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Saskatchewan Agriculture and Food

CO2 Levels in Low Tunnels

Plants use the energy in sunlight to convert carbon dioxide (CO2) and water into the sugars that form the basic building blocks for plant growth. Plant growth rates are strongly influenced by the availability of CO2. Under normal field conditions, CO2 levels are typically between 350 and 400 ppm. Once CO2 levels drop to 200 ppm, photosynthesis and growth slow, while higher than normal CO2 levels can accelerate plant growth. Deficient CO2 levels commonly occur within the confines of greenhouses as the rate at which the greenhouse crops absorb CO2 exceeds the rate it is replenished by introducing fresh outside air into the greenhouse. When greenhouse growers add CO2 to overcome this problem, they can substantially boost their yields if they add CO2 well in excess (ca 1000 ppm) of the normal atmospheric levels.

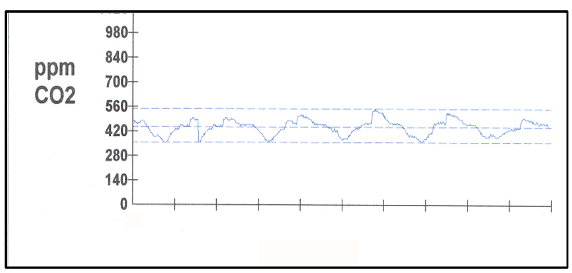
In Saskatchewan many growers are using low tunnels constructed of polyethylene or woven fibre to create the warm, sheltered microclimate preferred by crops like tomatoes, peppers and melons. Like a greenhouse, the low tunnels work by restricting movement of air in the vicinity of the crop - but the covers may also restrict replenishment of the CO2 utilized by the crop. This study examined the CO2 levels inside a standard low tunnel and explored the potential for adding CO2 into the tunnels as a means to enhance productivity.

The trials were conducted in 2001 and 2002 at the Department of Plant Sciences Horticulture Field Research Facility in Saskatoon. Peppers and melons were selected for testing as they respond well to the low tunnels. The plots were prepared by rototilling and then rows of wavelength selective IRT mulch were laid over standard drip tube. Greenhouse grown seedlings of the test crop were then transplanted into the mulch rows. The crops were then covered by standard low tunnels (1 m wide and 40 cm tall) constructed by covering wire hoops with clear polyethylene (perforated and non-perforated) or spunbond fibre (Reemay). The edges of the coverings were buried in the soil. Each test plot of the various coverings involved a minimum of 10 plants spaced 30 cm apart within the row. Each cover treatment was replicated at least twice. The crops were irrigated as required using the drip lines.

CO2 levels in the low tunnels were monitored by either placing a small CO2 analyser (Bacharach Model 2800) right inside the tunnel or by collecting a sample of air from inside the tunnel and running it through the analyser.

Results

CO2 levels in the low tunnels varied with the time of day, outside conditions and the type of cover used. In general, CO2 levels peaked just before dawn and then declined through the mid-point of the day, and then began to recover (Figure 1 and 2). CO2 levels at mid-day were well below ambient levels, reflecting the photosynthetic activity of the plants within the confines of the tunnels. By contrast, at night, CO2 levels in the tunnels were well above ambient - this reflects the tunnel materials trapping the CO2 generated at night by the respiration of the plants and the soil micro-organisms. The extent of the diurnal fluctuation in CO2 levels depended on the porosity of the covering material used - it was most noticeable when the tunnels were constructed of non-perforated clear polyethylene and it was barely perceptible when the tunnels were constructed of the more porous woven materials. Wind rapidly eliminated the CO2 gradients, irrespective of the type of cover employed.

