Yield Response to CO_2 Enrichment

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Credits

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Why CO_2 Enrichment?

- CO_2 is an essential plant nutrient
- CO_2 can become depleted in the greenhouse
- Supplemental lighting requires adequate CO_2 levels
- CO_2 enrichment can enhance plant growth and increase yields (up to 25% per year)
- In some ornamental crops, CO_2 enrichment can improve plant quality

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CO_2 Concentration

- Ambient CO_2 concentration is ~400 ppm (2016)
- CO_2 levels in a closed greenhouse can go below 200 ppm
- CO_2 concentrations above 10,000 ppm are harmful to humans
- Levels as low as 1,000 ppm may affect humans (Federal limit for occupational is an average of 5,000 ppm for eight hours)

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Plant Response to CO_2 Enrichment

- CO_2 concentrations above 1,200 ppm don't increase plant growth
- Increased CO_2 levels have a diminishing effect (e.g. an increase from 400 to 500 ppm has more of an effect than from 1,000 to 1,100 ppm)
- Plants can become acclimated to CO_2 enrichment

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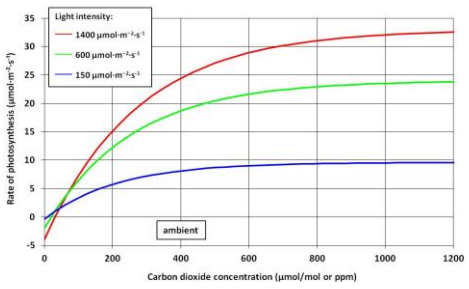
Influence of CO_2 Concentration and Light Intensity on Photosynthesis



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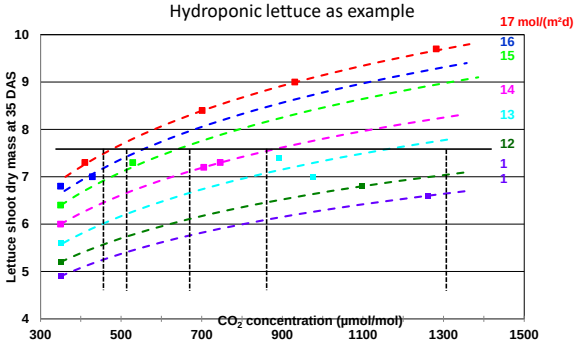
Trading off CO_2 and Light

Hydroponic lettuce as example



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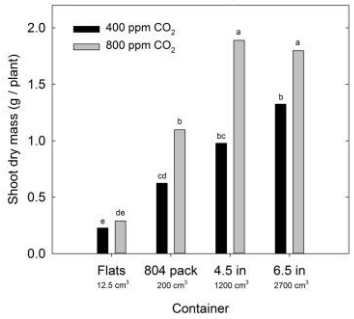
Dry mass of pansy plants after six weeks of growth in different containers



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CO_2 Enrichment Technology

- Liquid CO_2
  - Liquid CO_2 occupies less volume but requires refrigeration
  - Liquid is vaporized before release in the greenhouse
- Compressed CO_2
- CO_2 burners
  - Produce heat
  - Potential fire hazard
  - May release contaminants (ethylene and CO)

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CO_2 Distribution

- Liquid and Compressed CO_2 is typically distributed in inflatable polyethylene tubes toward the bottom of the plant canopy
- CO_2 burners are a point source within the greenhouse, above the canopy
- CO_2 diffuses quickly and is heavier than air

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Inflated polytube for CO_2 distribution

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- Special natural gas burners for CO_2 enrichment (unvented heater)
  - These units can be a potential fire hazard
  - Units must be properly adjusted to release pure CO_2 (and water vapor), and avoid the production of contaminants such as ethylene, carbon monoxide

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Recommended CO_2 Enrichment Rates

- Approximately 50 kg/ha (45 lb/acre) per hour is recommended to maintain ambient levels (400 ppm)
- Enrichment rates of 200 to 600 kg/ha (180 to 540 lb/acre) may be required to maintain CO_2 concentrations of 1,200 (influenced by infiltration)

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Factors Influencing CO_2 Enrichment Costs

- Method of CO_2 enrichment
- The unit cost of the CO_2 gas
- The number of hours during the day when CO_2 enrichment is used
- The air leakage rate of the greenhouse
- The amount of venting allowed during CO_2

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Monitoring and Controlling CO_2

- CO_2 sensors
  - Need periodic calibration for efficiency and worker safety
  - Mount in representative location close to plant canopy
  - Used to activate solenoid valves or turn burners on and off
- Computer control systems provide more flexibility and better management of CO_2 enrichment
  - Coordination with supplemental light
  - Managing ventilation
  - Let set point temperatures rise at beginning and end of light periods, delaying ventilation
- Control can be based on concentration (ppm) or flow rate ($g/m^2/hr$)

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Considerations Affecting CO_2 Enrichment

- Type of crop
- Ventilation requirements
- Presence of supplemental light
- Desired CO_2 concentrations
  - Maintain ambient levels
  - Enrichment
- Potential for CO_2 recovery from boilers with thermal storage
- Benefits/Disadvantages of gas burners
  - Heating needs and timing
  - Cost
  - Distribution
- Availability of computer control