Greenhouse Fertilization of the Future: Imagine the Possibilities

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This article is based on ideas which have been under development for several years as a part of Dr. Paul Nelson's floriculture nutrition research program at North Carolina State University. Under his guidance, many students and other faculty and scientists have contributed to the evolution of these concepts. Kim Williams recently completed her Ph.D. program under Paul Nelson's direction, and she will join the faculty of the University of Illinois in June 1995. This research has been funded primarily through grants from Sun Gro Horticulture, Inc.

You know those television commercials depicting conveniences that you will be able to enjoy thanks to the next generation of communications technology? Some of the images include sending a fax from the beach, taking a phone call on your watch, scanning prices of an entire cart of groceries at once, and saying "good night" to your child from an airport phone booth with a television screen. With this mind set of imagining the possibilities, can you imagine what the future of greenhouse fertilization might hold?

How about this scenario: A grower could purchase bags of substrate that already contained all of the nutrients that a floricultural crop would require for high quality, commercially acceptable growth throughout its entire production cycle. Rooted cuttings or young seedlings could be potted up in this substrate, set on a bench, and all the grower would have to do is water. No fertilization of any kind would be required during production. Sound crazy?

What if a foliage plant was grown or finished in a substrate that provided nutrients to the plant for two or three years after it was purchased by the consumer? Think about the marketing potential of selling plants that had a "built-in" fertilizer! Perhaps consumers and interiorscapers would no longer have to worry about fertilizing their interior plants.

Maybe the future of greenhouse fertilization includes the use of waste materials as fertilizer sources. Some waste products, like little chips of brick, have been shown to retain the nutrient phosphorus. There are a number of organic waste products, such as feathers and dried bacteria, that contain a substantial amount of nitrogen. Such waste materials might be used as fertilizers during greenhouse crop production, providing consumers with "environmentally friendly" floricultural products.

The research that is the foundation for these ideas was inspired by the foreseeable need of the greenhouse industry to substantially reduce the amount of nutrients in greenhouse irrigation runoff. Leaching of nitrates and phosphates from greenhouses can be an environmental hazard, and across the country, laws are being passed setting limits on nutrient contaminants in water flowing from greenhouse sites.

One of the reasons that nutrients are so easily leached from pots in greenhouses is that the *soilless*, peat-based and bark-based substrates that we commonly use for crop production do not have the ability to "hold on to" or *retain* most nutrients. Take phosphorus for example: Greenhouse mixes containing clay or loam soil aren't used much any more, but these *soil-based* substrates retain a lot of phosphorus. Nutrient retention is important, because if the substrate doesn't retain the nutrients applied, there is nothing to keep them in the pot and they will leach out of the bottom whenever the crop is irrigated.

A second reason that large quantities of nutrients are lost in greenhouse crop leachate is that in many cases, the concentration of nutrients we apply as fertilizer is much higher than what the plant really needs for adequate growth. Again, consider the situation with phosphorus: It has long been known that soil solution concentrations of 0.2 ppm phosphorus or lower, if the low level is sustained (that is the hard part), can produce high quality, commercially acceptable crops of most plant species, including many floricultural crops like chrysanthemums (Beckwith, 1965; Nishimoto et al., 1975). However, the amount of phosphorus that we apply during production results in much higher concentrations of phosphorus in the substrate solution (Fig. 1).

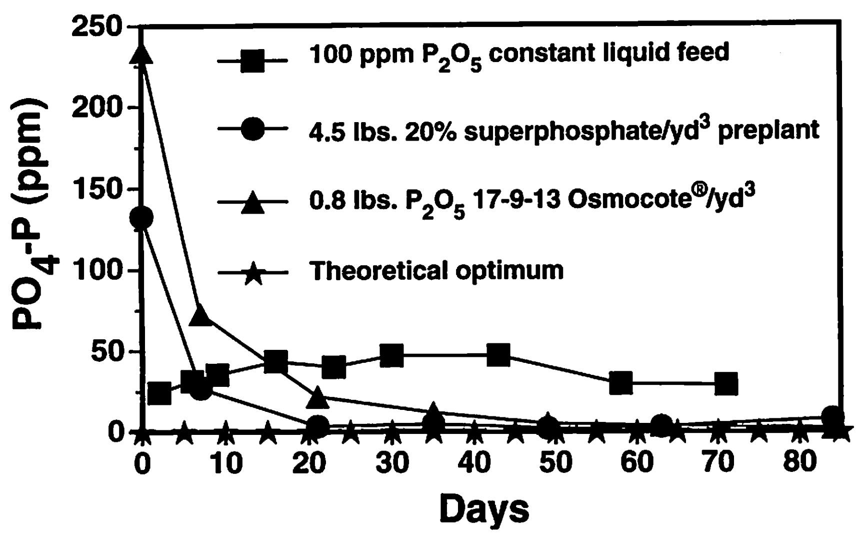

Figure 1. Substrate solution phosphorus concentrations during potted chrysanthemum production. Treatments are constant liquid feed with 100 ppm P_2O_5, a preplant substrate amendment of 4.5 lbs 20% superphosphate per yd^3, or a 0.8 lb P_2O_5 per yd^3 preplant substrate amendment supplied from 17-9-13 Osmocote®. The theoretical optimum phosphorus concentration is 0.2 ppm.

