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Example of plastic recycling at a nursery.

Recycle Your Pesticide Containers and Nursery Pots

The New Jersey Department of Agriculture will offer free recycling of empty plastic pesticide containers and nursery pots at five regional collection sites on Sept. 27 and Oct. 3, 8, 9 and 10 this year (2003).

Non-refillable, high-density polyethylene # 2 (HDPE #2) containers used by agricultural, professional and commercial pesticide applicators will be accepted at the collection sites, as will HDPE #2 nursery pots.

Containers must be no larger than 55 gallons and properly rinsed. Nursery pots must also be properly rinsed.

The program is open to anyone who holds a New Jersey Department of Environmental Protection pesticide license and to state, county and municipal government agencies. Participants must follow the processing guide or material will be rejected.

The NJ Department of Environmental Protection will issue one core credit to pesticide license holders for participating in the program. To receive credit, participants must bring their pesticide license to the collection site and must follow the processing steps. Credits will not be issued for recycling nursery pots.

To register for the program, contact Program Manager Karen Kritz of the New Jersey Department of Agriculture at (609) 984-2506 or karen.kritz@ag.state.nj.us. Please provide the estimated size and quantity of the various pesticide containers and nursery pots that will be delivered and to what site.

The fall 2003 agricultural product container-recycling program is a collaborative effort involving the New Jersey Departments of Agriculture and Environmental Protection, Atlantic County Utility Authority, Burlington County Solid Waste, Cumberland County Improvement Authority, Monmouth County Board of Chosen Freeholders, Pollution Control Financing Authority of Warren County, Ag Container Recycling Council and USAg Recycling, Inc.

Please see the following collection schedule and processing guide for further information or visit www.state.nj.us/agriculture/recyclyingpestcons.htm.

Carbon Dioxide Enrichment

A.J. Both

Just like water, nutrients, and light (energy), plants need carbon dioxide (CO_2) for the process of photosynthesis. Without sufficient CO_2 available, the growth rate of plants will be reduced. At ambient temperatures, CO_2 is a gas and plants take up CO_2 through their stomates located along the surface of the leaves. Thus, as long as the CO_2 concentration around the leaves is sufficient, plant growth will not be limited due to a lack of available CO_2. However, for plants grown in the greenhouse, the CO_2 concentration can be below the concentration normally measured in the outside air. The reason is that, particularly during periods with low outdoor temperatures (at night and during the heating season), the ventilation rate is too low to bring in sufficient amounts of "fresh" CO_2. When this happens, the demand for CO_2 is greater then the supply and the below normal CO_2 concentration limits the plant's growth rate. In addition, during these colder times of the year, some growers use supplemental lighting in an attempt to boost plant growth. But if the CO_2 concentration is too low, the added supplemental lighting will not increase plant growth much because the low CO_2 concentration limits photosynthesis. When such conditions happen regularly, growers often consider providing extra CO_2 to the plants. This article discusses some of the issues associated with CO_2 enrichment in greenhouses.

CO_2 gas is considered one of the so-called "greenhouse gases" because it can absorb heat. Thus, as the theory goes, heat that would otherwise be radiated from the Earth's surface into space is now trapped in the atmosphere, causing the average air temperature to rise. One of the by-products of burning fossil fuels, such as natural gas and oil, is CO_2. Since the industrial revolution that started in the eighteenth century, the burning of fossil fuels has increased tremendously, resulting in a steady increase in the CO_2 concentration in the atmosphere. Since the World's desire for energy is not likely to decline any time soon, the CO_2 concentration in our atmosphere is expected to continue to rise, further contributing to the so-called "greenhouse effect", but perhaps also boosting plant growth rates.

Today, on average, the outdoor CO_2 concentration is between 350 and 400 $\mu mol\ mol^{-1}$ (or ppm, which is perhaps a more commonly used unit). This concentration is often referred to as the ambient CO_2 concentration. The air we breathe consists of approximately 79% nitrogen, 21% oxygen, and some very small quantities of other gasses, among which 0.035-0.040% CO_2. In a well-lit closed greenhouse with a full canopy, the CO_2 concentration can drop below 200 ppm (or 0.020%) without CO_2 enrichment, significantly reducing the crop growth rate. A lot of research has been conducted investigating the positive effects of elevated CO_2 concentrations on crop growth. Many different plant species have been studied. These studies have shown that plant growth can be increased under elevated CO_2 concentrations, but that in general, a concentration above 1,000 ppm (or approximately three times the ambient concentration) no longer resulted in an increase in plant growth. This result is somewhat fortuitous because: 1) CO_2 concentrations above 5,000 ppm can be harmful to humans, and 2) increasing the CO_2 much above 1,000 ppm becomes more expensive because of the inevitable leakage of CO_2 through cracks and small openings in the greenhouse cover. Thus, it is often recommended to enrich the greenhouse environment to a concentration not higher than around 1,000 ppm. In addition, research has shown that an increase in the CO_2 concentration has a larger impact when the original concentration is closer to the ambient concentration (350-400 ppm) compared to being closer to the upper limit of CO_2 enrichment (around 1,000 ppm). In other words, adding CO_2 returns a bigger bang for the buck (in terms of increased crop growth) when the starting CO_2 concentration is lower rather than higher (over the 350-1,000 ppm of CO_2 range). It is also important to remember that some plant species get acclimated to elevated CO_2 concentrations and, over time, do not show a continued increase in crop growth.

