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INFLUENCE OF DOUBLE LAYER PLASTIC GREENHOUSE GLAZING ON FUEL REQUIREMENT AND LIGHT TRANSMISSION

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Introduction

In 1975 four identical quonset style greenhouses, each 20 × 48 ft, were constructed to evaluate solar energy transmission characteristics, fuel requirements and crop responses due to different plastic glazings. The houses are oriented north and south.

During five years of record keeping, the fuel requirements of the four differently glazed structures were influenced largely by the particular weather conditions of the year. The fuel savings of the double layers "602" polyethylene, compared to the newer single layer FRP cover, varied from 24 to 47% during the five year period. The Qualex covered structure required an average of 52% less fuel than the FRP during the 1979 to 1982 heating seasons (CGGA Bul. 381).

Sherry showed that the solar energy received under a new fiberglass reinforced plastic panel (FRP) cover was greater than under any other plastic glazing used in his evaluations (see Sherry et al., 1978. *Acta Horticulturae* 73:321).

Methods and Materials

The 1981-82 glazing evaluations had one structure recovered with 400 XRB 162GT Tedlar© film *(dbl. Tedlar)* attached to each side of tubular steel frames each 4 × 24 ft. and a second quonset with double layered, air-inflated, Monsanto 603 polyethylene. Four-year old *FRP* remained on a third structure and two-year old, 6 mm thick, structured polycarbonate *(Qualex)* remained on the fourth.

The solar energy received within each structure, at plant height, was recorded from September 20, 1981, through April 18, 1982, with horizontal silicon cell pyranometers having sensitivity to radiation from 350 to 1150 nm (nanometers). The spectral distribution of the sunlight inside the houses was measured with a recording spectroradiometer. A Quantum meter was used for instantaneous radiation readings.

Each structure was inividually metered for total natural gas consumed with the day and night fuel requirements separated. A photoelectric cell automatically changed the day and night temperature simultaneously in each house. The houses were heated to 16°C (61°F) during the day and 5°C (9°F) cooler at night.

A second phase of the evaluation involved retrofitting a glass covered peak house with *dbl. Tedlar* film attached to both sides of 50 inch × 17 ft - 9 inch square tubular steel frames. Pyranometers were located five feet below the south slope and the results compared to data obtained in glass (27 yrs.) and *FRP* (2 yr) covered structures, having similar instrumentation. All three structures, their long axis oriented east-west, were of identical size. Fuel was not considered.

Results

Quonset Fuel Requirements. The total fuel requirement (Sept. 17, 1981 - March 18, 1982) for the *dbl. Tedlar* covered structure was 5, 7 and 40% less than the *dbl. poly, Qualex* and *FRP* covered houses, respectively (Table 1). However, the data for the *Qualex* covered structure was influenced by 90 mph winds which damaged a portion of the panels in mid January. The glazing was reattached, but increased infiltration was noted.

The *FRP* covered structure required 6322 m^3 of gas, of which 66% was used at night. The *dbl. Tedlar, dbl. poly* and *Qualex* covered structures required 72, 71 and 68% respectively, of the total fuel consumed during the night. The effects of the double layers on day and night fuel consumption are noted in Fig. 1.

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Table 1. Natural gas required from Sept. 16, 1981, to April 9, 1982, for four quonset type greenhouses, each having a roof exposure of 1340 ft^2.

	Dbl. Tedlar	5 oz. FRP	Dbl. Poly	Dbl. Poly Carb
Day fuel used (m^3)[a]	1081 <50%	2151 (Base)	1189 <45%	1344 <38%
Night fuel used (m^3)	2737 <34%	4171 (Base)	2904 <30%	2878 <31%
Total fuel used (m^3)	3818 <40%	6322 (Base)	4093 <35%	4222 <33%
Percent fuel used at night	72	66	71	68

[a]1 m^3 (cubic meter) = 35.3 ft^3 (cubic feet)

