Retractable Roof Greenhouses and Shadehouses

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Greenhouse Structures

Open-roof greenhouses provide a natural environment for plant growth when the outdoor weather is suitable and an artificial environment when it is too hot or cold. Opening the roof over the plants increases light intensity, which can help to control the growth habit, flowering, and crop timing. It also reduces electricity costs because expensive fan cooling is not needed.

Roll-Up Roof

Several methods are used to open the roof. Some manufacturers make a roof that opens by rolling up the single or double layer of flexible plastic glazing that runs the length of the greenhouse bay. A small gear motor rotates a shaft that winds the plastic onto it like a window shade. A light, second framework over the structure secures the plastic from bellowing out during windy weather. Opening and closing the roof can be either manual or automatic. Each side of the roof can be controlled independently for flexibility in cooling.

Folding Roof

Folding roof greenhouses work well in snowy climates, as they can be tightly closed during cold weather. Most designs use standard vent hardware. Some have panels that hinge at the gutter and open upward. Opening is almost 100%. Others have panels that are hinged at the ridge and one gutter, and slide sideways on teflon bearings. Opening is about 85%. Most designs use rubber gasketing to seal the joints. Glazing can be glass, polycarbonate, or film plastic. Some manufacturers provide a movable gutter to collect rainwater when the roof is partially open. Wind sensors should be installed to close the roof in stormy weather. Movable shade is frequently installed with the open roof design. It reduces the heat load by reflecting the sun's rays back out. The shade curtain should be of a porous design to allow heat to escape. In northern climates, an energy blanket may also be installed to reduce heat loss during the winter.

Retractable Roof

These structures consist of a steel frame, flexible glazing, and cable support. Woven UV stabilized polyethylene film creates a watertight glazing. Depending on the cropping system, bracing of the structure can be external cables attached to deadmen, internal compression braces, or trusses with cable X-bracing. Flat roof designs are used where there is little rain or snow. A-roof designs shed the rain and snow to an internal gutter system. Designs that will carry up to 35 lb/ft^2 (170 kg/m^2) snow load and 100 mph (160 kph) wind loads are available. The roof opens in sections by moving the leading edge of the curtain. One gear motor will handle up to 50,000 ft^2 (4,650 m^2) of roof. Heating is more difficult than in a conventional greenhouse due to the single layer plastic and greater infiltration through gaps and cracks in the seals.

High Tunnel

These low-cost, unheated poly-covered hoophouses can extend the growing season or provide overwinter protection to plants. A couple of manufacturers make a gutter-connected model. Ventilation is manual, by rolling up the sides, opening the doors or, in the case of the gutter-connected design, pushing up the roof plastic. Cost is usually less than U.S. $1/ft^2 (U.S. $11/m^2).

Basic Principles of Natural Ventilation

Retractable roof designs can provide better dormancy maintenance, plant hardening, and insect screening through ventilation control. Natural ventilation systems operate on the principle that heat is removed by a pressure difference created by wind and temperature gradients. Wind plays the major role. For a well designed greenhouse, wind speeds of 1 mph (2 kph) are adequate to keep the inside temperature within 2 °F (1 °C) of outdoor ambient. Weather records show that there are very few days that the wind is less than 1 mph (2 kph), especially if the outdoor temperature is above 80 °F (27 °C).

Buoyancy, the effect from heated air getting lighter and rising, also aids ventilation. The trend toward taller greenhouses has helped this in that it gets the hot air higher above the plants. The standard gutter height is now 12 ft (3.5 m), and taller greenhouses are used for some crops.

Natural-cooled greenhouses provide more uniform temperature throughout the greenhouse as compared to fan cooling where the temperature between the intake louvers and fans may be as much as 15 °F (8 °C). Natural ventilation systems also reduce energy costs by eliminating the 0.5 to 1 kilowatt-hour/ft^2/year of electricity needed to operate a fan system. In snow country, installing small fans with a capacity of 1 to 2 cfm/ft^2 of floor area will allow ventilation when there is snow in the gutters and the roof cannot be opened.

Shadehouses

Shade structures are used to provide protection against wind and solar radiation. They are a useful tool for modifying the environment and extending the growing season, both in cold and warm weather.

In nursery operations, a shadehouse can provide temperature and weather protection year-round. It can also reduce irrigation needs during the summer. In some areas, the reduction in animal damage will help to pay for the structure.

Why Shading?

Incoming solar energy is converted to heat energy when it strikes plant leaves. This can result in excessive air, leaf, and soil temperatures. Placing plants under 30 to 50% shade in the middle of the summer can lower leaf temperature by 10 °F (6 °C) or more. This, along with reduced wind speeds, can significantly reduce transpirational water losses during the growing season.

