Colorado Flower Growers Association, Inc.

IN COOPERATION WITH COLORADO STATE UNIVERSITY

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The Use of Carbon Dioxide on Carnations

by

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A review and discussion of the research done to date at Colorado State University on the addition of CO_2 to carnation greenhouses should indicate possible avenues for practical application. While the response of roses to CO_2 atmospheric fertilization has been easily measured and made rather quickly applicable to commercial use, carnations have been slower to react to CO_2 and the practice of adding CO_2 to carnation greenhouses requires a careful evaluation of several contributing factors.

Questions which we have had to answer are: 1) What are the levels of CO_2 in a carnation house at various light levels? 2) How much time can CO_2 be added? 3) Can this time be increased, and how? 4) When and how much CO_2 should we add? 5) What results can be expected, and are these economically sound?

Goldsberry (2) grew carnations in air conditioned growth chambers which received normal sunlight, controlled temperatures and nutrition, and CO_2 levels from 200 to 550ppm. Under this set of conditions it was possible to measure the effects of CO_2, the one variable. Yield was increased 30 and 38% in chambers receiving 350 and 550ppm CO_2 when compared to the chamber in which 220ppm concentration was maintained. This yield increase was for a period of 53 weeks following planting, which included slightly more than 2 crops of flowers. The percentage of dry matter in the cut flowers and stems was raised significantly by increasing the CO_2 concentration. Stem length was shortened slightly, and time required to produce flowers was decreased at the higher CO_2 levels. Cut flower life was not affected.

The increase in yield was greatest when levels were maintained at 350ppm and much less substantial when increased another 200ppm. This would indicate that the most efficient use of CO_2 may come

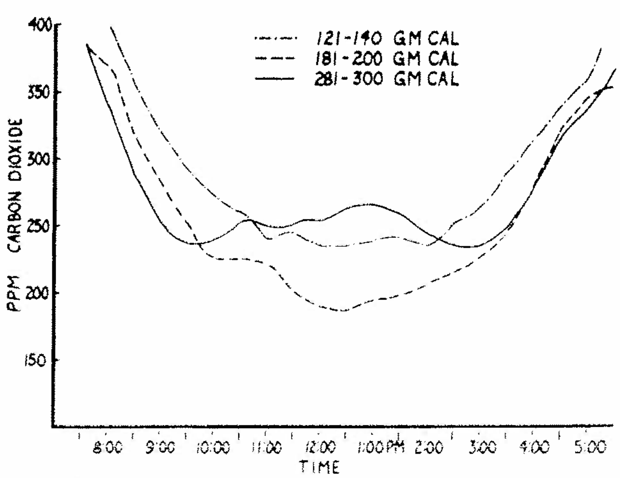

Fig. 1. Mean CO_2 levels in a carnation greenhouse at 3 levels of light energy.

from the judicious use of smaller amounts at the right times, in order to prevent the occurrence of deficiency levels.

CO_2 in a carnation greenhouse at various light levels

Almost continuous records of CO_2 concentrations in several greenhouses have been kept at CSU for 3 years. From a part of these records CO_2 measurements were grouped according to the light energy striking the greenhouses and the average readings at 30-minute intervals are plotted in Figure 1. Representative light levels only are used for clarity, but these show a distinct pattern. At the lowest light level (121-140 g cal/cm^2), which is about the darkest winter weather received in Colorado, the average CO_2 level decreases below 250ppm before 11AM and goes above 250 at about 2:30PM. It does not go below 235 on the average because the low light limits CO_2 assimilation. As the light level increases to 181-220 g cal/cm^2, average winter light in Colorado, CO_2 goes below 250ppm at 9:30AM, reaches a low point of 180ppm at noon, and increases to 250 around 3:30PM. On a bright winter or early spring day with solar energy at 281-300 g cal/cm^2, something different occurs to the CO_2 concentration in a carnation house. It goes down rapidly in early morning but remains just above or below 250ppm all day because ventilation is required on many days which have this solar energy level. From these measurements we can conclude that the more light we get, the more CO_2 we should add in order to keep the concentration in the greenhouse to a desired level. However, as soon as ventilation is on, the addition of CO_2 should stop, for levels immediately approach those of the outside atmosphere.

