## Cooling with Shade

By Thomas D. Landis

Using shade to reduce the sunlight and resultant heat reaching nursery crops is a time-honored cultural practice. Shading seedbeds was standard practice in early bareroot nurseries and two types of shade were employed. Shadeframes (Figure 1A) were also known as "low shade" to distinguish them from the "high shade" that was used to allow use of machinery in the seedbeds (Figure 1B). Back then, the primary objective of shading was to reduce the undesirable increase in temperature and resultant transpiration from direct sunlight. When modern irrigation practices were installed in nurseries, however, it was discovered that shade was really not necessary if adequate soil moisture was present.

### Horticultural Uses of Shading

Shadeframes are rarely seen in modern bareroot nurseries, and today, shading is primarily used in container nurseries. Shadecloth or fixed lath can be used to produce permanent shade, and some container nurseries use special lath houses to both shade and protect seedlings during the hardening phase and for overwinter storage. Standard shadeframes are made from snowfence, which consists of strips of wooden lath connected by wires with alternate open spaces that produce 42% shade. Although some container nurseries produce seedlings in shadehouses, this amount of shade is generally considered to be too high for most species.

Over the years, I have seen many nurseries with shadehouses or with shadecloth covering greenhouses and, in my opinion, shading is often used incorrectly. So, let's review the practice.

**Decrease Light Intensity for Shade-loving Species.** Shading is rarely used with crops of commercial conifers, and even "shade-tolerant" species like western hemlock (*Tsuga heterophylla*) can be germinated and grown in full sunlight. Growers have found that many species tend to grow excessively in height ("stretch") under heavy shade which contributes to poor shoot-to-root ratios.

Shade is used to grow other native plants, especially if the species is shade loving and will be outplanted underneath an existing plant canopy (Table 1). Seedlings that will be outplanted into full sun conditions should receive minimal or no shading, including during the Hardening Phase. In fact, excessive shade has been shown to delay hardening.

**Cooling in High Sunlight Environments.** Keeping greenhouses and other propagation structures cool is the biggest environmental challenge facing container growers, especially at lower latitudes and in climates with few cloudy days. Growers can choose from three options:

*Ventilation*—This is the most common method of cooling but greenhouses must be properly designed for it to be effective. Natural ventilation feature roof and side vents whereas mechanical systems use a staged sequence of vent openings and fan speeds.

*Evaporative cooling*—Evaporative pads and exhaust fans use the latent heat of evaporation to cool incoming air. Cooling is especially problematic, however, in humid climates where natural ventilation and evaporative cooling are ineffective. Fog systems use high pressure nozzles to produce a fine mist which cools the air and plants as it evaporates. Good quality water is required to prevent plugging nozzles and avoiding spots on foliage and surfaces.

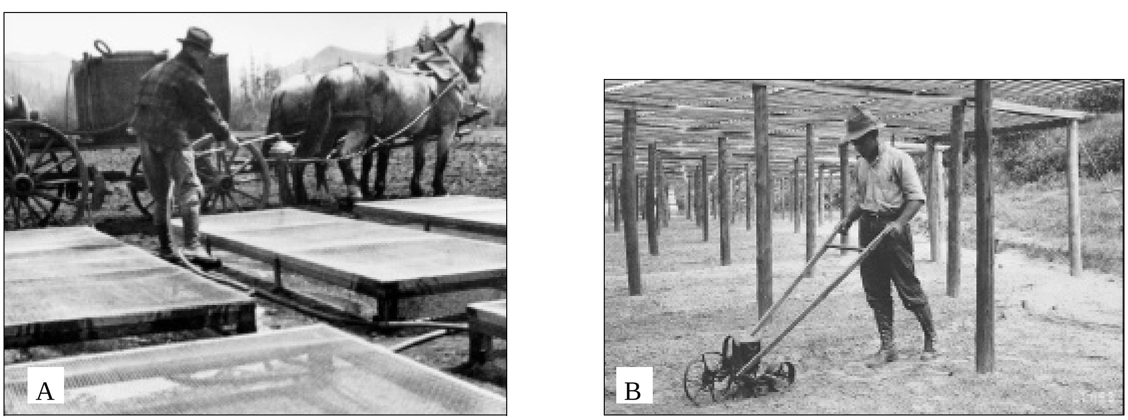

*Figure 1 - Historically, shadeframes over seedbeds were standard procedure (A) and "high shade" allowed equipment access (B).*

