# The Rise & Fall of Carbon Dioxide

During the winter production cycle, greenhouses are heated and gaps are sealed to decrease air infiltration resulting in lower bills. However, as plants consume $CO_2$ during photosynthesis, are the plants experiencing $CO_2$ concentrations that are too low? How quickly can this happen?

We can estimate the rate of change in $CO_2$ from initial conditions coupled with some assumptions. Knowing the dimensions of a greenhouse (e.g., a 150 x 30-ft., single span with 12-ft. sidewalls and 16-ft. height), we can calculate the amount of $CO_2$ (in this example, 3 lbs. of $CO_2$). If we have a sunny day and the greenhouse filled to about 80% of capacity, we can calculate that photosynthesis will remove 1.5 lbs. of $CO_2$ in one hour. That would decrease the original value from 400 to about 200 ppm. In a typically leaky greenhouse the actual drop would be closer to about 100 ppm in one hour. How does this theoretical calculation with assumptions, compare to real-world measurements?

In a simple survey carried out in a few greenhouses during the winter, $CO_2$ ranged from 300 to 330 ppm making it less than outside air and likely resulting in decreased growth rate. In some cases, $CO_2$ was below 200 ppm. If people were to increase $CO_2$ to above ambient conditions, what could be expected? In our own research, plants reached “full size” earlier with supplemental $CO_2$, but then the ambient $CO_2$-grown plants caught up. We believe the supplemental $CO_2$ plants maximize their growth earlier and reach an upper limit to their size as determined by their container size. When compared across container sizes, the effect of $CO_2$ increases as container size increases (Figure 1). If $CO_2$ is low, the growth of plants will be affected, so adding $CO_2$ may accelerate growth. Dropping temperatures can save money and energy but also slows growth and development. Can additional $CO_2$ compensate for growth at lower temperatures and what is the cost of such a system and strategy?

We were able to test this strategy in a commercial setting with two essentially identical single-span, double-poly houses. In one greenhouse we set up a $CO_2$ controller and a solenoid, a tank of liquid $CO_2$, a $CO_2$ controller to maintain day-time $CO_2$ at a concentration of 500 ppm, and a temperature of 62˚F (16˚C). The other greenhouse was left uncontrolled for $CO_2$ and a temperature set point of 65˚F (18˚C). Stock geranium plants were grown in both greenhouses and five lettuce seedlings were grown each house. During the growth period $CO_2$ and temperature was measured in both houses. $CO_2$ in the uncontrolled house was between 200 and 300 on sunny or partly sunny days, and always at least 100 ppm lower and at least three degrees warmer than the $CO_2$-controlled house. Geranium cuttings were collected and $CO_2$-controlled house produced about 0.5 more cuttings per pot and the stem diameter of the cuttings was noticeable larger than the uncontrolled house. The lettuce plants were harvested and fresh and dry weights were considerably greater in plants from $CO_2$-controlled house. Plant development was greater in these plants as well, with two more leaves per plant. Although they were grown in a cooler environment development was compensated by higher $CO_2$.

Using the software Virtual Grower a break-even was obtained for a three month growing season when cost for heating the greenhouse and total cost for adding $CO_2$ was compared. The solenoid and $CO_2$ controller can last several years and are re-scalable to different-sized greenhouses. For the same period the warmer greenhouse contributed 5,000 lbs. of $CO_2$ compared to the 1,200 lbs added in the controlled greenhouse suggesting that more $CO_2$ is produced using the traditional production method. These results are an encouraging step forward with design heating/control systems for a more economical and environmentally-friendly production approach. We will continue to share strategies on managing the often ignored “problem” of tight greenhouses leading to $CO_2$ starvation. If you have low $CO_2$, you’ve probably done an excellent job in sealing up the gaps in your facility. But consider adding $CO_2$ back into your greenhouses to take advantage of the greater control during this time.

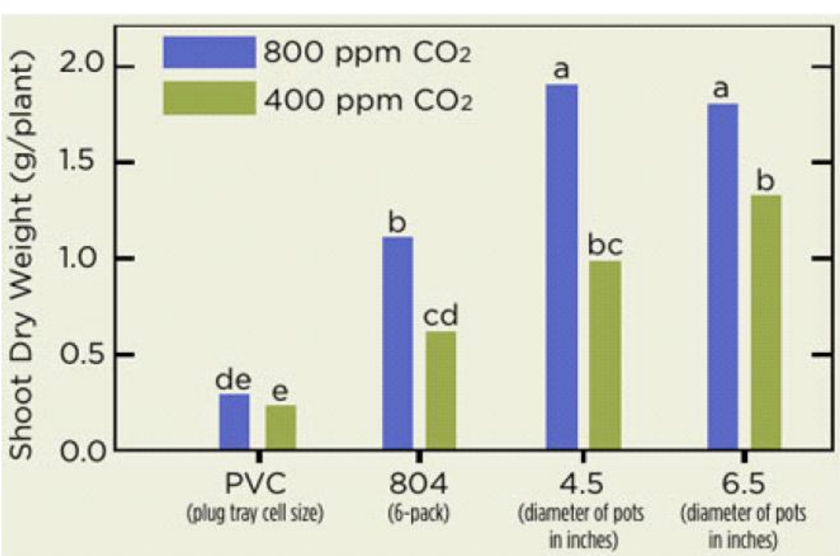


Figure 1. Vinca shoot dry weight with supplemental $CO_2$ in different container sizes. The influence of $CO_2$ on plant growth increased as container size increased. Different letters indicate significant difference in mean dry weight.

**For more information, contact: Jonathan Frantz, jonathanfrantz319@gmail.com. Dr. Frantz now works for Dupont Pioneer.**