COLORADO FLOWER GROWERS ASSOCIATION

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NIGHT HEAT REQUIREMENTS OF PLASTIC COVERED GREENHOUSES[1]

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Greenhouses have large heat requirements, but due to their role, standard insulation techniques are not practical. Research on the heat requirements of greenhouses covered with plastic has been limited until recent years. Axlund, *et al* (1), Lovelidge (3) and Roberts (6) observed fuel reductions of 25 to 30 percent when a double polyethylene film, air-inflated greenhouse cover was compared to a single film layer. Data obtained by Walker and Duncan (7) indicated a 46 percent reduction using the same materials.

A literature search revealed that no simultaneous comparisons of the heat requirements of greenhouses covered with fiberglass reinforced plastic (FRP) or single and double layer polyethylene film had been reported. In 1975 a program was initiated at Colorado State University to evaluate the heat requirements of greenhouses covered with new and well-weathered corrugated FRP panels and single and double layers of polyethylene film. This is the first of a series of reports on the influence of the covers on heat requirements and plant growth.

Materials and Methods

Four identical quonset style greenhouses were erected at the W. D. Holley Plant Environmental Research Center on the campus of Colorado State University. Each structure was 6.1 m (20 ft.) × 14.6 m (48 ft.), with the long axis oriented in a north-south direction.

The houses were covered with: (1) eight year old well-weathered corrugated fiberglass reinforced plastic panels (Old FRP): (2) two layers of ultraviolet-resistant weatherable polyethylene (Dbl Poly), separated by air at a positive pressure of 0.6 cm (2/10 in.) of water column; (3) a single layer of ultraviolet-resistant weatherable polyethylene (Sgl Poly); and (4) new corrugated fiberglass reinforced plastic panels (New FRP).

Identical environmental control equipment was installed in each greenhouse and their operational time monitored. Heat, provided by a horizontal discharge gas-fired unit heater, was directed into a "Fan Jet System" located in the ridge of each house, to provide constant air circulation. Heating and cooling equipment was controlled by a solid state thermostat located in an aspirated shelter near the center of each greenhouse. The greenhouses were heated to 11°C (52°F) from 1700 hours to 0800 hours.

Natural gas consumption in each greenhouse was monitored from 1 December 1976 through 10 March 1977, during the night heating period. Heat was calculated from the combustion efficiency of the unit heaters and the calorific value of the gas.

Records of ambient dry bulb and dew point temperatures, wind speed and cloud cover were obtained from a U.S. Weather Service Station, located 1 km (2/3-mile) north of the greenhouses.

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Results and Discussion

During the evaluation, the Dbl Poly treatment required 26.4, 26.9 and 27.6 percent less fuel than the new FRP, old FRP and Sgl Poly treatments, respectively (Figure 1).

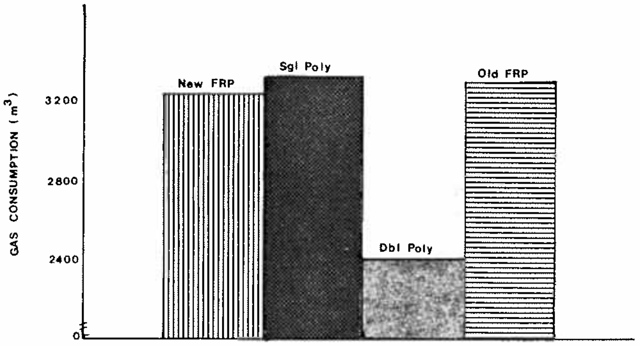

Figure 1. Natural gas consumption (m^3) of greenhouse structures covered with new corrugated fiberglass reinforced plastic panels (New FRP), single layer polyethylene (Sgl Poly), double layer air-inflated polyethylene (Dbl Poly) and well-weathered fiberglass reinforced plastic panels from 1 December 1976 through 10 March 1977, during nocturnal periods (1700-0800 hours). Note: $1 m^3$ = 35.3 ft^3.

The heat requirements of the new FRP, Sgl Poly and old FRP cover treatments were not significantly different, but were significantly greater than that of the Dbl Poly treatment (Figure 2). Dry bulb temperatures and wind speed were the most significant environmental factors influencing the heat requirements of the cover treatments. As the outside temperatures decreased, the effectiveness of the Dbl Poly cover increased. When temperatures reached -15°C (5°F) the reduction of fuel required by the Dbl Poly treatment exceeded 40 percent, compared to the other treatments. Such a high reduction is therefore possible under given conditions, and substantiates the potential capability of the Dbl Poly cover as noted by Walker and Duncan (7).

