Colorado Flower Growers Association Inc.

IN COOPERATION WITH COLORADO STATE UNIVERSITY
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Bulletin 189 | January, 1966

Progress Report on Greenhouse Coverings

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Three compartments of a greenhouse were covered in July, 1964 with A. Acrylated frost white fiberglass, B. Polyvinyl chloride rigid panels (opaque type), and C. Polyvinyl chloride rigid panels (crystal clear type). A fourth compartment (D) remained covered with sash bars and glass (approximately 10 years old).

The two benches (140 plants each) per house were planted with rooted cuttings of four varieties of carnations on June 29. Air temperatures were controlled at 52°F at night except in summer. The compartments were heated to 60°F days and cooled at 69°F. CO_2 was not added during the first winter but was maintained at around 500 ppm in all compartments during the winter of 1965-66. Hose irrigation with a nutrient solution was used. Other cultural practices were the same.

The south benches in all compartments were replanted in May, 1965 so that the response of 1- and 2-year plants could be measured the second year.

Spot recordings of direct solar energy inside the compartments at plant height were made at intervals to represent all seasons of the year. These were accomplished by means of the Yellott[2] Sol-A-Meter and Rustrak recorders. Records were also kept of ventilation fan operating time under the several covering materials as an indication of solar heat transmission.

Results

Yield and grade data are divided into periods to correspond roughly with the first fall and winter, spring, summer, and second fall conditions. The first fall, all plants were in their first crop. The second fall, only half the plants were producing a first crop.

Table 1 shows yield and grade of flowers produced under the four coverings. Table 2 shows the total yield and the yield of fancy and standard grade flowers by periods as a percentage of the yields under glass. Only two varieties (White Pikes Peak and Pink Sim) on the north benches supplied the data for the third period, May 9 to September 25. All other periods represent data from four varieties, including Coquette and Safari.

Frost white fiberglass and crystal clear PVC outproduced glass by 16 and 15% during the first 65 weeks of this experiment (Table 1). This higher yield was distributed in all grades of flowers but was highest in the design and fancy grades. The yield increase caused by these two coverings was greatest during the first three periods (Table 2). The increase in yield of fancy grade flowers was greatest for frost white fiberglass during the first, third, and fourth periods, whereas for clear PVC, this increase was greatest during the first, second, and third periods.

[1]Mary L. Schroeder assisted with this work and collected much of the data in completing a special undergraduate problem.

[2]John Yellott Engineering Associates, Inc., Phoenix, Arizona.

Table 1. Yield and grade of carnations (4 varieties) under four greenhouse coverings from June, 1964 to December 13, 1965.

Covering	Grade					Total Yield
	Design	Short	Standard	Fancy	Mean	
A	305	1,465	1,670	1,373	3.85	4,813
B	278	1,480	1,458	1,147	3.80	4,363
C	347	1,381	1,509	1,539	3.89	4,776
D	237	1,319	1,492	1,097	3.83	4,145
Index of yield by grade--glass = 100						
A	129	111	112	125	---	116
B	117	112	98	105	---	105
C	146	105	101	140	---	115
D	100	100	100	100	---	100

Coverings:
- A - frost white fiberglass
- B - rigid polyvinyl chloride panels (opaque)
- C - rigid polyvinyl chloride panels (crystal clear)
- D - greenhouse glass and sash bars (10 years old)

Table 2. An index of total yield and yield of fancy and standard grade flowers by period as affected by covering (glass = 100).

Covering	Period 1	2	3	4	Total all periods
Total yield					
A	118	121	119	103	116
B	111	115	108	81	105
C	112	123	121	105	115
D	100	100	100	100	100
Yield of Fancy grade flowers					
A	162	111	124	140	125
B	89	93	121	92	105
C	153	132	152	108	140
D	100	100	100	100	100
Yield of Standard grade flowers					
A	123	113	109	92	112
B	104	120	90	65	98
C	104	114	91	92	101
D	100	100	100	100	100

Periods
- 1 - June 29, 1964 to March 13, 1965
- 2 - March 14 to May 8, 1965
- 3 - May 9 to September 25, 1965
- 4 - September 26 to December 13, 1965

Compared to glass, all coverings improved flower grade during the third, or summer, period. Clear PVC was superior in this respect.

