

Current Status in U.S. Greenhouse Production and Newly Designed Naturally Ventilated Greenhouse in America

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INTRODUCTION

Ventilation is the primary method of controlling greenhouse air temperature, relative humidity, and carbon dioxide concentration. Two types of ventilation systems that are normally used are natural and fan. While fan ventilation is typically achieved with one wall as an inlet and the opposite wall as a fan outlet, natural ventilation is generally achieved by air exchanges that occur through multiple controlled openings due to natural pressure variations inside and outside the greenhouse.

While natural ventilation systems can be very difficult to design properly, there is a strong interest in designing and using naturally ventilated greenhouses for both high and low tech plant production systems as they generally require less electrical energy, less equipment operation and maintenance, and are much quieter than fan ventilation systems. Recently, various newly-designed greenhouses with natural ventilation systems have been developed to achieve high degree of natural ventilation rates.

In this paper, greenhouse industry in America and each state were briefly explained according to greenhouse crop productions and greenhouse cover materials. All data were from 1998 floriculture crops summery and 1997 Census of Agriculture made by United States Department of Agriculture (USDA) and National Agricultural Statistics Service (NASS). And then, the latest naturally ventilated greenhouse structures in U.S.A. were introduced.

TYPICAL GREENHOUSE CROPS AND COVERS

Main greenhouse productions in U.S. are floriculture crops, nursery crops, mushrooms, and vegetables in 1998. Floriculture crops, about 75% of U.S. greenhouse products are the biggest part of greenhouse crops. U.S. greenhouse productions increased 4.7% in sales over 1997 levels more than doubles any industry growth rate that USDA has reported in the last five years. Vegetables are only 4% of total greenhouse products in America.

Main floriculture products in greenhouse are bedding-garden plants, foliage, cut flowers and cut florist greens, and potted flowering plants. About 40% of U.S. floriculture products in greenhouse were bedding and garden plants. The U.S. greenhouse floriculture in 1998 increased about 4.5% compared to 1997. Considering major 36 states, the total under covered area including greenhouse and shade/temporary covered for floriculture crops was 9,945 hectares in 1998 while open ground usage totaled 18,925 hectares.

Considering the floriculture crops in 1998, film plastic (43%) and shade/temporary (39%) covers were the most popular in America. About 87% of shade and temporary covered areas for floriculture were found in Florida because of very hot and humidity summer weather.

Considering only 35 states without Florida, the film plastic covered areas were 63%, and fiberglass/other rigid covers, glass, and shade/temporary covered areas were 16%, 12%, and 9%, respectively. The biggest greenhouse industries are found in Florida and California.

California (20%) and Florida (16%) are the biggest greenhouse production areas for U.S. floriculture, followed by Michigan (7%), Ohio (5%), Texas (5%), New Jersey (4%), New York (4%), and Pennsylvania (4%). But, if the greenhouse and shade/temporary covers are considered together, Florida has the biggest floriculture production area under cover. Florida has 44% of under covered floriculture production area, followed by California (14%), Michigan (4%), Texas (4%), Ohio (3%).

NATURALLY VENTILATED GREENHOUSE TYPES

Table 1 shows the benefits and limitations of several options in natural ventilation. It should be noted that the market has become so diverse with these systems that there are often several versions of the same type of system. For instance, retractable open roof systems have made such a significant impacts on the market the last several years that choices now range from a poly roll-up roof system for standard greenhouses frames to sawtooth structures that feature a retractable roof and vertical top vents. Retractable open roof systems, especially hinged open roof greenhouses, have significantly grown in the market. It allows infinite ventilation control and direct exposed plants to sunlight as well as flexibility in choosing different coverings such as inflated double polyethylene, polycarbonate, or glass.

Table 1. Benefits and limitations of natural ventilation systems of greenhouses.

| Type* | Benefits ° | Limitations ° |
|--|--|--|
| Rack-and-pinion vents | <ul style="list-style-type: none"> · Air tight seals. · Excellent wind resistance. | <ul style="list-style-type: none"> · Smaller surface area of vent opening. · Vents can be inhibited by snow and ice. |
| Roll-up sidewalls ^ | <ul style="list-style-type: none"> · Easy accessibility for materials handling. · Greater opening for airflow than rack-and-pinion. | <ul style="list-style-type: none"> · Cold air dumps directly onto crops. · Air leaks are a potential problem in the North. |
| Roll-down sidewalls/ ^ Drop-down curtains | <ul style="list-style-type: none"> · Cool air enters above the crop. · Greater opening for airflow. | <ul style="list-style-type: none"> · Air leaks are a potential problem in the North. |
| Retractable open roof | <ul style="list-style-type: none"> · Infinite ventilation control. · Plants develop more hardy, compact. · Plants have direct exposure to sunlight. · Flexibility in choosing different coverings. | <ul style="list-style-type: none"> · Excessive snow or ice buildup can create problems. · It takes time to close roof manually during power outages. |

* The types of natural ventilation systems listed here may not represent all that is available

on the market.