In our research,, constant liquid fertilization (CLF) with 100 ppm P_2O_5 resulted in about 25 ppm phosphorus in the substrate solution over the course of a chrysanthemum cropping cycle. Superphosphate and broken prills of the slow-release fertilizer Osmocote® resulted in excessive levels of phosphorus in the substrate solution during the first couple weeks of the crop (Fig. 1). Although only 0.2 ppm phosphorus is required, standard industry fertilization practices such as our CLF, superphosphate and Osmocote® treatments result in much higher concentrations (Fig. 1). Because the substrate doesn't retain the phosphorus applied, it is vulnerable to leaching.

Mineral soils retain many (although not all) nutrients, so we worked with soil scientists to learn the mechanisms that allow soils to do this. Then, we tried to incorporate the mechanisms into a *soilless*, peat-based substrate. One way to do this is to take some material that has a great ability to retain a particular nutrient and "pre-charge" or soak it in a solution containing that nutrient. This material could then be mixed with peat and perlite and become a component of the soilless substrate. Ideally, this material would establish a low concentration of the nutrient in the substrate solution, and every time the plant absorbed or "took up" a nutrient molecule from the substrate solution, another nutrient molecule would be released from the pre-charged material to replace it (Figure 2 illustrates how this might work for phosphate molecules). This system could *sustain* the desired low concentration of the nutrient in the substrate solution.

One material that we tested to provide phosphorus during pot chrysanthemum production was an oxide of aluminum, alumina (Al_2O_3). We pre-charged alumina with phosphorus and then mixed it with sphagnum peat moss and perlite so that alumina was 30% of the total volume of the substrate. Chrysanthemums were grown in this substrate and did not receive any other kind of phosphorus fertilizer. The growth of these plants was no different from the growth of mums that received 100 ppm P_2O_5 as constant liquid fertilization (Fig. 3). An exciting discovery

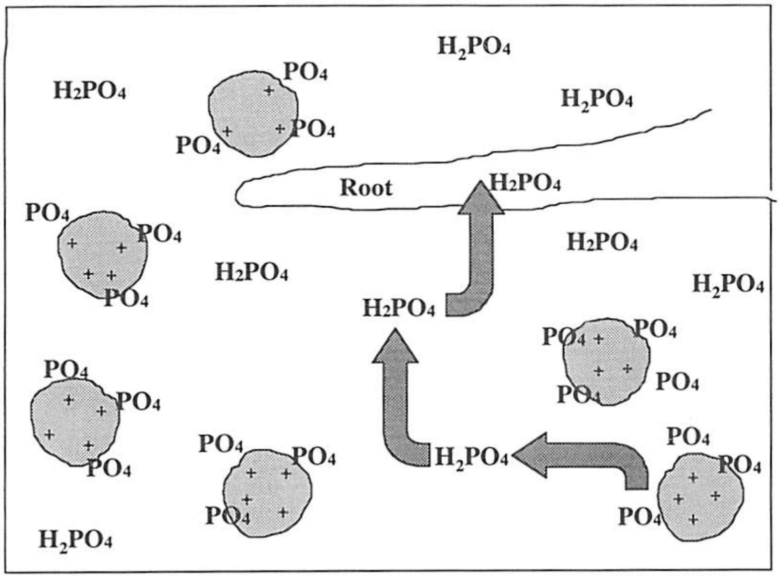

Figure 2. Diagram of a root growing in a substrate containing alumina pre-charged with phosphorus. As the root absorbs a phosphate molecule from the substrate solution, another phosphate molecule is released from the alumina to replace it.

made in this study is that the alumina sustained a phosphorus concentration in the substrate less than 1.5 ppm (Fig. 4)—very low compared to what we normally see in floriculture production, but still, the mums grew fine! Another exciting result is that the pre-charged alumina treatment resulted in *much less, almost* *99%* *less,* phosphorus loss through leaching. Only 1.4 mg of phosphorus was lost from each pot filled with alumina-containing substrate, but an average of 102.6 mg phosphorus was leached from pots that were fertilized with 100 ppm P_2O_5 at each watering. Pots were irrigated using a leaching fraction of 0.2 (20% of the irrigation solution applied leached out of each pot). This experiment demonstrates that commercially acceptable mums can be produced using very low concentrations of phosphorus in the substrate solution, and that leaching of phosphorus can be greatly reduced by incorporating 30% by volume of pre-charged alumina into the substrate.

