Colorado Flower Growers Association Inc.

IN COOPERATION WITH COLORADO STATE UNIVERSITY

Doris Fleischer, Executive Secretary
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The Effects of Glass and Fiberglass on Carnation Growth

by

Robert A. Briggs[/1] and W.D. Holley

Clear and coral fiberglass were compared to glass as greenhouse coverings for carnations from January 3, 1960, to April 1, 1961. Clear fiberglass increased yield by 12 percent while significantly improving mean grade of flowers.

Flower color was increased by either coral or clear fiberglass.

Cut flower life and flower volume were not affected by these coverings.

The production of dry matter by young plants during their first 9 weeks of growth was greater under glass and this is attributed to higher plant temperature.

Solar energy transmission measurements yielded the following information:

1. Clear fiberglass transmitted 12 percent less solar energy than glass when measured by a standard Weather Bureau Eppley pyrheliometer.
2. Clear fiberglass reduced energy transmission in the visible and infrared to 96 percent and coral fiberglass to 83 percent of that coming through glass.
3. The energy transmission in the ultra-violet and visible regions by clear fiberglass was 96 percent and by coral 58 percent that of glass.
4. Light transmission from a 6-volt tungsten lamp was 84 percent for glass, 36 percent for clear, and 30 percent for coral.
5. Excess solar heat in the glass house above that required to maintain a 65°F day temperature was 65 percent greater than in the coral house, and 26 percent greater than in the clear house.

Fig. 1. Coral, glass and clear fiberglass experimental houses.

/1 This is a part of the requirements recently completed by Robert A. Briggs for the Master of Science Degree in Horticulture at Colorado State University. The authors wish to acknowledge assistance in this work from the Colorado Flower Growers Association, Inc., and from Filon Plastics Corporation, Hawthorne, Calif.

In an experiment conducted at Colorado State University from December to February, 1956, plastic coverings inside the greenhouse increased dry matter yield of both carnation and tomato. Growth was 26 percent more under clear fiberglass while polyethylene, kodapak, and polyflex increased growth over glass by 8 to 10 percent. In this experiment the coverings were used to filter the light which was transmitted by a glass greenhouse.

Screening tests

Structures with approximate dimensions of 4 by 8 ft., 3 ft. high at the eaves and 50 inches at the ridge, were constructed of wood. The following materials were used to cover them: 1) greenhouse glass, 2) mylar W2 (5 mil thickness), 3) Eskaylite polyvinyl (8 mil), 4) velon screen (14 mesh), and 5-11) Filon 180 corrugated fiberglass paneling in the colors of clear white, frost white, coral, jade, amber, yellow and a special light purple. The sides of all houses were of velon screen to permit natural ventilation.

For ease of construction, all corrugated fiberglass paneling on the roof was arranged with the corrugations running lenthwise of the house. The structures were washed free of dust at least once each week and were spaced so there was no shading of one house by another.

On June 3, 1959, 50 carnation plants were transplanted to each house. These plants had been grown from April 7 in peat pots under a glass house, and were quite uniform. Throughout the experiment all plants were irrigated and fertilized with nutrient treated water. They were watered at tensions of 0.3 to 0.5 bars. Fumigants were used weekly to avoid insects.

All plants were pulled, their roots washed free of soil and their fresh weights obtained August 24. The plants were then dried in an oven to constant weight and individual plant weights obtained. Eskaylite, and clear, coral, amber, jade and frost colors of fiberglass produced significantly more dry matter than glass (Table 1). Mylar and glass gave approximately equal yields, while velon screen and yellow and lavender fiberglass reduced the growth of these plants.

Table 1. Effects of covering materials on growth of young carnation plants from June to August, 1959.

