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 well as 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/recyclingpestcon.htm.
Carbon Dioxide Enrichment
A.J. Both

Just like water, nutrients, and light (energy), plants need carbon dioxide (CO₂) for the process of photosynthesis. Without sufficient CO₂ available, the growth rate of plants will be reduced. At ambient temperatures, CO₂ is a gas and plants take it up through their stomata located along the surface of the leaves. Thus, as long as the CO₂ concentration around the leaves is sufficient, plant growth will not be limited due to a lack of available CO₂. However, for plants grown in the greenhouse, the CO₂ 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" CO₂. When this happens, the demand for CO₂ is greater than the supply and the below-normal CO₂ 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 CO₂ concentration is too low, the added supplemental lighting will not increase plant growth much because the low CO₂ concentration limits photosynthesis. When such conditions happen regularly, growers often consider providing extra CO₂ to the plants. This article discusses some of the issues associated with CO₂ enrichment in greenhouses.

CO₂ 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 CO₂. 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 CO₂ concentration in the atmosphere. Since the World's desire for energy is not likely to decline anytime soon, the CO₂ concentration in our atmosphere is expected to continue to rise, further contributing to the so-called "greenhouse effect", though perhaps also boosting plant growth rates.

Today, on average, the outdoor CO₂ concentration is between 350 and 400 ppm (or 0.035-0.040% CO₂). In a well-lit closed greenhouse with a full canopy, the CO₂ concentration can drop below 200 ppm (or 0.020%) without CO₂ enrichment, significantly reducing the crop growth rate. A lot of research has been conducted investigating the positive effects of elevated CO₂ concentrations on crop growth. Many different plant species have been studied. These studies have shown that plant growth can be increased under elevated CO₂ 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, a phenomenon somewhat fortuitous because: 1) CO₂ concentrations above 5,000 ppm can be harmful to humans, and 2) increasing the CO₂ much above 1,000 ppm becomes more expensive because of the inevitable leakage of CO₂ 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 CO₂ 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 CO₂ enrichment (around 1,000 ppm). In other words, adding CO₂ returns a bigger bang for the buck (in terms of increased crop growth) when the starting CO₂ concentration is lower rather than higher (over the 350-1,000 ppm of CO₂ range). It is also important to remember that some plant species get acclimated to ele-
vated CO₂ concentrations and, over time, do not show a continued increase in crop growth.

CO₂ can be supplied to the greenhouse environment using different methods. For example, CO₂ gas can be released from compressed CO₂ gas tanks. Since CO₂ is a by-product of many different chemical processes, compressed CO₂ is often readily available for a reasonable price. Note: compressed CO₂ gas is added to soft drinks to produce the fizz. But a lot of compressed CO₂ tanks are needed to provide a larger sized greenhouse with sufficient CO₂. Therefore, growers that use a lot of CO₂ can opt to install a liquid CO₂ tank that can be purchased or rented through local gas distributors. A refrigeration unit is connected to such a tank to cool the CO₂ to a temperature where it becomes a liquid. The advantage of storing CO₂ as a liquid is that you need less volume, but on the other hand you need a refrigerator (and electricity) to keep the CO₂ cold enough so it will stay in the liquid form. The liquid CO₂ is vaporized (i.e., converted from a liquid to a gas) before it is released into the greenhouse. CO₂ 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. CO₂ gas is heavier than air. Along the length of these inflatable polyethylene tubes are small holes through which the CO₂ can escape, ensuring even distribution throughout the greenhouse. Another method of CO₂ enrichment uses CO₂ burners (i.e., natural gas burners) to produce CO₂ from the combustion of natural gas. These burners are usually distributed throughout the greenhouse to increase the uniformity of the gas distribution. Drawbacks of CO₂ burners can be that they produce (some) heat at the same time they produce CO₂ and that improperly installed burners can be a fire hazard. During normal greenhouse operation, heat and CO₂ are not always needed at the same time. Finally, CO₂ can be captured from heating system exhaust gasses and used for greenhouse enrichment.

With any of the different CO₂ distribution methods, it is important that no harmful contaminant gases 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 CO₂ enrichment should make sure that the CO₂ gas released is of the highest purity (check with your gas supplier and/or inspect all CO₂ burners regularly).

When growers use supplemental lighting during the darker periods of the year, it is often recommended they enrich the greenhouse environment with CO₂ at the same time. This procedure ensures that the CO₂ 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, CO₂ enrichment quickly becomes uneconomical because any released CO₂ will quickly be vented to the outside air, and, thus, wasted. Some growers continue with CO₂ 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 CO₂ concentration still makes economic sense.

For control of the CO₂ concentration, a CO₂ sensor is needed. Accurate CO₂ 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 CO₂ gas into the greenhouse, or to turn the CO₂ burners on and off. Some CO₂ 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 CO₂ concentration is not elevated above 3-4 times the ambient concentration (dangerous and eventually fatal CO₂ concentrations start around 5,000 ppm). CO₂ enrichment is generally only supplied during the light period of the day (which includes any
hours of supplemental lighting), since adding CO₂ 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 CO₂ enrichment. This means that instead of adding a certain amount of supplemental lighting, the CO₂ concentration can be increased resulting in the same increase in crop growth. The obvious advantage is that adding CO₂ 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 CO₂ 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 CO₂ enrichment uneconomical). The benefits of CO₂ enrichment can be further explored 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 CO₂ 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, CO₂ enrichment is probably not economical.

A deflated polyethylene tube (visible between the two metal heating pipes on the floor of the greenhouse) used to distribute CO₂ gas. The tomato crop is grown hydroponically in gutters that are elevated for ease of harvesting.

A liquid CO₂ storage tank secured with a gate.

A CO₂ sensor located inside a greenhouse and used for monitoring and control of the CO₂ 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 CO₂ gas to be distributed throughout the greenhouse.