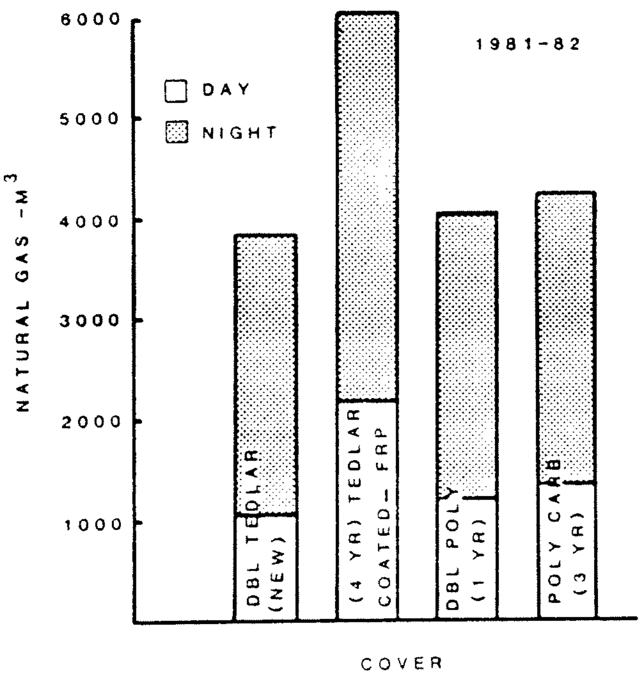

Fig. 1: The relationship of day and night fuel consumption in four quonset structures during the heating season, each having 1340 ft^2 of exposed roof with different glazings.

Radiant Energy Transmitted. The average percent solar radiation transmitted through the *FRP, dbl. poly, dbl. Tedlar* and *Qualex*, from September 20, 1981 through April 18, 1982, to sensors at plant height was 82, 66, 63 and 59 percent respectively. The consistent low level of energy transmitted through the *Qualex* cover (Fig. 2) was attributed to its panel configuration and reflective surfaces, greenhouse orientation and aging characteristics.

The reduced solar energy received under the *dbl. Tedlar* cover from the week of Nov. 22 through Jan. 31 was caused by the accumulation of condensate on the inner surface of the exterior Tedlar layer. One half of the panels were cleared by passing dry air through the cell panels for 48 hours at a rate of 15 ft^{3}hr^{-1}. It was calculated that sunlight was reduced an average of 9.7% due to the presence of condensate. Based on these calculations, the removal of the condensate would have increased the transmission of

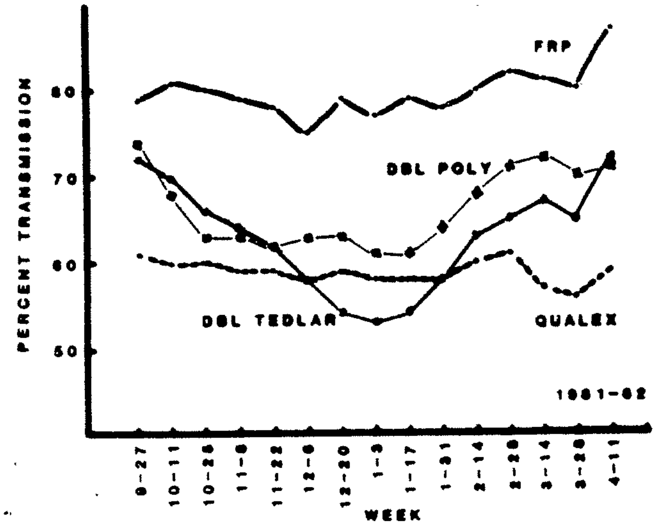

Fig. 2: Three day moving means of percent solar radiation received at plant height under four greenhouse glazings from 20 September 1981 to 18 April 1982.

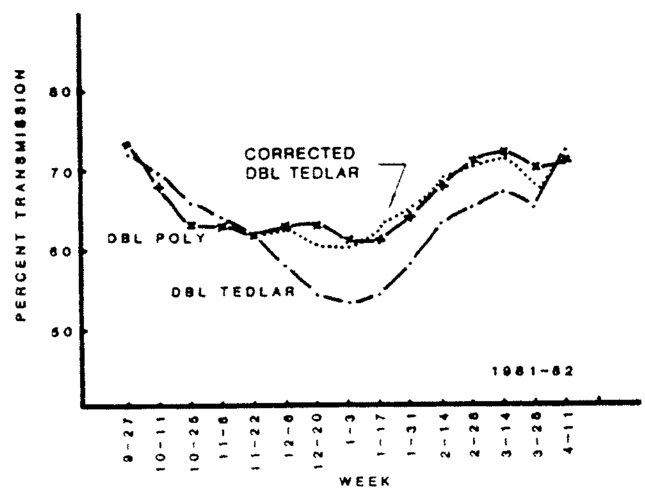

Fig. 3: Calculated change in the energy transmitted by double Tedlar if condensate had not been present from 22 September 1981 to 11 April 1982.

the *dbl. Tedlar* to a level close to that of the *double poly* (Fig. 3).

The energy transmitted through *glass* and *dbl. Tedlar* covers from June 1 through July 1, 1982 was comparable (Fig. 5). The total radiant energy transmitted by the *FRP* cover during the 5 week period was 18 and 20% greater than the *dbl. Tedlar* and *glass* respectively. Shading compound present on the glass was gradually removed by rain the last of May and first of June.

