading that occurs in a grower location can easily be measured using a hand held light meter. Over at least 3 days that have either cloudy or sunny conditions, measure the light level outdoors in the morning, midday, and afternoon (whatever units used by the meter are fine). Immediately after each outdoor measurement, also measure light level inside the greenhouse with the shade open and shade closed so there are triplets of data (full sun, greenhouse without the shadecloth closed, and greenhouse with shadecloth closed). Enter into the worksheet in Table 2, and average each column. Repeat in both the winter, and in the summer.

Table 1. Estimated daily light integral of photosynthetically active radiation in $mol \cdot m^{-2} \cdot d^{-1}$ in full sun (with no shade). The data were converted from mean daily global radiation ($MJ/m^2$) climate data from the National Institute of Water and Atmospheric Research (NIWA) for the 1981-2010 period for weather station locations having at least 5 complete years of data (Source: <https://www.niwa. co.nz/education-and-training/schools/resources/climate/radiation>). The conversion factor was 2.08 $mol \cdot m^{-2} \cdot d^{-1}$ for each $MJ/m^2$ based on Both (2002).

| Location | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | YEAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kaitaia | 45 | 40 | 34 | 24 | 18 | 15 | 16 | 21 | 28 | 35 | 41 | 46 | 30 |
| Whangarei | 44 | 38 | 32 | 23 | 17 | 15 | 15 | 21 | 28 | 35 | 41 | 42 | 29 |
| Auckland | 47 | 41 | 33 | 24 | 17 | 14 | 15 | 21 | 28 | 36 | 43 | 46 | 30 |
| Tauranga | 49 | 42 | 34 | 24 | 17 | 14 | 15 | 21 | 28 | 37 | 43 | 46 | 31 |
| Hamilton | 46 | 40 | 33 | 24 | 16 | 13 | 14 | 20 | 27 | 35 | 42 | 45 | 30 |
| Rotorua | 47 | 40 | 33 | 24 | 17 | 13 | 15 | 19 | 27 | 35 | 42 | 45 | 30 |
| Gisborne | 49 | 40 | 32 | 23 | 16 | 13 | 14 | 20 | 29 | 39 | 45 | 48 | 31 |
| New Plymouth | 50 | 44 | 35 | 24 | 16 | 13 | 15 | 20 | 27 | 36 | 45 | 46 | 31 |
| Napier | 48 | 40 | 33 | 23 | 16 | 13 | 14 | 21 | 29 | 39 | 45 | 47 | 31 |
| Wanganui | 49 | 42 | 33 | 23 | 15 | 12 | 14 | 19 | 27 | 35 | 44 | 47 | 30 |
| Palmerston North | 46 | 41 | 32 | 22 | 14 | 11 | 13 | 18 | 25 | 32 | 41 | 44 | 28 |
| Masterton | 46 | 39 | 31 | 21 | 15 | 11 | 12 | 18 | 27 | 35 | 44 | 46 | 29 |
| Wellington | 48 | 42 | 32 | 21 | 13 | 10 | 12 | 18 | 26 | 35 | 42 | 46 | 29 |
| Nelson | 49 | 43 | 33 | 24 | 16 | 12 | 13 | 19 | 28 | 35 | 43 | 47 | 30 |
| Blenheim | 49 | 42 | 35 | 24 | 16 | 12 | 14 | 20 | 29 | 39 | 46 | 48 | 31 |
| Westport | 45 | 40 | 31 | 20 | 13 | 10 | 12 | 17 | 24 | 32 | 42 | 42 | 27 |
| Kaikoura | 45 | 38 | 31 | 21 | 14 | 11 | 12 | 18 | 27 | 36 | 45 | 46 | 29 |
| Hokitika | 44 | 38 | 30 | 20 | 13 | 10 | 12 | 17 | 24 | 32 | 40 | 42 | 27 |
| Christchurch | 45 | 38 | 29 | 20 | 13 | 10 | 11 | 16 | 25 | 35 | 43 | 45 | 27 |
| Mt Cook | 46 | 41 | 31 | 21 | 12 | 9 | 11 | 16 | 23 | 35 | 45 | 44 | 28 |
| Lake Tekapo | 50 | 43 | 33 | 22 | 14 | 11 | 13 | 18 | 28 | 39 | 49 | 49 | 31 |
| Timaru | 42 | 35 | 29 | 20 | 13 | 11 | 12 | 17 | 26 | 34 | 41 | 43 | 27 |
| Queenstown | 49 | 43 | 32 | 21 | 13 | 10 | 12 | 18 | 27 | 38 | 46 | 50 | 30 |
| Clyde | 47 | 42 | 32 | 20 | 12 | 9 | 10 | 17 | 27 | 37 | 46 | 49 | 29 |
| Manapouri | 45 | 39 | 28 | 18 | 11 | 8 | 9 | 15 | 23 | 34 | 43 | 46 | 27 |
| Dunedin | 40 | 35 | 26 | 17 | 10 | 8 | 9 | 14 | 22 | 32 | 38 | 40 | 24 |
| Invercargill | 41 | 36 | 26 | 16 | 9 | 7 | 9 | 14 | 23 | 32 | 41 | 44 | 25 |
| Chatham Islands | 42 | 36 | 27 | 18 | 11 | 8 | 10 | 15 | 23 | 31 | 40 | 43 | 25 |
| Antarctica, Scott Base | 52 | 28 | 9 | 1 | 0 | 0 | 0 | 0 | 5 | 22 | 48 | 60 | 19 |
| Average[1] | 46 | 40 | 32 | 22 | 14 | 11 | 13 | 18 | 26 | 35 | 43 | 46 | 29 |