Material	Average fresh weight (gm)	Average dry weight (gm)	Index of dry matter yield
Clear fiberglass	172.0	32.21	118
Coral fiberglass	168.2	31.21	115
Eskay-lite	166.5	31.21	115
Amber fiberglass	160.7	29.98	110
Jade fiberglass	154.9	28.88	110
Frost fiberglass	157.1	29.69	109
Mylar	148.0	28.40	104
Glass	138.6	27.24	100
Velon screen	136.9	24.58	90
Yellow fiberglass	129.8	23.58	87
Lavender fiberglass	118.9	22.17	81

The greenhouse environment

Since clear and coral fiberglass were the most promising permanent building materials from this screening test, special houses were constructed and covered with these two materials and glass. The houses were oriented east-west and are approximately 15 ft. by 18 ft. with 7 ft. to the eaves and 10 ft. to the ridge. The framework was constructed of wood with a 2½ ft. transite wall around the base. The houses were so spaced that they did not shade each other (Fig. 1).

The houses were cooled or ventilated by fans and evaporative pads, and heated with gas space heaters hung from the ridge in each house. Night temperature was controlled at 52° during the heating season and houses were heated to 60°F and cooled at 65 during daytime.

Rooted cuttings of four carnation varieties were benched on January 3, 1960, and grown with a single pinch. Yield, grade and other quality measurements were taken from the beginning of flowering in late May until April 1, 1961. Early injury from flue gases to plants in the coral house caused a serious increase in branching and yield of the first crop, hence the yield and grade data from this house had to be discarded. Some spotty gas injury after November 5, in all houses led to the exclusion of this data from Table 2. A summary of yield, grade and reasons for downgrading the flowers is included in this table for the time up to November 5, for the clear fiberglass and

Table 2. Summary of production and grade of carnations grown under clear fiberglass and glass from January 3, to November 5, 1960.

	Houses	
	Clear	Glass
Total yield (no. of flowers cut	4423	3961
Flowers/sq. ft.	42.53	38.09
Mean grade	4.267	4.079
Mean fresh weight (gm) of cut flowers		
Fancy	28.8	28.1
Standard	20.9	21.5
Percent distribution of grades		
Fancy	44	34
Standard	45	49
Short	4	8
Design	7	9
Percent flowers downgraded		
Insufficient weight	28	18
Short stems	19	37
Malformed flowers	9	11
Total downgraded	56	66

Table 3. Mean cut flower life of carnations grown under clear and coral fiberglass and glass.

Date of sample	No. of flowers per sample	Cut flower life in days		
		Clear	Glass	Coral
Aug. 15, 1960	20	7.0	7.9	7.1
Aug. 17, 1960	20	6.1	6.0	6.0
Aug. 19, 1960	20	7.3	7.5	7.0
Aug. 22, 1960	20	7.4	7.4	7.2
Aug. 24, 1960	20	6.8	7.1	6.9
Aug. 26, 1960	20	6.9	6.9	6.9
Aug. 31, 1960	20	8.3	8.1	8.0
Sept. 21, 1960	20	8.8	8.5	8.0
Oct. 10, 1960	12	7.9	7.6	7.8
Nov. 16, 1960	12	6.4	6.8	6.5
Jan. 4, 1961	12	6.3	6.2	6.0
Feb. 24, 1961	8	5.9	6.3	6.4
March 4, 1961	20	7.3	7.0	7.4
March 29, 1961	20	7.6	7.1	7.3
Mean		7.14	7.17	7.04

Table 4. Average flower color of carnation varieties Pink Mamie and Pikes Peak Frosted grown under clear and coral fiberglass and glass.