- Benefits and limitations may vary from systems to systems. Continuous improvements in natural ventilation systems have eliminated many limitations.
- ^ Sidewalls and roof vents work best when used together as a system.

In addition to new developments in top ventilation, there have been tremendous upgrades with sidewall systems. Perhaps the biggest advantage that newer side ventilation systems (i.e. roll-up sidewalls, drop-down curtains, etc.) have over traditional rack-and-pinion ventilation is in the surface area. Sidewalls often start or end at the eave of the greenhouse and can be opened up to 3.7m (12ft) tall and be fitted to walls more than 91.4m (300ft) long. These systems can also be opened at desired levels, depending on the needs of the crop.

RETRACTABLE OPEN ROOF GREENHOUSE TYPES

Until the beginning of 1990', selecting a retractable-roof greenhouse was fairly simple and few greenhouse manufacturers produced a couple of basic styles. Today, no fewer than 20 manufacturers now have some styles of retractable house. There are several typical types of retractable roof system of naturally ventilated greenhouses such as flat roofs, low profile, peak roofs, roll-up roofs, and hinged-roof greenhouse.

From the beginning, flat-roofed retractable systems caught on quickly with nursery stock and hardy perennials growers for temporary crop production. While they don't stop rain (the roof fabric is porous), they're popular because they can open nearly 100% to prevent heat buildup and give outdoor growing conditions, but quickly close tight to protect crops from occasional frost and cold weather. They are especially popular in coastal areas with less harsh winters - the Pacific Northwest, Southeast, mid-Atlantic, and Southwest.

Brand new on the market is the "low-profile" house, a hybrid between the flat-roof and A-frame house. This style offers rain protection without the structural costs of a peaked-roof house. They are sometimes built in a sawtooth configuration. Key to the design is the self-guttering roof fabric material which has a tough monofilament weave and built-in folds to better channel rain and dew from the fabric. The roof drive is generally a push-pull system rather than cables. The push-pull system is more expensive, but is more precise and dependable than cables.

Peak-roofed retractables give benefits of both retractables and traditional greenhouses: outdoor growing conditions and full weather and climate control. These houses have been equipped with everything from Dutch trays to flood floors to HID lights - anything a grower would put into a regular greenhouse.

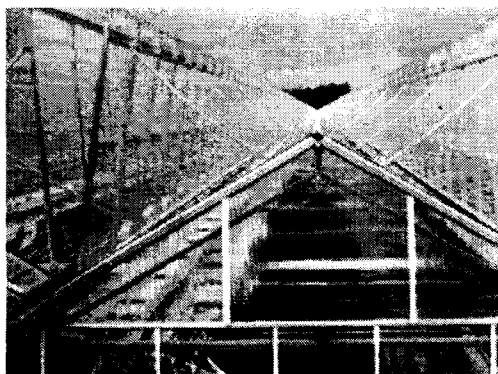
For growers who want a large measure of ventilation capacity but more year-round climate control, a double-polyethylene house with a roll-up roof has been introduced in the market. This system uses inflatable double-polyethylene film that fits over a frame, which can be opened and unrolled. The system can be retrofitted to existing structures. Major benefits include the energy efficiency of double polyethylene, along with the low replacement cost.

Perhaps the houses garnering the most attention today are the peaked-roof houses with hinged roof panels. Instead of flexible curtains forming the roof, rigid panels open and close via rack-and-pinion drives. It allows flexibility in choosing different coverings such as inflated double polyethylene, polycarbonate, or glass. The panels open by rack-and pinion drives and stand straight up above the gutter. When closed, the top panel nestles on the bottom, creating a tight seal, thanks to a rubber gasket. The house roof can open partially like a traditional ridge vent or fully for maximum ventilation. There is another type of retractable-panel house which was introduced two years ago to the North American market from Europe. From the outside, the house resembles a standard Venlo-style house. But, rather than open at the ridge like the previous type, the roof, which is hinged at the peak, slides on Teflon wheels from gutter to

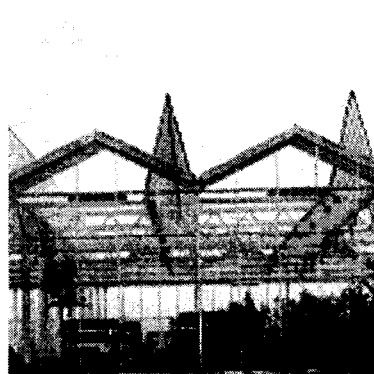
gutter, a scissors effect. The end that moves also has a moving gutter under it that collects any dew or rain on the roof and prevents it from falling on the exposed crop below.

Figure 1 Two types of hinged open roof glass greenhouses. The panels open by rack-and-pinion drives and stand straight up above the gutter (a) and the roof is hinged at the peak and slides on Teflon wheels from gutter to gutter (b).

(a)



(b)



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