[1]Average includes all weather stations other than Chatham Islands and Antarctica.

Table 2. Work sheet to calculate the shade level in a greenhouse location with and without the shadecloth closed.

| (A) Light level outdoors | (B) Light level inside, without shadecloth closed | (C) Light level inside, with shadecloth closed | % shading without shadecloth closed | % shading with shadecloth closed |
|---|---|---|---|---|
| (A) | (B) | (C) | (1 – B/A)*100 | (1 – C/A)*100 |
| Example: 10 klux | Example: 6 klux | Example: 3 klux | (1-6/10)*100 =40% | (1-3/10)*100 =70% |
| 1. | | | | |
| 2. | | | | |
| 3. | | | | |
| 4. | | | | |
| 5. | | | | |
| 6. | | | | |
| 7. | | | | |
| 8. | | | | |
| 9. | | | | |
| Ave. (1 to 9): | Ave. (1 to 9): | Ave. (1 to 9): | Ave. (1 to 9): | Ave. (1 to 9): |

By comparing the light levels in Table 1 against recommended levels in Table 3 and other resources such as Faust (2011), it is possible to consider appropriate shading strategies and appropriate shade levels. The average light level in the darkest months (June, July) of 13-14 $mol \cdot m^{-2} \cdot d^{-1}$ was approximately ¼ the light level during the sunniest months (December and January) at 46 $mol \cdot m^{-2} \cdot d^{-1}$. This light range emphasizes the need to reduce shading during winter months. There was greater variation in light level between locations during winter months than in summer. During winter, the average light level in Invercargill (southern South Island, 7 $mol \cdot m^{-2} \cdot d^{-1}$) was approximately half the light level in Kaitaia (northern North Island, 15 $mol \cdot m^{-2} \cdot d^{-1}$), emphasizing the need to customize winter shade level in different locations.

Table 3. Guidelines for optimum daily light integral levels for floriculture production. For more information on finished plants, refer to Faust (2011).

| Production phase | Daily light integral range ($mol \cdot m^{-2} \cdot d^{-1}$) |
|---|---|
| Propagation (unrooted and under mist) | 4 to 8 |
| Propagation (rooted to hardening off) | 8 to 14 |
| Finishing of most flowering crops | At least 10 |
| Finishing of orchids, ferns, tropical foliage | 6 to 10 |

Most South Island and southern North Island locations had less than 12 $mol \cdot m^{-2} \cdot d^{-1}$ of full sunlight during the darkest months, indicating minimal need for additional shading during winter. September to April had high light levels and greatest need for shading during propagation, with the shoulder months of May and August being intermediate.

In winter (June), Figure 1 shows that greenhouses applying 75% shade (including both the covering material, greenhouse structure, and shade cloth) would result in light levels 2 to 4 $mol \cdot m^{-2} \cdot d^{-1}$, which is below the recommended DLI even for low light crops or the mist propagation phase (from Table 3). No more than 50% total shade should be applied during winter, which in many greenhouses with double-polyethylene or fiberglass covering would not require shade cloth. Cuttings could be hardened off during winter with no shade at all. In contrast, during the summer at least 75% shade cloth is likely to be needed during the mist phase.