Date of sample	No. of flowers per sample	Mean color rating/a					
		Pink Mamie			P. P. Fr.		
		Clear	Glass	Coral	Clear	Glass	Coral
June 20, 1960	12	1.8	2.1	---	1.3	1.7	---
July 13, 1960	6	2.3	2.2	2.3	1.2	1.5	1.5
August 2, 1960	4	2.5	2.5	2.0	1.3	1.8	1.8
August 10, 1960	5	2.8	3.0	2.8	1.0	1.0	1.3
August 15, 1960	5	2.6	2.4	1.4	1.2	1.2	1.2
August 19, 1960	5	1.4	2.0	1.2	1.0	1.2	1.2
August 22, 1960	5	2.2	2.6	1.6	1.4	1.6	1.2
August 24, 1960	5	2.0	2.0	1.2	1.2	1.4	1.0
August 26, 1960	5	1.6	1.8	1.4	1.0	1.2	1.4
August 31, 1960	5	2.2	2.0	1.6	1.2	1.4	1.2
Sept. 21, 1960	5	2.0	2.2	1.8	1.5	2.4	1.6
Oct. 10, 1960	3	1.3	1.3	1.0	1.0	1.3	1.0
Nov. 16, 1960	3	1.0	1.0	1.0	1.0	1.0	1.0
Jan. 4, 1961	3	1.7	2.0	1.3	1.7	1.7	1.3
Feb. 24, 1961	2	1.0	1.0	1.0	1.0	1.0	1.0
March 4, 1961	5	1.2	1.6	1.6	1.2	1.0	1.2
March 29, 1961	5	1.2	1.4	1.0	1.4	1.6	1.0
Mean		1.81	1.95	1.51	1.21	1.41	1.24

/a Rating scale 1 = good color; 2 = slightly faded color; 3 = faded color.

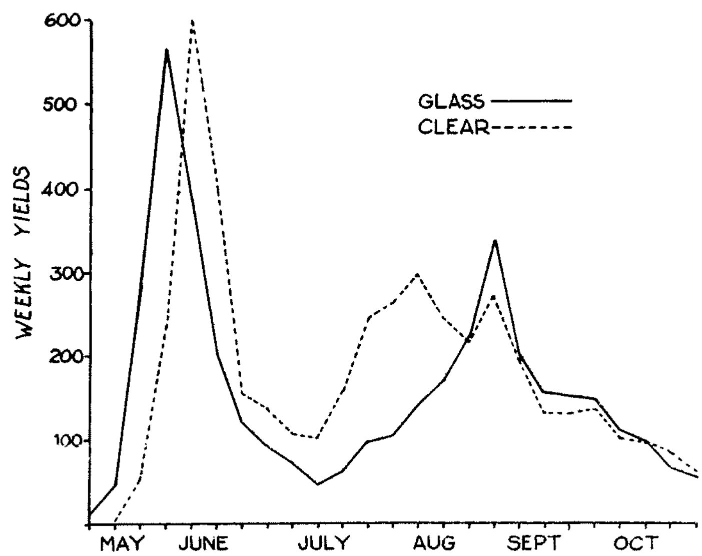

Fig. 2. Yield of flowers from clear and glass houses to November 5, 1960.

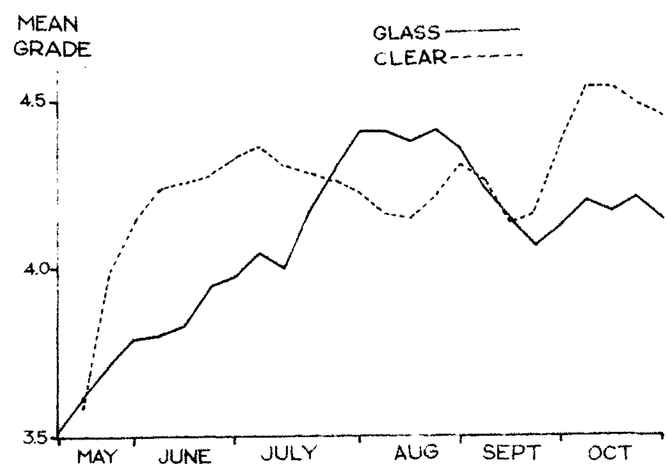

Fig. 3. Mean grade of flowers from clear and glass houses. Mean grade a numerical average with design = 2, short = 3, standard = 4 and fancy = 5

glass houses. The clear house produced 12 percent more flowers with 10 percent more of them in the fancy grade. The clear house also produced fewer flowers in the short and design grades, giving a significant improvement in mean grade of all flowers cut.

