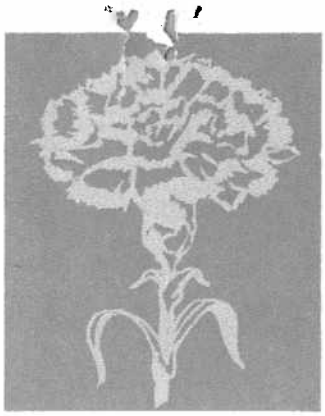

COLORADO FLOWER GROWERS ASSOCIATION, INC.

IN COOPERATION WITH COLORADO STATE UNIVERSITY
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Ventilation Temperatures, CO_2 Levels, and Rose Production

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CO_2 levels above 1500 ppm, combined with ventilation temperatures of 84° F or higher, during the heating season in Colorado, will increase rose production 16 to 20%. Love Affair, Cara Mia, and Forever Yours will respond to such treatment, but Love Affair reacts more vigorously. Higher temperatures and CO_2 levels will reduce average stem length and weight. However, the yield increase more than offsets the slight reduction in stem length. Combining average length, weight, and yield into a "Quality Index" will show higher quality for cut roses produced in 1500 ppm CO_2 levels and where first stage cooling is set to 84° F. Forever Yours will outproduce Love Affair more than 40%, with Cara Mia between the two.

In a preliminary report, Mathis (CFGA Bul. 270) showed that ventilation temperatures starting at 84° F, during the summer will cause a large number of unsalable flowers, although total yield may be increased nearly 50%. It appears that cooling temperatures of 78 to 84° F, combined with mist and elevated CO_2 levels will not affect roses adversely if time at these elevated temperatures is short. But, if such temperatures are maintained for the greater part of the day, the concomitant reduction in weight and stem length can cause excessively poor quality.

Methods

The treatments were identical to those employed by Mathis, except that the CO_2 levels were increased. Briefly, the varieties Love Affair and Forever Yours were planted in the ground in 4 individual, 16 x 18-foot fiberglass houses May 25, 1972, 24 bushes of each variety per house. Two rows of Cara Mia across the ends of each bench served as buffers. A high pressure mist system maintained relative humidity above 70%. CO_2 was injected from sunrise to sunset. Nutrients were injected into the watering line, with irrigation frequency adjusted by a combination of observation, watering records, and tensiometers. Generally, soil moisture suction was not allowed to exceed 30 as indicated by the tensiometers.

Following Mathis' preliminary work during the 1972 summer, ventilation temperatures were adjusted downward on Sept. 25, 1972, with first stage cooling starting at 76° F in all houses. On Oct. 31, 1972, the treatments were set up as outlined in Table 1. Air temperature at the thermostat was recorded continuously in each house. CO_2 levels were monitored for one or two 10-minute periods daily between 10:00 a.m. and 2:00 p.m. Roses were cut daily and the length and weight of each cut flower measured.

Results

The reported data are divided into two periods. From Oct. 31 to Jan. 3, 1973, total first stage cooling time at the low temperatures was less than one hour. Data on the basis of differences in CO_2 levels is presented for this period. From the middle of January, cooling fan time gradually inceased (Figure 1). From Jan. 28 to termination on June 2, 1973, data are reported on the basis of ventilation temperature and CO_2 level. Figure 1 shows, however, that total ventilation time was still less than a fourth of the maximum daylight

hours. It is possible that the treatments could have continued into June before quality reduction began to reach unacceptable levels.

Table 1: Experimental Conditions:

Night temperature all houses: 62° F
Base day temperature all houses: 72° F

Treatment	Ventilation temperature (°F) First Stage	Second Stage	CO_2 level (ppm)
Lo Temp Lo CO_2	78	82	500-800
Hi Temp Lo CO_2	84	88	500-800
Lo Temp Hi CO_2	78	82	1500-2000
Hi Temp Hi CO_2	84	88	1500-2000

Oct. 31, 1972 to Jan. 14, 1973

Table 2 presents the stem length distribution and total yields as a function of variety and CO_2 level. In general, Love Affair produced fewer flowers with poor quality. There was a slight shift toward shorter stems for both varieties at the high CO_2 level. But, the increase in yield at high CO_2 concentration more than offset the slight decrease in weight and length. Roses grown at 1500 to 2000 ppm CO_2 produced 16% more flowers during this period than roses grown at 500 to 800 ppm. Although Love Affair, on the average, produced about 45% fewer flowers in all treatments, it responded slightly more to increasing CO_2 (21% increase versus 14% for Forever Yours).