How much time can CO_2 be added to carnations?

Cool growing crops such as carnation and snapdragon require much more ventilation to keep temperatures down, thereby reducing the time CO_2 can be added. Korns (4) added CO_2 automatically to a carnation house by connecting the ventilating fan and CO_2 flow valve to a double-pole relay. When the fan was off, CO_2 was flowing, and vice versa. He recorded the CO_2 flowing time by means of a clock attached to the circuit. Table 1 shows Korn's determinations from August 1961 to April 1962. The possible flow time was set with a 24-hour time clock and was decreased from August to December. This data tells us for the first time that a carnation house is in a closed system (no ventilation on) about half the daylight hours from August to April in Colorado. It is during this time we are growing in a closed system that we can hope to use carbon dioxide most efficiently. While closed-system time is appreciable in cooler climates, it can be increased from September to May by clear fiberglass coverings by approximately 27% (3). Research is already under way to find additives to fiberglass or glass which will increase the reflection of infra red thereby further increasing the time CO_2 can be added. We already have carnation varieties and clons that require warmer day temperatures, which will also increase the time in a closed system. There is also some evidence that the optimum temperature for plants increases at higher CO_2 levels (1). All of these factors working together may eventually allow us to add carbon dioxide 90% of the daylight hours during late fall and winter.

Table 1. Per cent of daylight hours CO_2 could be added automatically to carnation greenhouses at Fort Collins, Colorado, 1961-62.

Month	Possible hours/day	Possible hours/month	Time CO_2 added-hours	Lbs. liquid CO_2/month[a]	Per cent time CO_2 added of possible
August	10	310	25	2.9	8
September	10	300	156	17.9	52
October	9	279	128	15.7	46
November	9	270	194	22.3	72
December	8	248	169	19.4	68
January	8	248	164	18.9	66
February	8	224	139	16.0	62
March	8	248	124	14.3	50
April	8	240	72	8.3	30
Total		2367	1171	135.7	

[a]Pounds added per 300 sq. ft. at rate of 1 cu ft/hr/300 ft^2

What results can be expected?

As a part of his automated temperature research, Korns (4) had two greenhouse compartments in which the only factor in variance was CO_2. Both were inside compartments with day and night temperatures correlated with light. CO_2 was added to C Compartment during daylight hours when the ventilation was off at the rate of 1.2 cu ft/hr/300 ft^2. One half of the area was used for successive crops of young carnation plants. Thirty rooted cuttings were started every 3 weeks and grown for 12 weeks, pulled, and dry matter production determined. He produced 19 overlapping crops from which to measure growth at all times of the year. The other half of each compartment was in producing White Sim from which yield, grade and other measurements were taken. These plants were started January 7, 1961, and records terminated in May of 1962.

Table 2. Mean increase in dry matter production of young carnation plants grown 12 weeks in 6-inch pots.

Growth period	Dry weight increase as % of original weight: Compartment B No additional CO_2	Compartment C CO_2 added when fan not running
1/10 to 4/4/61	718	829
1/31 to 4/25	834	966
2/21 to 5/16	1066	1119
3/14 to 6/6	1192	1230
8/29 to 11/21	612	699
9/19 to 12/12	460	495
10/10 to 1/2/62	312	340
10/31 to 1/23	323	402
11/21 to 2/12	402	446
Mean	657	725

Minimum dif. for significance at 5% level = 13

The mean increases in dry matter for periods when CO_2 was being added to Compartment C are shown in Table 2. The dry matter increase is shown as a percentage of the dry weight of the original cuttings. While the difference averaged only 10% in favor of CO_2 additions, these differences were consistent and highly significant. Since temperatures were maintained nearer optimum for producing plants and there was some leakage of CO_2 into check Compartment B (Table 4), the differences could be expected to be greater. The differences in yield and grade of cut flowers in Table 3 are also less than they would have been had the partition between compartments been gas tight. Table 3 includes the flowers cut before July 2, 1961, and those from September 10 to January 27, 1962. CO_2 was not added at other times.