Weekly yields from the two houses (Fig. 2) show the first crop one week earlier from the glass house, however, first and second crops were completed earlier in the clear house. The mean grade of flowers was higher for the clear house every month except August (Fig. 3), when plants in this house were just past a peak crop and the glass house was increasing toward the second crop.

Other measurements of quality

Samples of flowers were placed in a controlled 70°F keeping room on 14 dates and their useful life measured. Table 3 shows a difference in keeping life due to sampling date, but no difference due to greenhouse covering.

Cut flower volume as measured by milliliters of water displaced indicated only a difference in size of flowers of 2 percent in favor of either of the fiberglass coverings.

Flower color was arbitrarily rated for the varieties Pink Mamie and Pikes Peak Frosted on random samples of flowers on 17 dates. A rating scale of 1 for good color, 2 for slightly faded, and 3 for faded color was used. The fiberglass houses caused a distinct improvement in flower color (Table 4). Pink Mamie was best in the coral house, whereas Pikes Peak Frosted was the best color in the clear house. Colors were appreciably better under all coverings during the winter months.

Solar energy measurements

Standard Eppley pyrheliometers installed in the clear fiberglass and glass houses picked up 12 percent less solar energy in the clear house.

Silicon cells were used to measure the visible and shorter infra-red regions of the solar spectrum. Continuous recordings were made of this solar energy absorbed by matched cells in each of the houses from September 13, 1960, to January 10, 1961. Coral fiberglass transmitted 83 percent and clear fiberglass 96 percent of the amount of energy transmitted by glass. On cloudy days the amount of solar energy was least in the coral house, and about the same in the clear and glass houses. On bright sunny days the amount of solar energy transmitted varied with the houses.

The amount of solar energy transmitted in the ultra-violet and visible regions was measured by selenium cells from January 12, to March 10. The darkest period (Jan. 12 to Feb. 1) showed the three houses transmitting very close to the same amount of energy in this region. As daylength and light intensity increased the clear and glass houses transmitted a higher percentage of energy than the coral house. The coral and clear fiberglass houses transmitted 58 and 96 percent, respectively, of the amount of solar energy in this region transmitted by glass.

A Beckman Model B spectrophotometer, with a 6-volt tungsten lamp as the light source, was used to measure transmission of light for the three covering materials. With this instrument, glass transmits about 84 percent of this light, clear fiberglass 36 percent, and coral 30 percent.

Table 5. Time of cooling fan operation to maintain 65°F for three structures

Date	Time in minutes Clear	Glass	Coral
April 16, 1961	23	29	21
April 17, 1961	193	195	172
April 18, 1961	197	286	143
April 19, 1961	336	396	201
April 20, 1961	174	136	111
April 21, 1961	233	230	167
April 22, 1961	183	225	139
April 23, 1961	148	188	91
April 24, 1961	0	5	0
April 25, 1961	112	181	104
April 26, 1961	84	103	82
April 27, 1961	147	217	135
April 28, 19t1	140	156	124
April 29, 1961	172	248	173
April 30, 1961	115	251	86
May 1, 1961	28	51	12
Mean	143	181	110

Since the excess heat over and above that needed to maintain the day temperature in a greenhouse is undesirable, a clock was attached to the cooling circuit in each house. The fan speed and amperage of the motors were set together and identical air openings provided the ventilators on the opposite ends of the houses. The time in cooling fan operation is shown in Table 5. Over a 16-day period, cooling capacity required to keep the day temperature down to 65°F or under, was 65 percent greater for the glass house when compared to coral, and 26 percent more for glass than clear fiberglass.

Growth of young plants

Two rooted cuttings per pot of the variety Red Gayety were planted in 18 6-inch pots of old greenhouse soil on June 6, 1960. Six pots were placed in each house and watered on demand with nutrient solution for 9 weeks. At 3-week intervals an additional lot of plants was started. After three weeks of growth the plants were pinched to the fifth pair of leaves. After six more weeks the plants were pulled, their roots washed free of soil, and fresh and dry weights obtained. The net increase in dry matter was calculated and is shown in Fig. 4 for 12 lots of plants. Young plants produced an average of about 8 percent less dry matter under the clear or coral fiberglass when compared to glass. The percentage of dry matter in the plants was increased slightly by fiberglass. The results on young plants under coral and clear fiberglass were so similar that only the weights from clear are included in Fig. 4.