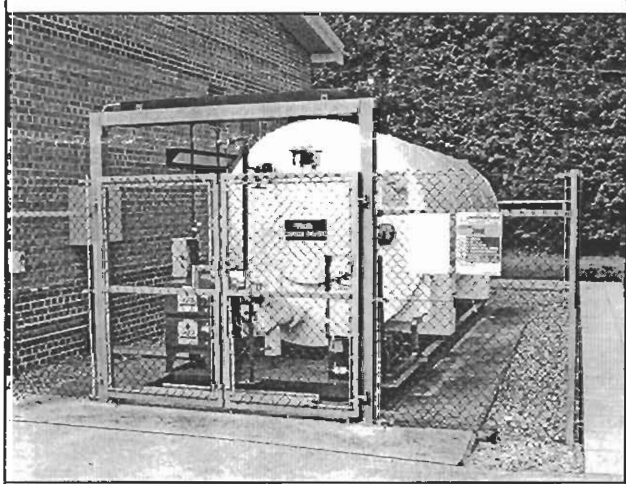
CO_2 can be supplied to the greenhouse environment using different methods. For example, CO_2 gas can be released from compressed CO_2 gas tanks. Since CO_2 is a byproduct of many different chemical processes, compressed CO_2 is often readily available for a reasonable price. Note: compressed CO_2 gas is added to soft drinks to produce the fizzle. But a lot of compressed CO_2 tanks are needed to provide a larger sized greenhouse with sufficient CO_2. Therefore, growers that use a lot of CO_2 can opt to install a liquid CO_2 tank that can be purchased or rented through local gas distributors. A refrigeration unit is connected to such a tank to cool the CO_2 to a temperature where it becomes a liquid. The advantage of storing CO_2 as a liquid is that you need less volume, but on the other hand you need a refrigerator (and electricity) to keep the CO_2 cold enough so it will stay in the liquid form. The liquid CO_2 is vaporized (i.e., converted from a liquid to a gas) before it is released into the greenhouse. CO_2 gas is often distributed throughout the greenhouse with small inflatable polyethylene tubes that run the length of the greenhouse and are mounted inside and towards the bottom of the plant canopy (CO_2 gas is heavier than air). Along the length of these inflatable polyethylene tubes are small holes through which the CO_2 can escape, ensuring even distribution throughout the greenhouse. Another method of CO_2 enrichment uses CO_2 burners (i.e., natural gas burners) to produce CO_2 from the combustion of natural gas. These burners are usually distributed throughout the greenhouse to increase the uniformity of the gas distribution. Drawbacks of CO_2 burners can be that they produce (some) heat at the same time they produce CO_2 and that improperly installed burners can be a fire hazard. During normal greenhouse operation, heat and CO_2 are not always needed at the same time. Finally, CO_2 can be captured from heating system exhaust gasses and used for greenhouse enrichment.

With any of the different CO_2 distribution methods, it is important that no harmful contaminant gasses are released at the same time. For example, ethylene gas is known to cause serious problems for some crop species even at extremely low concentrations. Therefore, a grower using CO_2 enrichment should make sure that the CO_2 gas released is of the highest purity (check with your gas supplier and/or inspect all CO_2 burners regularly).