| Table 1. Native plant species commonly grown under full sun or shade, along with species which grow under either condition (Courtesy of T Luna) | | | | |
|---|---|---|---|---|
| **Species** | **Common Name** | **Sun Requiring** | **Shade Requiring** | **Sun or Shade** |
| *Artemisia tridentata* | big sagebrush | X | | |
| *Carex aquatilis* | water sedge | X | | |
| *Prunus virginiana* | chokecherry | X | | |
| *Dryopteris filis-mas* | male fern | | X | |
| *Chimaphila umbellata* | pippesisiwa | | X | |
| *Gymnocarpium dryopteris* | oak fern | | X | |
| *Ceanothus sanguineus* | redstem ceanothus | | | X |
| *Rubus parviflorus* | thimbleberry | | | X |
| *Pteridium aquilinum* | bracken fern | | | X |

*Shading*—The basic concept is to reduce the amount of incoming solar radiation that converts to heat inside the propagation structure. Historically, growers with glass greenhouses applied whitewash paint during the summer so that the white color would reflect sunlight and thereby cool the interior of the structures. With the newer types of greenhouse glazing, whitewash is uncommon and shadecloth is used instead. Whether shadecloth is effective in cooling depends on two things: 1) the color and composition of the shadecloth, and 2) how it is installed.

### Types and Colors of Shadecloth

Since black woven shadecloth was introduced in the 1960s, many growers have installed it over their greenhouses for cooling during the heat of summer (Figure 2). This is one tradition that needs to be re-examined.

**Shadecloth composition.** Many different types of shadecloth are available and there are several dconsiderations before purchase including durability, fire resistance, shrinkage, percentage shade, and method of manufacturing:

- Polypropylene is strong, resistant to abrasion and will only shrink about 1%.
- Saran is fireproof but, because it can shrink about 3%, should be installed with a slight sag.
- Knitted polyethylene is strong, ultraviolet resistant, and will not fray when cut or ripped.
- Polyester fabrics are fire resistant and can be interwoven with aluminum strips.

> On a sunny summer day, a 30 x 100 ft greenhouse can capture about 3.2 million BTU of solar heat, which is the same as burning 32 gallons of fuel oil. (Bartok 2001)

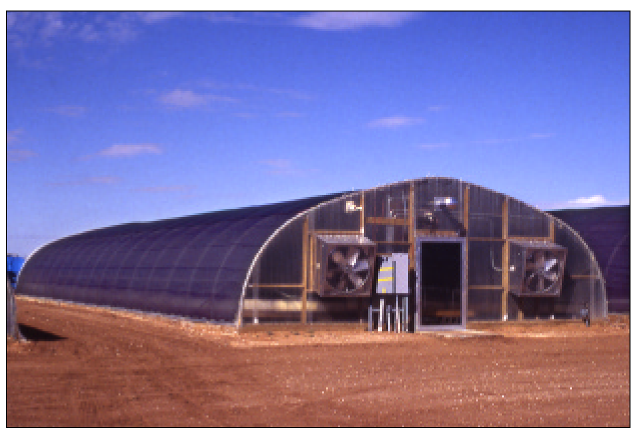

*Figure 2 - Black mesh shadecloth has traditionally been installed directly over greenhouses but is not the most effective application (see Figure 3A).*

Aluminet® keeps a greenhouse 8 to 10 °F cooler than standard black shadecloth, but is twice as expensive

**Shadecloth color.** As already mentioned, black is the traditional color for shadecloth (Figure 2). It may seem logical that, because black shadecloth reduces the amount of light reaching the crop, it is also a good way to cool plants. That's not necessarily the case, however. If you remember your physics, "black bodies" absorb visible light and reradiate it as heat whereas white objects reflect light.