The increase in standard or short grade flowers by the three coverings was considerably less. Opaque type PVC was not satisfactory as it gradually darkened and became more opaque to solar energy. B compartment was recovered with clear fiberglass in November, 1965 to compare light transmission of this material with the three more satisfactory coverings.

Discussion of results

Briggs (1) and subsequent workers (4, 5, 6) have shown that fiberglass coverings increase yield and grade of carnations in Colorado, in spite of a reduction of measurable light under these coverings. Carpenter (2) has obtained similar results for other crops under fiberglass at Kansas State University. While the increase in growth under fiberglass was greatest during higher light periods, its use has been economically sound at all times of the year in Colorado. Diffusion of the light and reduction of solar heat have been postulated as the major reasons for improved growth under fiberglass coverings.

The results of this experiment and data by Hanan (3) help clarify the reasons for better growth under some greenhouse coverings. Plant temperature is one of the major factors affecting plant growth and quality. Heretofore, the greenhouse environment has been largely controlled by air temperature. The most successful growers have been those who, knowingly or unknowingly, maintained conditions under which the differential between air and plant temperature was least. Hanan demonstrated that greenhouse covering materials greatly influence the heat absorbed by plants and the increase in plant temperature above that of the surrounding air.

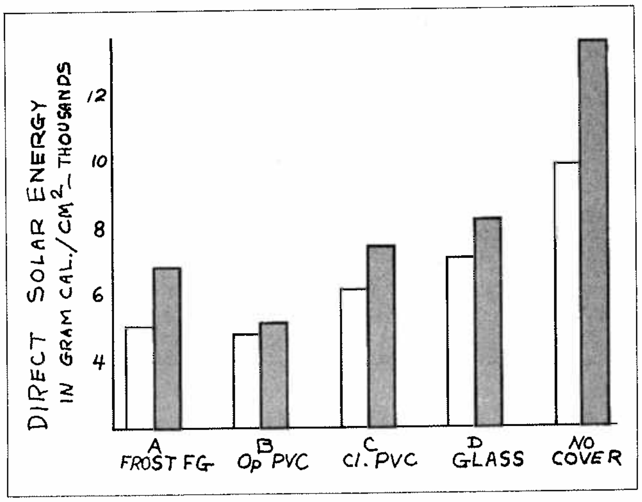

Fig. 1. Direct solar energy recorded for 23-day periods under 4 coverings and in the open. Left bar--March-April; right bar--June-July.

Table 3. Direct solar energy recorded under four greenhouse coverings for two 23-day periods at Fort Collins, Colorado in 1965.

Covering material	March-April		June-July	
	Total solar energy in g cal cm^2	Percent of outside solar energy	Total solar energy in g cal cm^2	Percent of outside solar energy
Frost white fiberglass	4,975	50.6	6,792	50.2
Opaque PVC	4,709	47.9	5,081	37.5
Crystal clear PVC	6,117	62.2	7,424	54.8
Glass and bars	7,108	72.3	8,167	60.3
No cover	9,829	100.0	13,539	100.0

Figure 1 and Table 3 show the measured direct energy under the four coverings during spring and summer periods. All coverings substantially reduced the solar input measured as direct radiation. Plants under glass received up to 20% more of this energy than those under other coverings, but growth was improved under clear PVC or frost white fiberglass. Plant temperatures under the three plastic coverings used in this experiment were probably below those under glass when solar input was high.

A major problem in measuring solar energy is that our instruments are sensitive to both the visible and infrared regions of the spectrum. Visible light is much more important to plant growth while infrared is responsible for plant temperature. Reduction of infrared could result in improved plant growth while the same reduction of visible light could reduce growth seriously. There is even the possibility that a reduction of infrared could counteract a reduction of visible light, the net result being little effect on plant growth.

With this in mind, these results indicate that plants do not need all of the direct solar energy they receive in glass houses. Growth was improved by modifying this energy input. While diffusion of the energy may have been important to the results in the frost white fiberglass house, it was less so in the clear PVC house. The reflection of infrared was no doubt a major factor causing better growth under these two coverings. Further temperature and light measurements are needed to delineate the effects of these and other greenhouse coverings on the energy relationships in greenhouses. The reflection of solar heat should be one of the most important considerations for greenhouse coverings of the future.

Literature cited

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