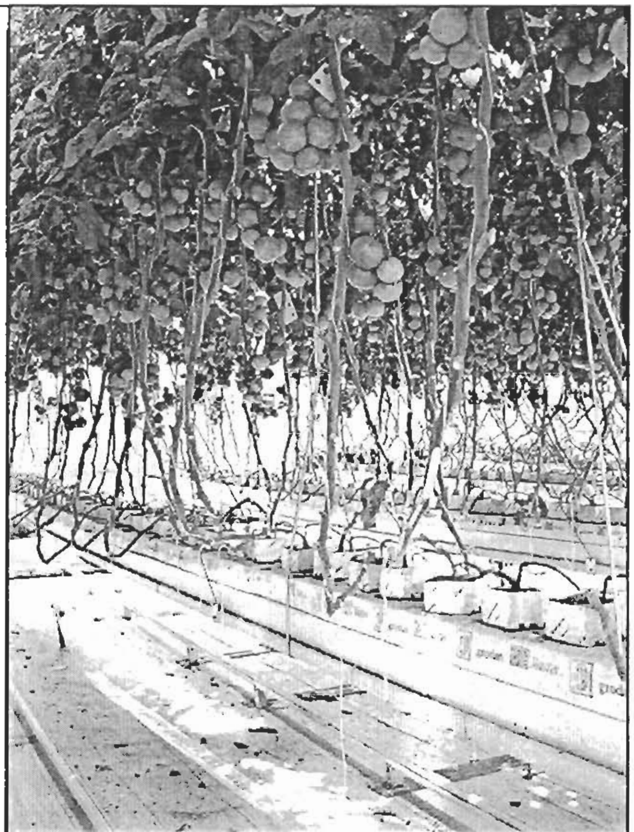
When growers use supplemental lighting during the darker periods of the year, it is often recommended they enrich the greenhouse environment with CO_2 at the same time. This practice ensures that the CO_2 concentration does not limit plant growth during those hours of the day when (expensive) supplemental lighting is used to boost crop growth. However, when any amount of ventilation is needed to maintain the set point air temperature, CO_2 enrichment quickly becomes uneconomical because any released CO_2 will quickly be vented to the outside air, and, thus, wasted. Some growers continue with CO_2 enrichment during periods when only a little ventilation (e.g., the first ventilation stage) is required because they feel that even a little increase in CO_2 concentration still makes economic sense.

For control of the CO_2 concentration, a CO_2 sensor is needed. Accurate CO_2 sensors are relatively expensive and need periodic calibration. The sensor should be mounted at a representative location and close to the plant canopy. Manual or computer control can be used to open and close a solenoid valve that releases the CO_2 gas into the greenhouse, or to turn the CO_2 burners on and off. Some CO_2 sensors are temperature sensitive, and those sensors should be located inside an insulated and aspirated box. This box prevents solar radiation from influencing the measurements. There are no human health concerns as long as the CO_2 concentration is not elevated above 3-4 times the ambient concentration (dangerous and eventually fatal CO_2 concentrations start around 5,000 ppm). CO_2 enrichment is generally only supplied during the light period of the day (which includes any hours of supplemental lighting), since adding CO_2 during the dark period has little positive effect on plant growth.

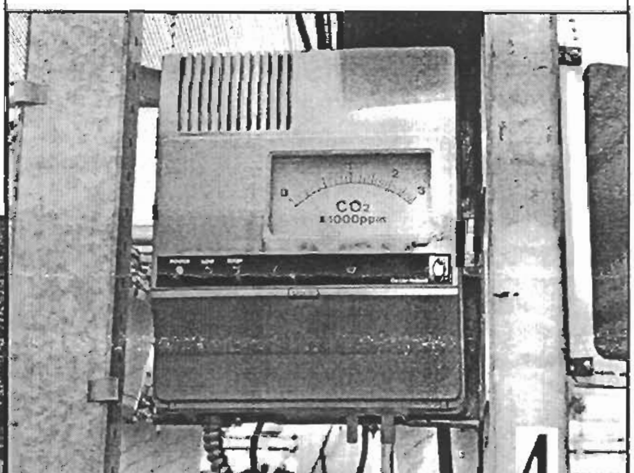
For some crops (e.g., leafy vegetables), research has shown that, within limits, supplemental lighting can be "traded" for CO_2 enrichment. This means that instead of adding a certain amount of supplemental lighting, the CO_2 concentration can be increased resulting in the same increase in crop growth. The obvious advantage is that adding CO_2 is likely to be cheaper than running the supplemental lighting system. A computer control system can be used to determine when it is more advantageous to add CO_2 or when it is necessary to run the supplemental lighting system (e.g., when the solar radiation causes the greenhouse to heat up above the set point temperature, necessitating the operation of the ventilation system and making CO_2 enrichment uneconomical). The benefits of CO_2 enrichment can be further exploited when the set point temperatures are allowed to drift upward at the beginning and towards the end of the light period. These higher set point temperatures would delay the onset of ventilation, making CO_2 enrichment economical during those periods of the day. However, such a strategy should always be tested first for the particular crop(s) grown. During periods of the day with a high light intensity, it is likely that the ventilation system is needed to maintain the set point temperature, and under those conditions, CO_2 enrichment is probably not economical.



A liquid CO_2 storage tank secured with a gate.



A deflated polyethylene tube (visible between the two metal heating pipes on the floor of the greenhouse) used to distribute CO_2 gas. The tomato crop is grown hydroponically in gutters that are elevated for ease of harvesting.



A CO_2 sensor located inside a greenhouse and used for monitoring and control of the CO_2 concentration. The readout from this sensor can be used to operate a solenoid valve either manually or with a computer control system. Opening the valve will allow pure CO_2 gas to be distributed throughout the greenhouse.