Jan. 28, 1973 to June 2, 1973

The results for this 18-week period are set out in Table 3 and Figures 2 and 3. Either a high ventilation

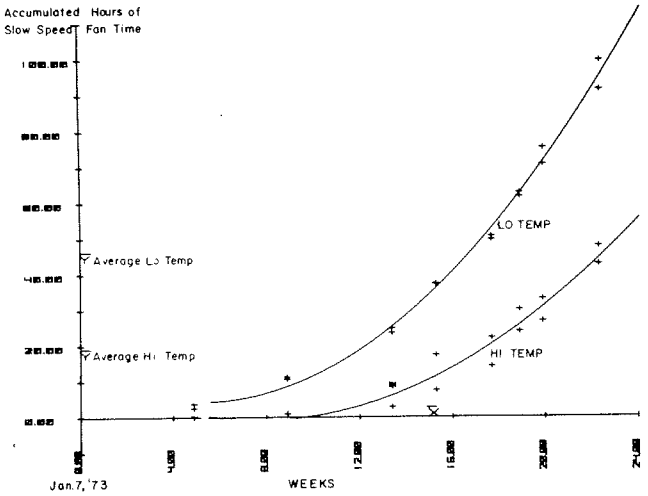

Figure 1: Accumulated hours of first stage exhaust fan time, beginning Jan. 7, 1973.

temperature, high CO_2, or combination of the two resulted in higher yields. The combination of 84° F first stage cooling and 1500 to 2000 ppm CO_2 increased total yield for this period 33% over the 78° F and 500-800 ppm treatment. The high percentages of stems 27 inches and over resulted from cutting stems to the break or below to prevent flowers from growing into the roof. This procedure did not appear to greatly affect yield or time to flower. This "non-effect" has been suggested by Goldsberry (unpublished data).

Higher temperatures caused a reduction in mean stem length and weight, which, in the case of Forever Yours, was compensated by the increase in CO_2 level (Figure 2). The decrease was relatively slight, and computation of a "Quality Index" (Figure 3) showed that the yield increase as a result of high CO_2 and longer CO_2 injection periods more than offset any decrease in stem length and weight. There was some indication toward the end of May that quality of Love

Table 2: Effect of two CO_2 levels on stem length distribution and total yield of Forever Yours and Love Affair roses for a 12-week period beginning Oct. 31, 1972.[1]

CO_2	Variety	Percent stem length distribution 9"	9-12	12-15	15-18	18-21	21-24	24-27	27	Yield (total)	Yield per plant
High[2]	Forever Yours	—[3]	—	3	9	21	27	23	16	792	16.5
	Love Affair	2	1	7	14	23	21	20	17	556	11.6
Mean		1	—	5	11	22	25	22	14	1348	14.0
Low	Forever Yours	—	—	1	6	16	25	27	23	693	14.4
	Love Affair	—	2	5	11	23	17	26	17	466	9.7
Mean		—	—	3	8	19	22	26	21	1159	12.1

[1] *48 plants per variety.*
[2] *"High CO_2," ranging from 1500 to 2500 ppm; "Low CO_2," ranging from 500 to 800 ppm with exhaust fans off, from sunrise to sunset.*
[3] *Less than 1%.*