White shadecloth absorbs much less heat than black and other colors are intermediate. New "aluminized" fabrics do a great job of reflecting incoming sunlight. For example, Aluminet® is a special knitted fabric made from high density polyethylene strips laminated with aluminum. It is available in several shading levels and is lighter in weight than standard shadecloth.

Surprisingly enough, published data about inside temperatures with different types and colors of shadecloth is hard to find, especially in high sunlight environments. However, the temperatures in Table 2 illustrate the physics involved. Solar radiation is converted to heat only when it is absorbed, and air temperatures only heat up when greenhouse surfaces and plants reradiate this heat. Therefore, although the air temperatures are very different, the white shadecloth reflected more sunlight and therefore kept the growing medium significantly cooler. For your crop, this would be reflected in less transpirational water loss.

**Shadecloth Installations**

The installation method is just as important as the type of shading material. In the typical case, growers just install the shadecloth directly on top of the covering. This is less effective for cooling, however, because sunlight is absorbed by the shadecloth and then conducted and reradiated into the propagation area (Figure 3A). Improperly installed shadecloth can also interfere with proper ventilation and further add to the heat load.

The best way to install shadecloth is to support it above the covering leaving a layer of air underneath. This is more effective because the absorbed heat cannot be conducted through the covering but rather exhausted with natural ventilation (Figure 3B).

One innovative way to increase the cooling effect is to install irrigation lines with mist nozzles over the shadecloth. The resultant evaporative cooling can be very effective if the water is free from soluble salts.

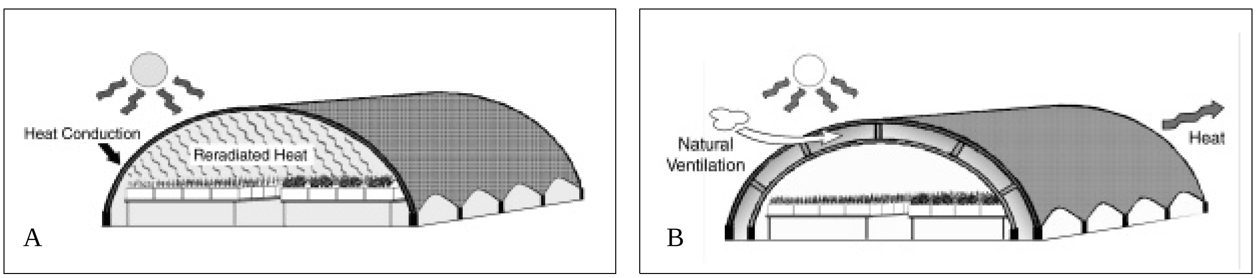


*Figure 3 - Black shadecloth absorbs sunlight which is converted to heat which is conducted and reradiated into the greenhouse (A). Instead, shadecloth should be mounted above the greenhouse covering so that heat can be ventilated outside (B).*

**Table 2. Comparison of temperatures (F°) inside a greenhouse with different types of shadecloth in Northern Oregon in September (modified from Svenson 2000).**

| Shading Material | Air Temperature (F°) | Growing Medium (F°) |
|---|---|---|
| None | 88 | 118 |
| Black shadecloth—30% shade | 88 | 115 |
| Black shadecloth—63% shade | 90 | 108 |
| White shadecloth—50% shade | 89 | 92 |