As a demonstration, we placed a WatchDog 2475 data logger in an orchid production greenhouse in south Auckland during April 2014. *Phalaenopsis* orchid is a low-light crop (Faust, 2011), and a target threshold was set at 3 to 6 mol·m$^{-2}$·d$^{-1}$ during propagation. Measured light level averaged 1.5 mol·m$^{-2}$·d$^{-1}$, and ranged from 0.8 to 2.8 mol·m$^{-2}$·d$^{-1}$ during the cloudiest and sunniest days, respectively, with around 90% shading of ambient sunlight. Based on these measurements, the grower reduced the shade level during May by removing one layer of fixed shade, in order to increase growth rate.

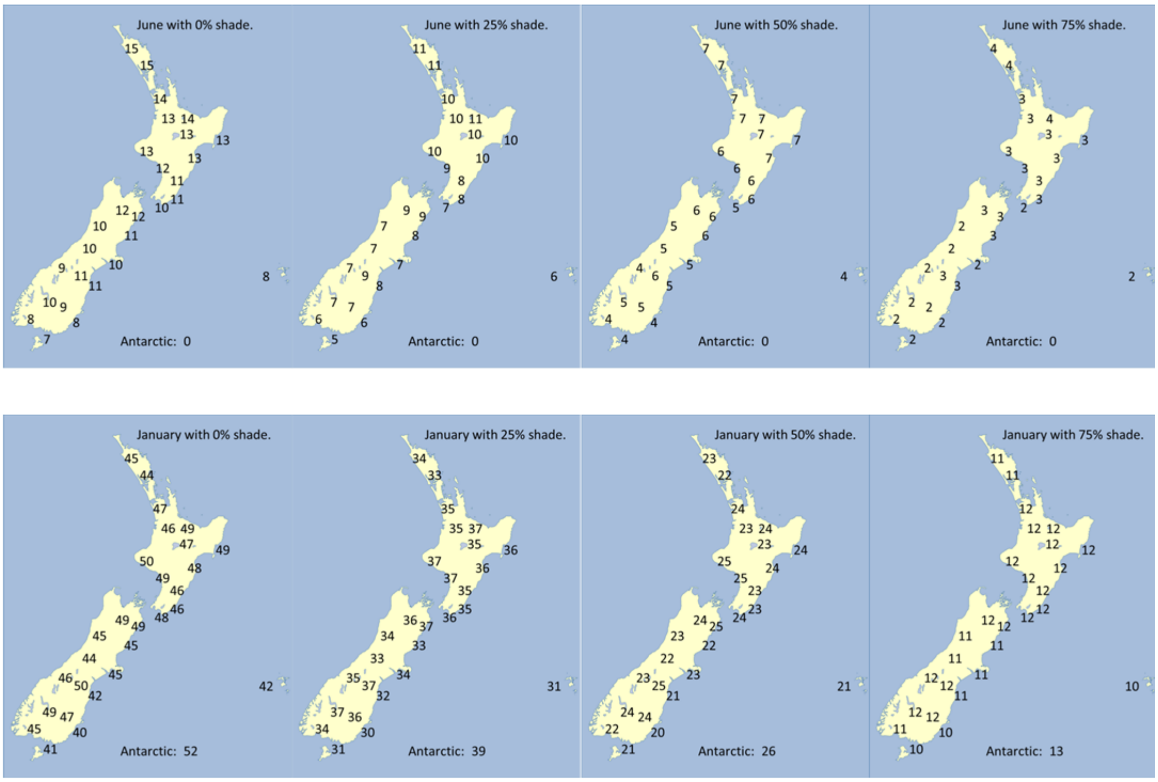


Fig. 1. Estimated daily light integrals (mol·m$^{-2}$·d$^{-1}$) with four levels of shading (0, 25, 50, and 75%) during minimum (June) and maximum (January) sunlight months in New Zealand. Data were calculated by multiplying the full sun DLI in Table 1 times (1 – shade level). For example, in Kaitaia during June the full sun DLI was 15 mol·m$^{-2}$·d$^{-1}$. With 75% shade, this would be reduced to 15 * (1-0.75) = approximately 4 mol·m$^{-2}$·d$^{-1}$.

## CONCLUSION

The climate data in both Table 3 and represented as light maps in Figure 1 provide useful information to help guide shading strategies. Although heavy shade is needed in New Zealand during summer months for propagation, it is easy to over-shade during the winter. During the darkest months, shade cloth should in many cases be completely removed, particularly when hardening off cuttings and finishing many floricultural crops.

## Literature Cited

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