Discussion and implications of results

Solar heat measurements and results with young plants throughout the year indicate higher plant temperatures under glass. Since young plants require higher temperatures, this probably accounts for increased production of dry matter by young plants in the glass house during their first 9 weeks of growth. The glass house came into production from a January planting one week earlier, however the clear fiberglass house produced two complete crops before the glass house (Fig. 2). This indicates that fiberglass makes a more efficient plant growing structure during periods

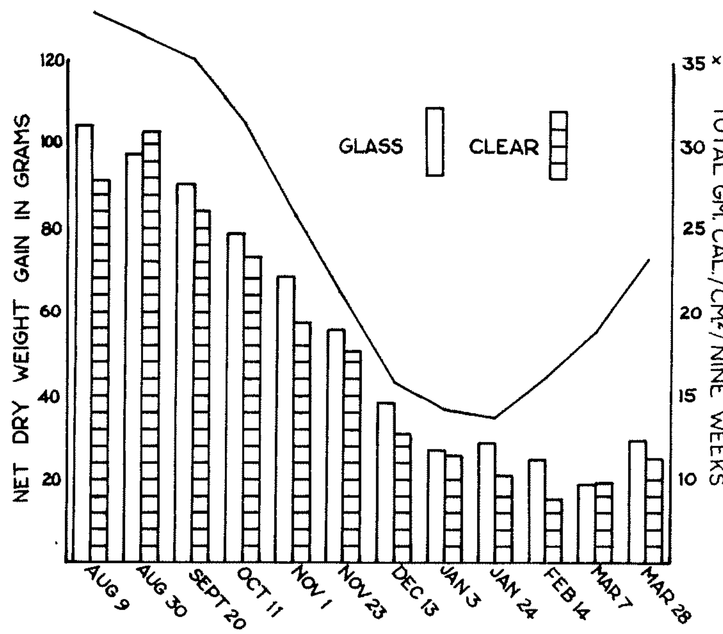

Fig. 4. Production of dry matter under glass and clear fiberglass by 12 lots of young carnation plants harvested at 9 weeks of age.

of high light. It probably loses its efficiency advantage on darker days or during the shortest days of winter. How fiberglass performs in sections with darker winters should be investigated.

Flue gas complicated this experiment so yield and grade records from the coral house and from all houses after November 5, had to be discarded. Poor heat distribution from the space heaters probably contributed to the short internodes and lower grades of flowers during the heating season. Parts of the experiment are being repeated using a steam heating system, in order to compare the structures during midwinter.

Mean grade of flowers was improved by clear fiberglass, principally by delaying slightly the first crop so that fewer flowers were downgraded because of short stems. Flower color was significantly better under either of the fiberglass houses. Flower malformation, which is primarily due to temperature fluctuations, was over twice as great in the glass house during the November to April period. Since glass transmitted more solar heat, and possibly the heat is more concentrated in the plant, flower buds probably reached a higher temperature under glass during the bright, cold days of winter. When cooling fans came on, the resulting drop in temperature of the developing buds was greater in the glass house than under fiberglass.

Diffusion of light and heat

This investigation indicates differences in carnation growth under fiberglass and glass. This difference may be due to the modification of the light by the greenhouse covering. Direct light is the light which comes through the glass and casts a shadow. Diffuse light is uniformly dispersed light and does not cast a direct shadow after it has passed through the fiberglass. The upper surface of leaves at right angles to direct light may become light saturated while other leaves are shaded and well below the saturation point. In diffuse light with no shadows all leaves may be functioning at a higher rate. If this is true, the higher the incident light on a structure, the greater the advantage there should be from the use of fiberglass.

Your editor, W D Holley

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OFFICE OF EDITOR
W. D. HOLLEY
Colorado State University
Fort Collins, Colorado

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