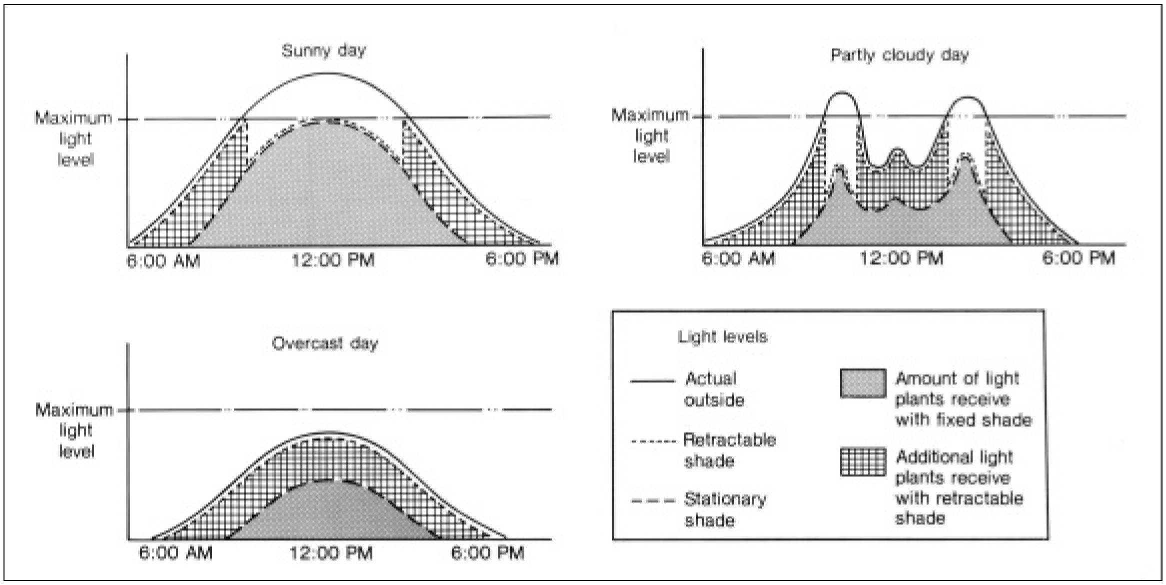


*Figure 4 - Retractable shadecloth allow plants to receive more sunlight than "fixed" installations, especially early in the morning, late in the afternoon, and on days with variable clouds (Landis and others 1992).*

**Retractable Shading**

Sunlight intensity changes during the day with the angle of the sun and the degree of cloud cover. Because of the labor involved, however, it is uneconomical to adjust the shadecloth manually to prevailing light conditions. With the advent of automatic retractable shading systems, however, container growers have the option of adjusting the light intensity within the growing area to maximize photosynthesis or lower temperature several times a day. Although relatively expensive, automatic shading systems can greatly increase the amount of sunlight reaching the crop and therefore increasing seedling growth rates (Figure 4). In an operational greenhouse trial, an automated shading system allowed the crop to receive 50% more hours of PAR than the crop in a house with permanent shade (Vollebregt 1990). A novel type of shade curtain with alternating bands of aluminized and clear material has the added advantage of actually reflecting diffuse light back into the greenhouse while reflecting away unwanted thermal radiation. Garzoli (1988) considered these reflective shade screens invaluable for cooling greenhouses across Australia.

**References**


Bartok Jr JW. 2001. The basics of shading for proper temperature control. GM Pro 21(5): 72-73.

Landis TD, Tinus RW, McDonald SE, Barnett JP. 1992. Atmospheric environment. Volume 3. The Container Tree Nursery Manual. Washington (DC): USDA Forest Service. Agriculture Handbook 674. 145 p.

Nijskens J, Deltour J, Coutisse S, Nisen A. 1985. Radiation transfer through covering materials, solar and thermal screens of greenhouses. Agricultural and Forest Meterology 35: 229-242.

Parbst K. 2005. Keep your greenhouse cool. GM Pro 25 (4): 30-35.

Roberts WJ. 1990. Four ways to keep cool. Greenhouse Grower 8(4): 22, 24.

Svenson SE. 2002. Shady business, Part II. American Nurseryman 195(4): 43-46, 48-51.