BioChambers
PROVIDING GROWTH TO RESEARCH.

FREQUENTLY ASKED QUESTIONS
with Dr. Patrick Friesen

FAQ QUESTION #3

How do I know if I need CO_2 control?

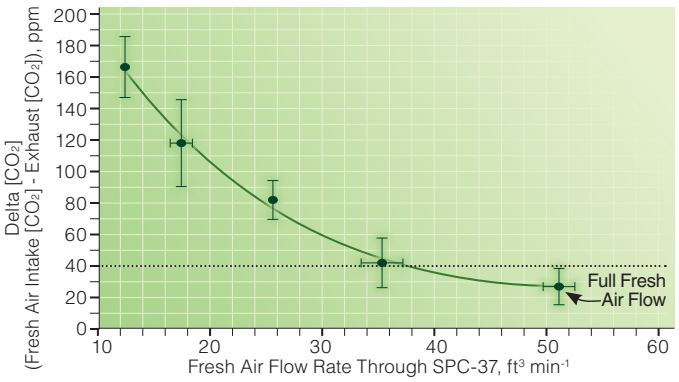
The CO_2 concentration inside your growth chamber or room can affect the growth rate of the majority of plant species. CO_2 concentrations lower than 375ppm can almost linearly reduce growth (Sage & Coleman 2001), whereas elevated CO_2 concentrations (700 to 900ppm) generally stimulate growth, but at a lower magnitude than low CO_2 growth reduction (Mortensen 1987, Poorter 1993). CO_2 growth effects are most pronounced and prevalent in plants that use C_3 photosynthesis, which include the majority of plant species. To fully realize the growth stimulus of elevated CO_2 pot size, nutrition, temperature, and light intensity (PPFD) must scale with the desired growth response (Cao et al 1994, Chagvardieff et al 1994, McConnaughay et al 1993). For pot size, CO_2 growth effects appear to be somewhat proportional to general pot size effects on growth, with greater absolute biomass gains at higher CO_2 concentrations in larger pots (Arp 1991, Kerstiens & Hawes 1994, Poorter et al 2012). Plants that use C_4 photosynthesis show a more variable growth response to CO_2 concentration, and in general show less growth effects across a wider range of CO_2 concentrations below and above current atmospheric (415ppm) compared to C_3 plants. Plants that use Crassulacean Acid Metabolism generally show CO_2 growth effects in between those of C_3 and C_4 plants (Poorter 1993). In the leaf and seed tissue of C_3 plants grown at elevated CO_2, protein and mineral nutrients are generally reduced, whereas in leaf tissue total non-structural carbohydrates and soluble phenolics increase, as well as one report of increased iron content in lettuce (*Lactuca sativa* L.) (Chagvardieff et al 1994, Myers et al 2014, Poorter et al 1997).

Plants photosynthesize and consume CO_2, drawing down the CO_2 concentration inside growth chambers and rooms. Fresh air replaces the CO_2 consumed through photosynthesis; more fresh airflow means less CO_2 drawdown. Conversely the more plant material inside a growth chamber or room, the greater the CO_2 drawdown. For most reach-in growth chambers at full fresh air flow, in most situations the CO_2 drawdown will be within 10% of the fresh air coming in (eg. if the fresh air coming in is 400ppm CO_2, the CO_2 concentration inside the growth chamber will be 360ppm or higher) (Friesen 2017, Peet & Krizek 1997, Figure 1). While reach-in chambers generally have sufficient fresh airflow per unit volume of growth space to mitigate substantial CO_2 drawdown, larger walk-in rooms may be more susceptible to larger CO_2 drawdowns if they are filled with large, actively-growing plants.

