Supplemental carbon dioxide

A summary of its benefits

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In the commercial production of plants, five factors determine the extent to which the plant's genetically pre-determined potential is fulfilled:

1) the environmental temperature the plants are grown in.

2) the quality, quantity, and duration of light the plant is exposed to.

3) the amount of water available to the plant for the processes of growth and transpiration.

4) the amounts and types of nutrients present in forms that can be readily absorbed by the plant.

5) the atmospheric composition that surrounds the plant. We wish to discuss a part of this final factor, the carbon dioxide fraction.

The atmosphere is 78 percent nitrogen (N_2), 21 percent oxygen (O_2), .95 percent argon (A), 0.1 miscellaneous gases, and .033 percent carbon dioxide (CO_2). It is this 330 parts per million of carbon dioxide that is the carbon source of plants. Carbon is fixed by photosynthesis and is the basic building block of all plant components.

In a field situation, air moves freely around the plants and the CO_2 concentration is held fairly constant by mixing and diffusion. A greenhouse is very similar to a field when the vents are opened or fan and pad cooling allows for air exchange. However, as outside temperatures drop and steps are taken to tighten up the greenhouse for heating conservation, air exchange and mixing are greatly reduced.

Therefore, as the crops in a tight greenhouse photosynthesize during the day, the carbon dioxide is fixed and removed by the plant but is not replenished by air exchange. The level of carbon dioxide can be reduced to as low as 150 ppm (Wittwer and Robb). With less carbon dioxide available to the plant, photosynthetic carbon fixation is decreased and plant growth is inhibited as surely as if the plant had a water or nutrient deficiency.

Carbon dioxide stress does not readily identify itself like water stress, which appears as wilting or yellowing, or as nutrient deficiencies, which often show as chlorosis or discoloration. Rather, carbon dioxide stress results in reduced growth and/or lower quality. Without a control plant growing in normal or enriched CO_2 environments, it is difficult or impossible to perceive the reduced growth and quality.

Just as plant growth is increased when nutrients are added to an unfertilized soil, the addition of CO_2 to supplement or increase the ambient CO_2 concentration will enhance growth. Increased yield and improved quality have been documented time after time in research articles (See Table I).

Little attention however has been paid to CO_2 enrichment in recent years. During the 1960s, addition of CO_2 to greenhouses was common. Growers, however, have allowed their equipment to deteriorate and CO_2 is not extensively used now. We feel that the subtle changes in crop quality and timing often were not visible to the grower's eye one year to the next without a control plant, and therefore supplemental carbon dioxide has fallen out of common use.

Our primary purpose is to increase the grower's awareness of CO_2, its benefits, and the crop losses possible in our now tightened-down, energy-conserving greenhouses. Tight greenhouses are ideal for supplementing CO_2 because little CO_2 is lost by air exchange. Yet when CO_2 is not supplemented, severe deficiencies can occur due to low air exchange rates.

We feel that supplemental CO_2 is a good investment for the grower where outside temperatures are low during much of the winter and little venting occurs. Assuming CO_2 generation inside a greenhouse using natural gas, we calculate the total cost of supplementing CO_2 to 1500 ppm for eight hours per day for 120 days to be approximately 4 cents per square foot. This does not account for the additional benefit received in the form of supplemental heat. A geranium cutting producer has recently indicated to us that he gets a solid 20 to 25 percent increase in cuttings by supplementing CO_2 in his stock plant ranges.

While addition of CO_2 can be easily accomplished by open-flame burners inside a greenhouse, care must be taken to prevent oxygen depletion, resulting in ethylene and carbon monoxide production. Recommended spacing and installation procedures should be followed when purchasing and installing open-flame CO_2 burners.

Stan Schumacher is a graduate student conducting research on photosynthetic efficiency and plant modeling at Michigan State University. His assistantship is supported by a grant from the Fred C. Gloeckner Foundation. Royal Heins is an assistant professor at MSU.

For further reading...

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Table 1. Influence of enriched carbon dioxide atmospheres on plant growth and yield. This table is representative of the CO_2 literature and is not intended to be a complete listing of all references.

Crop	Effect	Response	CO_2 conc.	Reference
African violet	Increased dry weight	20%	500 ppm	Shaw and Rodgers (1964)
Carnation	Increased yield vs 200 ppm vs 350 ppm Earlier flowering	 37% 7% 2 weeks	550 ppm	Goldsberry (1961)
	Increased yield Increased number of "Fancy" flowers	9% 20%	Not stated	Holley and Juengling (1963)
	Increased cutting production	25 more cuttings per ft^2	550 ppm	Goldsberry (1966)
Cucumber	Increased yield	10-25%	Variable, up to 9000 ppm	Owen and Small (1926)
Cyclamen	Increased flower number Increase plant dry weight	0-115% 22-31%	Not stated	Cummings and Jones (1918)
Geranium	Increased branching Increased flower number Shorter maturation time	14% 72% 1 month	1100 ppm	Shaw and Rodgers (1964)
	Improved cutting production	12-40%	Not stated probably 1000 ppm	Malmburg (1966)
Mums	Increased stem length Increased weight	19-37% 0-47%	1200-1500 ppm	Koths and Adzima (1965)
	Increased fresh weight Increased stem length	33-48% 26-28%	1000 ppm 1000 ppm	Shaw and Rodgers (1964)
	Increased cutting production	29%	1100-1800 ppm	Kobel (1965)
Rose	Increased yield	31%	1100 ppm	Shaw and Rodgers (1964)
	Increased yield	12-33%	Not stated	Goldsberry and Holley. (1962)
	Increased yield Improved grade (increase in % of stems 18-30 inches in length)	60% 16%	1200-2000 ppm	Lindstrom (1965)
	Increased yield	7-27%	1200-2000 ppm	Mastalerz (1977)
	Increased yield	14-22%	2000 ppm	Mattson and Widmer (1971)
Snapdragon	Increased fresh weight Increased dry weight	57-86% 67-90%	1200-2000 1200-2000	Lindstrom (1964)
Tomato	Increased plant weight Larger leaf area Increased fruit production	83% 50% 13%	Raised to 10,000 ppm in the morning, then allowed to decline during the day	Bolas and Melville (1935)
	Increased yield	10-25%	Variable, up to 9000 ppm	Owen, Small, and Williams (1926)

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Forty florists from 15 states dedicated their time and skills once again to make Christmas at the White House a seasonal spectacular for the thousands of visitors to the mansion. Helping to carry out the Victorian theme of this year's holiday decor were members of Florists' Transworld Delivery, American Floral Services, the Society of American Florists, and other industry organizations. Pictured with some of the florist volunteers as the tree in the Blue Room was being finished is First Lady Rosalynn Carter.

Coming ...
Greenhouse Mgt. — Part 7