Discussion

Fuel Requirements. The total fuel required by the *Qualex* covered structure during the 1981-82 heating season, was not what would be expected, based on data obtained the two previous seasons. However, there was little difference in the relative proportions of fuel used by the different structures from month to month. Based on two previous

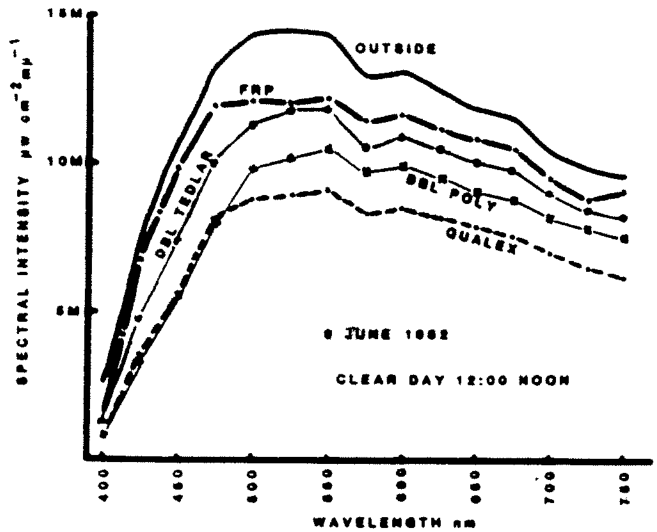

Fig. 4: Spectral transmission curves of insolation received at plant height in four differently glazed greenhouses.

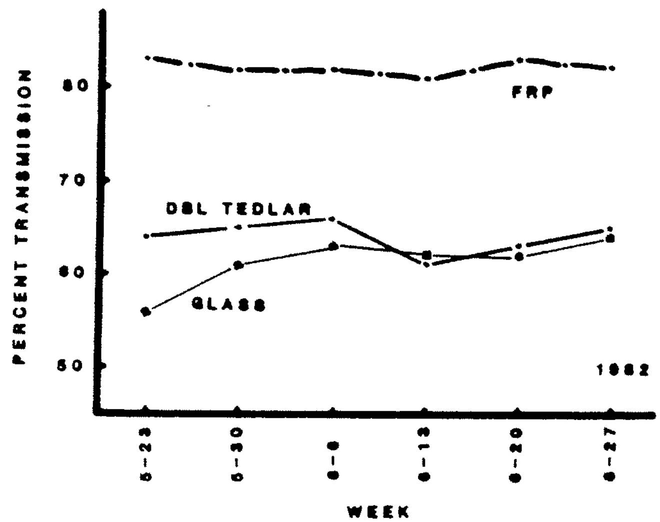

Fig. 5: Percent energy received five feet under the coverings of peaked greenhouses during a six week period. Shading compound was gradually washed off the glass.

years' data, (CGGA Bul. 381) the *Qualex* covered house averaged a 50% fuel savings compared to the *FRP* covered "control" unit. The *double poly* covered sructure savings ranged from 24 to 46.5% during the five year evaluation period (compared to *FRP)* and averaged 6% more fuel required than the *Qualex* cover for the last two heating seasons. It is possible, based on the weather that occurred during the 1981-82 heating season, that the total fuel savings for the *Qualex* structure would have been two to six percent greater than the *double poly* structure and at least equal to the *dbl. Tedlar* covered structure, if the *Qualex* cover had not been damaged by wind.

The increased fuel requirements for the *Qualex* covered structure during daylight hours, compared to the other double covers, could be attributed to the reduced "passive solar" effect created by the cover. However, there are probably no statistically significant differences in fuel consumption due to any of the double covers.

Light Transmission. The amount of sunlight received by plants through a greenhouse cover during a growing season is what counts, not that determined with artificial light in a laboratory. Past (Sherry, 1978) and unpublished research at CSU, has shown that a winter average of 60% total solar radiation at plant height is the cut-off point for acceptable carnation production. When less than an average of 60% light is received by carnations in the CSU greenhouses during a winter season, they will be delayed two to four weeks, have elongated stems and slightly smaller flowers. Both the "603" *double poly* and *polycarbonate* covers, hovered around the "60%" level.

The spectral curves evaluated with the spectroradiometer, indicated a similar photosynthetic active region (PAR) was present under all four greenhouse covers, but their intensity varied. Even though several researchers have suggested that PAR should be the main measurement used to establish the transmission characteristics of greenhouse covers, it appears that pyranometers sensitive in the PAR region, 400 to 720 mu, provide adequate information for general conclusions. Methods of measuring insolation at plant level must be standardized, however, and definitely present a challenge to the greenhouse cover manufacturers and researchers of tomorrow.

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