The other important variable that determines the CO_2 concentration your plants experience is the CO_2 concentration of the fresh air flowing into the growth chamber or room. Without CO_2 control, the CO_2 concentration of the fresh air flowing into a growth chamber will depend on a number of factors that are challenging to estimate. First, proximity of the growth chamber facility to large urban centers and industry will affect how close CO_2 concentrations are to current atmospheric. On average, ground level CO_2 concentrations were 25 to 95ppm higher than atmospheric CO_2 concentration over a 24 hour period across three locations on different continents

FIGURE 1

Drawdown of CO_2 concentration as a function of fresh air flow inside a BioChambers SPC-37 filled with well-watered and fertilized maize and soybean (mean ±SE). Leaf temperatures ranged from 25.5 – 26.5°C and photosynthetic photon flux densities (PPFD) averaged 430 µmol m^{-2} s^{-1} across the upper leaves. The leaf area index (leaf area/growth area, m^2 m^{-2}) of all plants was 0.48. Flow rates were decreased by manually closing the fresh air intake valve from fully open (arrow). After each flow rate change, at least 45 minutes was given before measurements were recorded to allow for steady state conditions. Dotted line is the 10% recommended drawdown limit of Morse (1963) assuming the ambient CO_2 concentration entering the chamber is current atmospheric (~400ppm).



(Ziska et al 2001). Next, the topography surrounding the facility can also affect the CO_2 concentration of the building's fresh air intake. For example, CO_2 concentrations can be further elevated when CO_2 is trapped within a natural or constructed valley and close to industry or urban centers (Bjorkegren et al 2015).

Building layout and volume, ventilation, and occupancy can all further affect the CO_2 concentration of the air flowing into your growth chamber. Smaller volume spaces, less ventilation, and more people (exhaling CO_2) increase the CO_2 concentration inside the facility, often increasing throughout the workday (Franco & Leccese 2020, Persily & de Jonge 2017). Even with a building ventilation rate acceptable for the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) indoor air quality standards and typical occupancy, indoor CO_2 concentration can often reach 1000ppm or more (Janssen 1989, Persily & de Jonge 2017). When CO_2 concentrations are continually measured inside buildings at a university campus, variability in CO_2 concentrations are due to overall occupancy and building volume per person (Franco & Leccese 2020). The more CO_2 enriched air from building occupants mixes into growth chamber spaces, the more the CO_2 concentration of the air entering growth chambers is elevated above outside concentrations. Generally, the closer growth chambers are to occupied spaces, the more CO_2 will diffuse and buildup in the air entering growth chambers. If growth chamber exhaust air re-enters the same space, the number of growth chambers and rooms filled with plants in the same space can also affect the CO_2 concentration of the air inside them. During the day, CO_2 drawdown can lower the CO_2 concentration inside other equipment if they all share the same intake and exhaust air. During the night when most plants respire CO_2, the opposite effect can occur and CO_2 concentrations can build up.

Questions to ask yourself when deciding whether or not to include CO_2 control:

- Are the growth rates of my plants strongly affected by CO_2 concentration?
- What are my plant growth goals?
- Is a comparable growth rate to other studies important to my research?
- Are comparable leaf or seed tissue concentrations of protein, iron, zinc, non-structural carbohydrates, or soluble phenolics to other studies important to my research?
- Would it be cost effective to include additive CO_2 to stimulate plant growth for production purposes?
- Will I be completely filling a large growth room with plants in a generally unoccupied space, where a CO_2 drawdown below current atmospheric is possible?
- Will my growth chamber or room be installed in a space with CO_2 concentrations 500 to 1000ppm higher than the CO_2 concentration of the air outside the facility due to the exhalation (respiration) of people working inside the building?
- Will people be working inside a growth room for extended periods? If so, is a buildup of CO_2 concentration acceptable?

These are the questions to ask yourself when deciding whether to include CO_2 control in your new growth chamber or room. CO_2 control options include additive CO_2 to elevate CO_2 concentration above fresh air ambient and CO_2 removal (scrubbing) to achieve below fresh air ambient CO_2 concentrations. For a more detailed discussion of fresh air intake and CO_2 drawdown, please read: Are you filling your chambers to capacity? You may be starving your plants. (https://www.biochambers.com/pdfs/fresh_air.pdf)

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