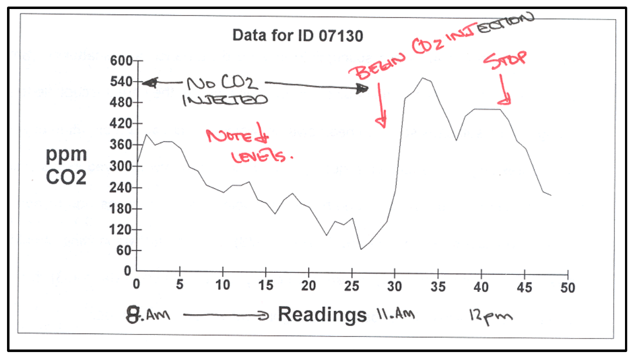


1Fig. 1. CO2 levels over several days inside a low tunnel constructed of perforated clear polyethylene.

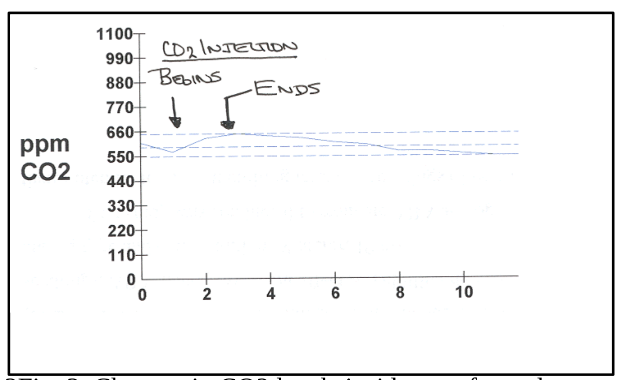
These results suggest that plants growing within the confines of low tunnels may be experiencing growth limiting shortages of CO_2, particularly if the tunnels are constructed of relatively non-porous materials. Increasing the rate of ventilation of the tunnels would overcome this problem, but it would also interfere with the growth enhancing effect of the higher temperatures that occur within the confines of a closed tunnel.

The drip lines used to irrigate the crop represented a potential means for delivering supplemental CO_2 to the crop within the covered rows. In this trial, the drip lines were occasionally disconnected from the water source and re-attached to a tank of compressed CO_2. In-line regulators were used to control the rate flow of CO_2 into the lines. Two rates of CO_2 addition were tested ... the higher rate represented double the lower rate. The CO_2 was typically injected for 1-2 hours commencing in mid-morning. CO_2 was not injected on cloudy days, as bright sunshine is required for the plants to utilize the CO_2. Similarly, CO_2 injection was canceled on days when the wind speed exceeded 25 km/h, as preliminary trials showed that any CO_2 injected into the tunnels under windy conditions was rapidly lost. Changes in CO_2 levels in the tunnels in response to the added CO_2 were monitored using the previously described system. Levels of CO_2 achieved within the low tunnels in response to the CO_2 injection treatment varied with the duration of application, the rate of CO_2 applied, distance from the injection point and the type of covering used.

An increase in CO_2 levels in the tunnels was detectable within minutes of the start of the injection period (Figure 2). CO_2 levels usually peaked within the first hour, with the level achieved at the plateau reflecting the amount being injected versus the amount being lost due to ventilation. A similar pattern in CO_2 levels was observed when the CO_2 injection stopped - with the rate of decline reflecting the rapidity of air exchange within the tunnels (Figure 3). Almost invariably, CO_2 levels returned to ambient within 1-3 hour of termination of the injection. Throughout the injection period, the CO_2 levels measured near the injection point were considerably higher than those further down the row (Figure 4).
It appears that the drip lines are not delivering the CO_2 uniformly - with the high rates adjacent to the delivery point reflecting higher gas pressures at that point. Differences in CO_2 levels obtained with the two rates of injection were obvious (Figure 4). The higher rate consistently produced peak CO_2 levels well above the maximum measurement capacity of the sensor used in this trial. The lower rate produced much more reasonable CO_2 levels, particularly if there was enough wind to assist in the ventilation of the tunnels. CO_2 levels in the non-perforated polyethylene tunnels were far higher than those observed for the perforated poly. CO_2 levels in the woven fabric tunnels were never discernibly higher than ambient.