Dry bulb temperatures accounted for most of the variability in the treatment heat requirements, over 80 percent, and wind speed less than 10 percent.

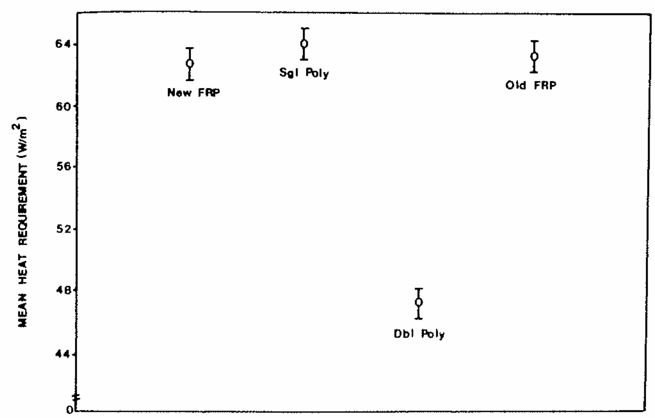

Figure 2. Mean heat requirement (W/m^2) of the cover surface area during night periods (1700 to 0800 hours) from 1 December 1976 through 10 March 1977. Means are not significantly different at the 5% level if horizontal bars overlap. Note: 1 watt (W) per sq. meter (m^2) = 317 BTU/hr/ft^2.

The potential of these covers for reducing heat loss due to wind is evident when these results are compared with the study undertaken by Morris (4). He reported that the heat required by a glass-covered greenhouse would double when wind speed was increased from 0 to 6.7 M/S (15 mph). The heat requirements at an average temperature of 0°C (32°F), of the new FRP, Sgl Poly, old FRP and Dbl Poly treatments increased 112, 82, 73 and 42 percent respectively; significantly less than that reported on a glass-covered house.

Cloud cover and dew point temperature did not significantly influence the heat requirements of these covers. Huang and Hanan (2) indicated that heat loss should increase under clear nights compared to overcast nights. However, Scholte-Ubing (6) has noted that cloud cover does not significantly influence the heat loss from glass-covered structures. The presence of a layer of condensation on the inner layer of these covers possibly reduced the effects of a clear sky, was reported by Walker and Walton (8).

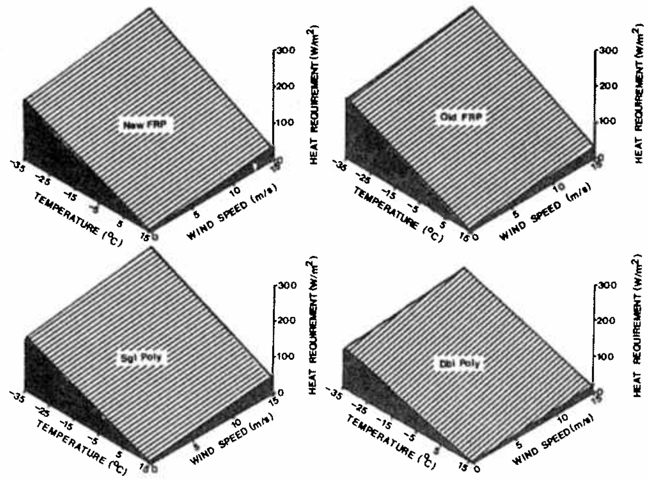

Figure 3. Influence of temperature (C) and wind speed (m / s) on the heat requirements (W / m^2) of greenhouses covered with new corrugated fiberglass reinforced plastic panels (New FRP), well-weathered corrugated fiberglass reinforced plastic panels (Old FRP), single layer polyethylene (Sgl Poly) and double layer air-inflated polyethylene (Dbl Poly). Response surfaces determined by multiple step-wise regression. Note: 1 meter per second (M/S) = 2.24 mph; +15°C = 59°F; -15°C = 5°F and -35°C = -32°F.

Conclusions

Results of this study substantiate the value of a double layer air-inflated polyethylene cover, compared to single layer polyethylene or fiber glass covers for heat conservation purposes. The potential for heat conservation was shown to be a function of temperature and wind speed. Expected savings in heat for a given location with the double layer polyethylene cover would depend on the climate of the area.

Choice of a greenhouse cover should not be made solely on the basis of the results presented here. Other factors, such as solar radiation transmission, heat loss during light periods, crop responses, durability, etc., determine the overall advantage of a cover. These factors will be discussed in forthcoming reports.

Acknowledgements

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