Not all plants require full sunlight to grow. Most plants can only utilize a limited amount of light, called the light saturation level. African violets lose chlorophyll at an intensity of 1,500 foot-candles (ft-c) (16,100 m-c). Foliage plants may be burned at a level over 2,000 ft-c (21,500 m-c). Red oak (*Quercus rubra*) and Douglas-fir (*Pseudotsuga menziesii*) have a saturation level of about 3,000 ft-c (32,300 m-c). Chrysanthemum and geranium plants will take around 4,000 ft-c (43,000 m-c). Rose and carnation plants will take full summer light intensity of up to 10,000 ft-c (107,600 m-c). The science of shading is really an art as the level of light that you allow to reach the top of the plant is reduced significantly by the time it reaches the bottom leaves.

Lath Houses

The original shadehouses were called lath houses, as they were frame structures covered with wood lath. Most were made with poles set into the ground with 2-in (5-cm) framing lumber nailed to the poles to support the lath. A 50% shade was created by leaving a space equal to the width of a lath between adjacent laths.

When woven polypropylene was first introduced to the greenhouse industry, shadehouses took on a new appearance. Wire or cable was adequate to support the lightweight material. Today, most shade structures are covered with either polypropylene, polyethylene, polyester, or a composite fabric which usually contains aluminized polyester strips.

Most greenhouse manufacturers can supply a shadehouse. They can be either fixed-roof or retractable-roof design. Fixed-roof designs are either rigid frame or cable frame.

Cable Frame Shadehouses

The cable frame shadehouse probably evolved from the shade tobacco industry where several thousand acres are covered annually in Connecticut and other states to modify the environment to produce tender tobacco leaves for the wrapper of the best quality cigars. Posts surrounded by concrete are set into the ground on an approximate 20 ft by 20 ft (6 m by 6 m) spacing. Height can be 8 ft to 16 ft (2.5 to 5 m). Deadmen located around the perimeter provide the bracing for the tension in the wires. Stainless steel cable with adjustable turnbuckles are strung between the posts to support the cloth shade material. In the tobacco shadehouses, the edges of the material are sewn around the wires with a strong thread. In the nursery shadehouses, clips or hooks are used. Shade material hung on the sidewall around the perimeter is attached to the upper wire and usually buried in the soil. It provides wind protection to the plants. Due to the variables in construction, cable shadehouses usually do not carry a design wind or snow load.

Rigid Frame Shadehouses

In rigid frame shadehouses, the cable is replaced by pipe or rollformed truss members. This supports the shade cloth. Instead of deadmen, diagonal knee braces, both horizontal and vertical, create the rigid frame. Post spacing is less than with the cable system, usually 10 to 18 ft (3 to 5.5 m). Shade material can be attached with tek screws or clips.

Retractable Roof Shadehouses

Retractable roof shadehouses use the same technology as that used in greenhouses. They are available from several manufacturers in several widths. They can have either cable or truss supports, and usually carry a design wind load.

As solar radiation varies considerably over the day and from season to season, the main advantage of the retractable design is the ability to regulate the amount of sunlight that reaches the plants. Increased plant growth results as ventilation can be controlled to reduce temperature. Ventilation can also reduce disease incidence. Reducing the intensity of sunlight can lower irrigation needs as plants and soil are kept cooler.

Both cable and truss style retractable roof designs utilize standard energy blanket technology for opening and closing the shade. One gear motor can handle up to 50,000 ft^2 (4,650 m^2) of growing area. The shade material is usually stored at the post line. For areas that receive considerable snowfall, the roof is retracted and snow is allowed to cover the plants, providing insulation. The shade material is stored under a protective hood so that it doesn't get covered with snow.

For a grower that is now utilizing the conventional 14 ft (4 m) wide overwintering hoophouse covered with white poly for protection of perennials, herbs, and nursery stock, a retractable roof structure can give better temperature control. It can also reduce plant handling cost, as the larger area under one roof and the vertical sides allow the use of mechanized handling equipment.

Sidewall and Endwall Ventilation

In most greenhouses and shadehouses, it is advantageous to have sidewall ventilation. First, it can be used as a first stage of cooling. Second, in larger structures, it can supply most of the intake air and the roof vents act as the outlet.

Sidewall and endwall covering can be fixed poly, roll-up curtains, or rigid polycarbonate.

Manual and motorized rollup systems are available. These use a conventional roll-up mechanism and small gear motor. Ventilation rate is controlled by the size of the opening. The drop-down system works better in cooler weather as the air is introduced above the plants. Restraining cables or guides are installed to keep the detached sidewall curtain from blowing on windy days.