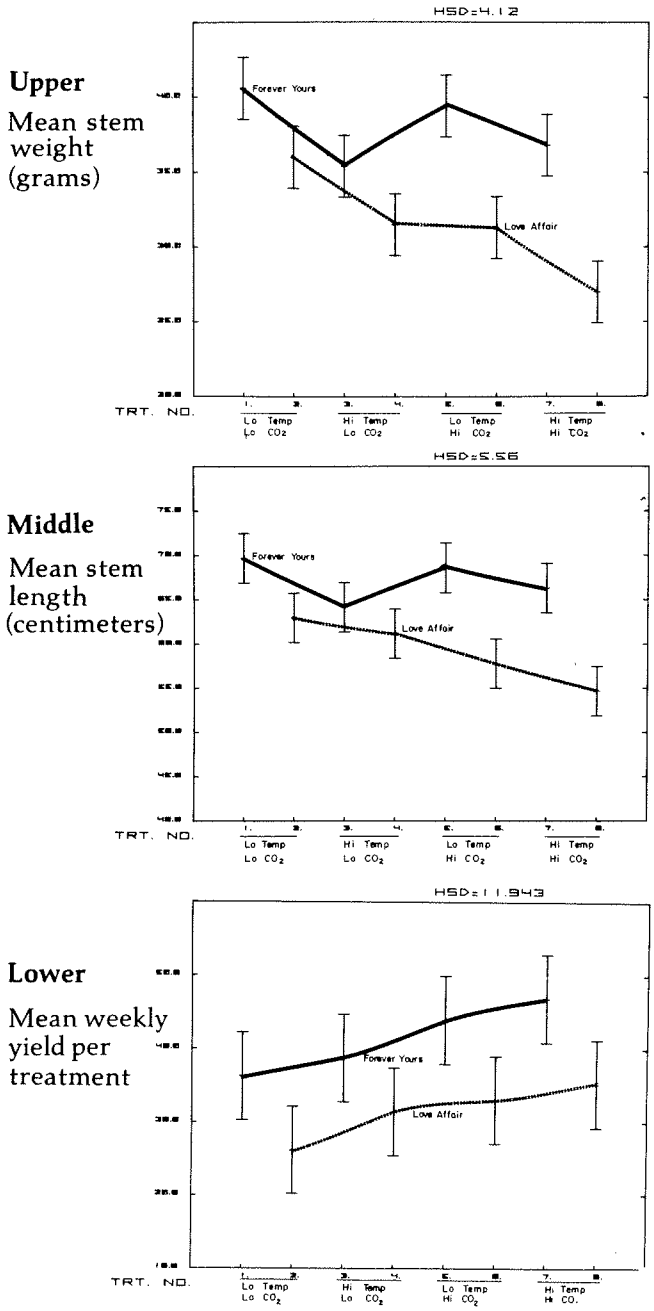

Figure 2: Summary of effects of CO_2 levels and ventilation temperatures on Forever Yours and Love Affair roses produced between Jan. 28, 1973, and June 2, 1973. "Lo CO_2" levels 500-800 ppm; "(Hi CO_2" levels 1500-2000 ppm; "Lo Temp" first stage ventilation at 78° F; "Hi Temp" first stage ventilation on at 84° F. Vertical bars through each point are limits for a 95% confidence interval. That is, where the bars of two points being compared do not overlap, there is a 95% probability that the differences are real.

Affair was beginning to suffer. The 9-inch, or less, stem lengths were 14% of the total flowers cut as contrasted to 4% for Forever Yours in the same treatment (Table 3). Similarly, as in the first 12-week period, Love Affair showed a greater response to treatment (37% yield difference between treatment extremes versus 30% for Forever Yours). However, Love Affair produced 25% fewer cut roses on the average.

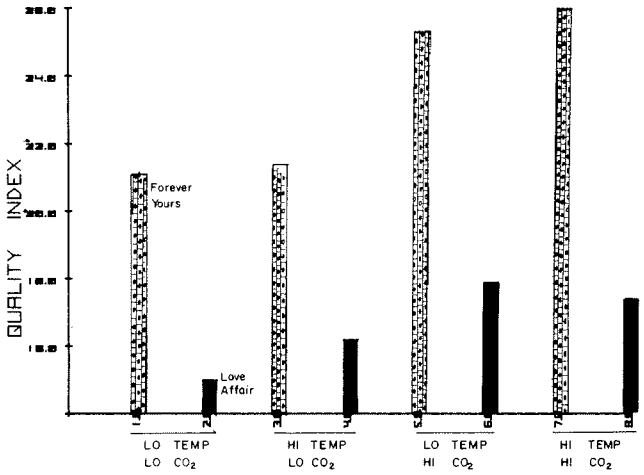

Figure 3: Mean Quality Index of Forever Yours and Love Affair roses subjected to different CO_2 levels and ventilation temperatures.

Q.I. = **Mean stem Weight** X Yield

Oct. 28, 1972 to June 2, 1973

Figures 4 and 5 compare treatments for both reporting periods. Figure 5 shows that roses subjected to 1500-2000 ppm CO_2 increased the number of cut flowers produced on the average of 138 per week, whereas those plants subjected to 500-800 ppm increased total production at the rate of 118 flowers per week (96 plants). That is, one may expect, on the average, a 17% increase in total flowers produced each week when roses are subjected to 1500-2000 ppm CO_2. Figure 5 is a smoothed curve of total weekly production for Forever Yours in the treatment extremes. A number of points may be emphasized: 1) During the experimental period there were 5 peaks of production for the "hi temp-hi CO_2" treatment as compared to 4 for the "lo temp-lo CO_2" treatment. 2) The peak production and number of flowers during off-crop production steadily increased throughout the experimental period (30 weeks) in the "hi temp-hi CO_2" as compared to the "lo temp-lo CO_2" treatment. 3) The time to return from peak production to the next peak for Forever Yours at "hi temp-hi CO_2" was usually one week quicker than Forever Yours in the "lo temp-lo CO_2" treatment. Similar plots of Love

Table 3: Effect of CO_2 level and ventilation temperature setting on stem length distribution and total yield of Forever Yours and Love Affair roses for 19-week period beginning January 28, 1973.[1]