Table 3. Summary of production[a] on White Sim benched January 7, 1961.

	Compartment B	Compartment C
Yield	792	914
Mean grade	4.61	4.59
Mean weight of cut flowers in grams		
Fancy grade	30.7	31.5
Standard grade	20.3	22.4
Per cent distribution in grade		
Fancy	78	73
Standard	13	16
Short	2	2
Design	7	9
Per cent downgraded		
Insufficient weight	6.7	4.2
Insufficient stem length	5.1	10.1
Inferior fls. and weak stems	4.3	4.5
Split calyxes	1.1	1.7
Bullheaded fls.	1.7	2.8
Slabsided fls.	2.5	2.7
Hollow centers	0.6	1.0

[a]Measurements include flowers cut before July 2, 1961, and from September 10 to January 27, 1962. Test plots 42 ft^2-- 126 plants.

Test plots contained 42 ft^2 or 126 plants. Yield was increased by 15%, with the average weight of both fancy and standard grade flowers significantly greater at the higher CO_2 level. In the compartment where CO_2 was added, the principal reason for downgrading was lack of stem length, while insufficient weight for the grade (small flowers and stems) is usually the major reason. A few more malformed flowers in the CO_2 compartment were traced to erratic thermostat action on isolated occasions.

Table 4. Average daily carbon dioxide levels in 4 greenhouse compartments.

Per cent fan ventilation time in Compartment C	Carbon dioxide levels (ppm) Compartments A	B	C	D
Greater than 50% of time	330	345	370	320
Less than 50% of time	288	350	420	290

Miscellaneous measurements made on the cut flowers from these two compartments showed no significant differences in percent day matter of the cut flowers or flower heads. Flowers from plants receiving higher CO_2 had significantly heavier flower heads and more internodes per fancy length stem. Five buds of 1/4" diameter were tagged on 7 dates in each compartment. The buds developing in CO_2 enriched atmosphere opened consistently 2 days sooner, or in 54 days compared to 56 for those in Compartment B. Stem strength as measured by degrees divergent from horizontal was slightly better from Compartment C, however the difference was not significant. Cut flower life measured on six dates averaged the same.

The conservative nature of the differences obtained in Tables 2 and 3 can be seen by studying the average daily carbon dioxide levels presented in Table 4. These levels are separated into those when fan ventilation was operating more than half and less than half of the time. If the ventilating fan operated in B while CO_2 was flowing in C, leakage occurred through the partition and raised the level above A or D, neither of which received additional CO_2. While D was adjacent to C, the fan in C was always in operation when the fan operated in D. Table 4 shows a significant increase in the daily CO_2 concentration in Compartment C, but it also shows that the difference would have been greater, had not leakage occurred into B.

A look at the cost

The pounds of liquid carbon dioxide or dry ice required per month are calculated in Table 1 for the year 1961-62. This serves only as a guide for ventilating time varies with years and climates. Due to the slow rate of development of carnations it is important to use CO_2 as early in the fall as possible in order to increase yield before June of the following year. Appreciable CO_2 adding time can be gained in late summer and fall by adjusting the time clock to start the flow 1 hour after daylight and stop at sunset. By setting the thermostat which controls the first stage of ventilating fans at 65°, appreciable CO_2, adding time can be gained in early morning and on cool days. Other means of adding CO_2 automatically when the house is closed during daylight hours will suggest themselves.

On the basis of the measurements in Table 1, 135 lbs. of CO_2 would be used per 300 sq. ft. from August to April inclusive. At 5 cents/lb. this would amount to a cost of 3.4 cents per sq. ft. of bench area. Since the addition of CO_2 after February may be of little value on carnations, other than to increase summer yield, 1/6 of the total CO_2 for the year could be saved by stopping flow on March 1. Or better still, finding ways of using this CO_2 in the fall when it will do the most good for winter yield and quality.

Summarizing the effects to be expected from the addition of this amount of CO_2 to carnations, 1) yield should be increased by at least 10%, and 2) heavier flowers and stems should keep the quality consistently high, helping to nullify the effects of low light periods.

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