2Fig. 2. Changes in CO_2 levels within a perforated polyethylene low tunnel. From 8-11 am no CO_2 injected, then CO_2 injected at the low rate for 1 h.

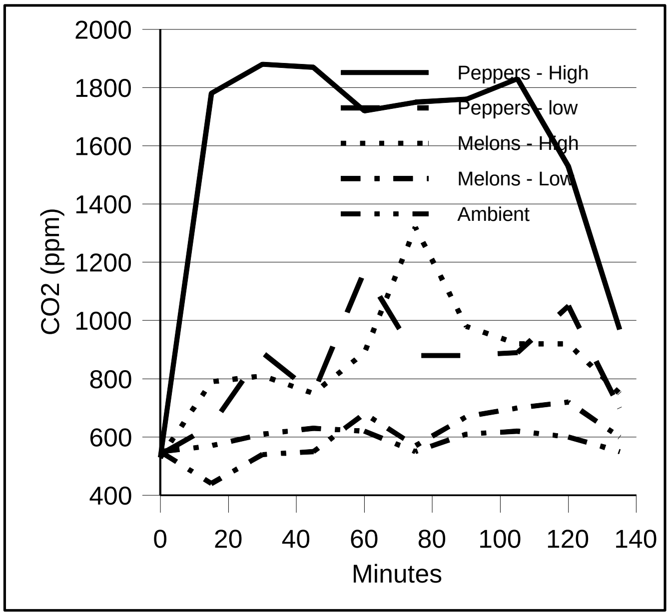


3Fig. 3. Changes in CO_2 levels inside a perforated polyethylene tunnel as a function of CO_2 injection. CO_2 injection (low rate) begins at reading 1 and continues for 2 hours to reading 3. Readings continue for 7 hours after injection

Crop Growth.

In 2001, health of the crops in the various treatments was observed but their growth was not formally evaluated. Crops grown under non-perforated polyethylene tunnels showed obvious signs of heat stress.   The leave edges became chlorotic and then necrotic, the stems were thin and curled, and the flowers consistently aborted.   Although the non-perforated covers were clearly superior in terms of their ability to generate and retain enhanced levels of CO2, the heat stress associated with the absence of adequate ventilation overcame any benefits associated with a CO2 enriched environment.

In 2002, the fresh weights of the pepper and melon plants were determined 8 weeks after they were transplanted into tunnels constructed of perforated polyethylene. The pepper plants grown with the supplemental CO2 were no taller than the controls but were on average 13% heavier. There was no significant effect of the CO2 treatments in the melons. It should be noted that in this trial, the melon plants were located further downstream from the CO2 injection point that the peppers and therefore would have received less CO2.



4Fig. 4. CO2 levels inside a perforated polyethylene low tunnel - two CO2 injection rates. Injection stops at 100 minutes.   Melons were further down the injection line than the peppers.

Conclusions - this study demonstrates that transient CO2 deficits occur within the confines of low tunnels, particularly if non-porous covering materials are used and the tunnels are located in relatively sheltered areas.   The impact that these CO2 deficiencies have on growth of the covered crops is difficult to determine as it is confounded by the beneficial effects that the covers have on growth. The greatest deficiencies occur under the least porous covers, but these covers also provide the warmest and most sheltered microclimate. Introducing supplemental CO2 into the low tunnels through the drip irrigation system was technologically simple - but the results were mixed. The levels of CO2 achieved were very non-uniform along the length of the drip tube, with excessive levels developing adjacent to the injection point and very little delivered only a few dozen meters further down the line. Drip lines are commonly employed for the delivery of CO2 in commercial greenhouses, but in those situations, the resulting delivery gradients are dissipated by fans creating a horizontal air flow pattern. As air flow within the low tunnels is limited, some other means of achieving a more uniform CO2 distribution pattern will need to be developed. More efficient control of the CO2 injection process could be achieved if the injection system and the monitoring system were electronically linked so that the CO2 was only injected when needed and at the appropriate dosages. These types of systems are in place in most greenhouses.