Treatment	Variety	Percent stem length distribution								Yield (total)	Yield per plant
		9"	9-12	12-15	15-18	18-21	21-24	24-27	27		
Lo Temp	Forever Yours	—[2]	2	3	4	7	11	16	55	641	26.0
Lo CO_2	Love Affair	5	6	5	4	10	11	14	45	471	19.6
Mean		3	4	4	4	8	11	15	51	1112	23.2
Hi Temp	Forever Yours	3	4	6	6	9	9	11	51	698	29.1
Lo CO_2	Love Affair	6	8	6	5	6	11	14	44	567	23.6
Mean		4	6	6	5	8	10	12	48	1265	26.4
Lo Temp	Forever Yours	2	4	5	5	9	7	12	57	792	33.0
Hi CO_2	Love Affair	8	9	7	6	10	9	11	40	591	24.6
Mean		4	6	5	5	9	8	12	50	1383	28.8
Hi Temp	Forever Yours	4	4	6	4	6	9	12	54	835	34.8
Hi CO_2	Love Affair	14	14	9	5	6	7	11	33	645	26.9
Mean		8	8	7	4	6	8	12	45	1480	28.8

[1]*"Lo Temp," ventilation started at 78°F; "Hi Temp," ventilation started at 84°F; "Lo CO_2," concentration ranging from 500 to 800 ppm with no ventilation; "Hi CO_2," concentration ranging from 1500 to 2500 ppm with no ventilation.*
[2]*Indicates less than 1%.*

Affair did not show the regular progression of production peaks, although yield gradually increased toward the end of the experimental period.

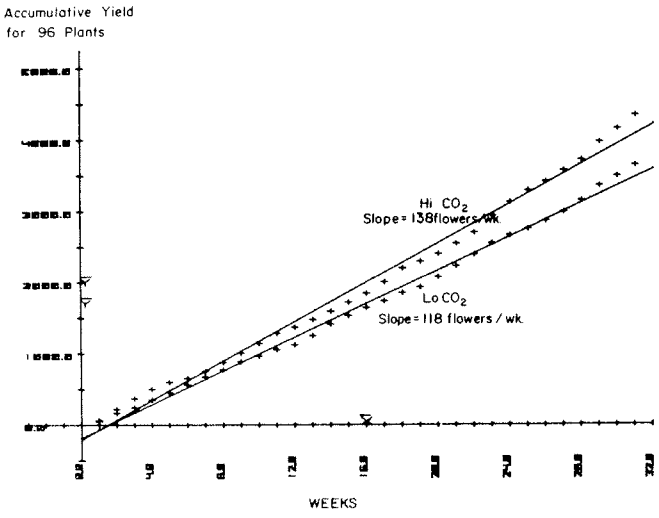

Figure 4: Weekly accumulated yield of Forever Yours and Love Affair roses subjected to CO_2 levels of 500-800 ppm and 1500-2000 ppm. The number for each slope shows the rate at which flowers were being produced each week (96 plants per treatment).

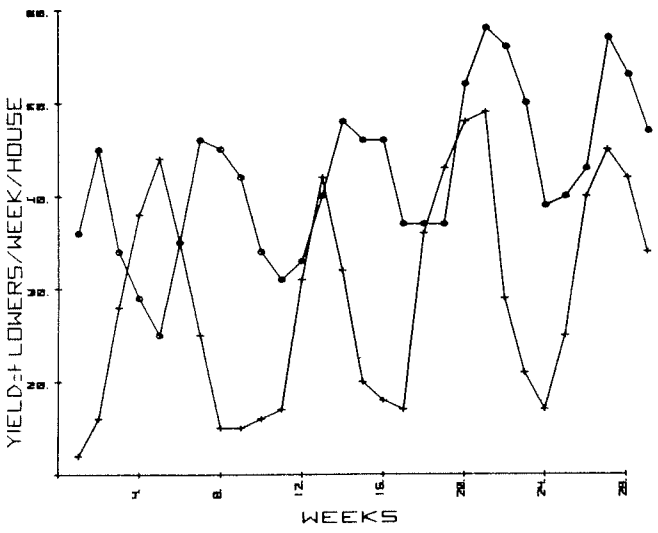

Figure 5: Smoothed weekly production of Forever Yours roses subjected to 1500-2000 ppm CO_2 and first stage ventilation at 84° F (circles); and the same variety subjected to 500-800 ppm and first stage ventilation at 78° F (crosses). Experiment beginning Oct. 31, 1972, and terminated June 2, 1973.

Summary

Increasing the temperature at which cooling begins allows roses to be subjected to high CO_2 levels for a longer period. If we assume that the 1972-73 heating season is representative for Colorado, then a first stage cooling setting of 84° F is acceptable. We estimate that total weekly, first stage cooling time should be less than 6 hours. When it begins to exceed this amount, there is increasing probability that temperatures may remain high enough and exhaust fans run long enough, to significantly reduce CO_2 levels and reduce quality. The cooling temperatures should then be adjusted downward to below 78° F for the first stage. One may characterize the best rose environment as one in which people are uncomfortable. High temperatures and high CO_2 levels should be accompanied by high relative humidity levels.

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