We tested a different material for potassium retention, the zeolite clinoptilolite. Zeolites are a group of clay minerals that have a unique molecular structure giving them the ability to retain a large quantity of cations, like potassium. Other researchers have successfully grown commercially acceptable plants using zeolite as the sole source of potassium (Pond and Mumpton, 1984), so we decided to test zeolite with a floricultural crop. We pre-charged clinoptilolite with potassium, mixed it with peat

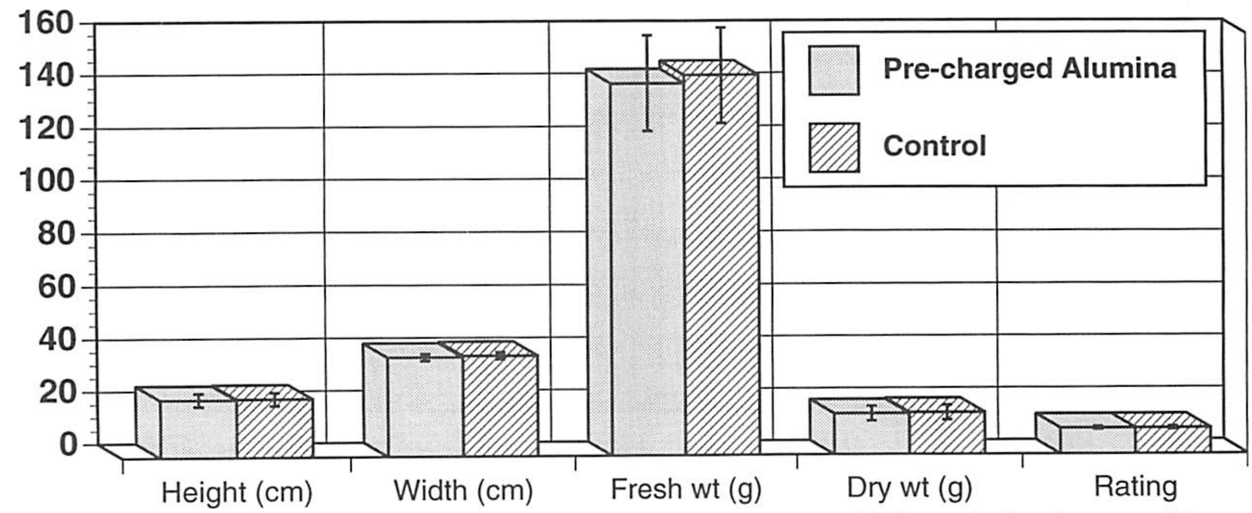

Figure 3. Growth measurements of potted chrysanthemum (one cutting per 4 1/2" standard pot) grown with phosphorus supplied from pre-charged alumina or from fertilization at each watering with 100 ppm P_2O_5 (control). The lines on the bars indicates the LSD at $\alpha = 0.05$. Leaching of phosphorus was only 1.4 mg per pot for the alumina treatment while phosphorus lost from the control pots averaged 102.6 mg.

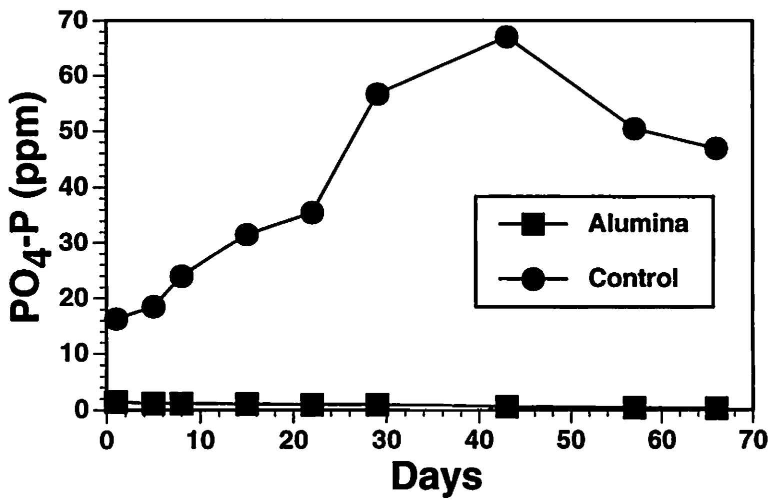

Figure 4. Phosphorus concentrations of the substrate solution during potted chrysanthemum production. Phosphorus was supplied with pre-charged alumina or from 100 ppm P_2O_5 at each watering (control). The standard error for the experiment (SE) is ± 1.0 ppm.

moss and perlite so that 20% of the volume of the substrate was clinoptilolite, and compared this potassium delivery system to standard commercial fertilization practices. The growth of the plants receiving potassium only from pre-charged clinoptilolite was no different than growth of plants fertilized at each watering with 200 ppm K_2O (Fig. 5). The zeolite treatment resulted in a 77% reduction in leached potassium as compared to the 200 ppm constant liquid feed (CLF) K_2O treatment. The amount of potassium leached from the pots containing zeolite was only 42.6 mg per pot compared to 185.5 mg per pot for the CLF treatment.

This research shows that we can engineer soilless substrates that would supply all the phosphorus and potassium required to grow a chrysanthemum crop. Research is continuing to refine these ideas and to work toward the retention of other nutrients in soilless substrates.

Of course, there are disadvantages with pre-charged substrates: ❶ This kind of system would require that growers control and monitor their leaching fraction when they irrigate to be certain adequate nutrient levels are being maintained in the substrate solution. This is very simple to do, but it is not a common practice for

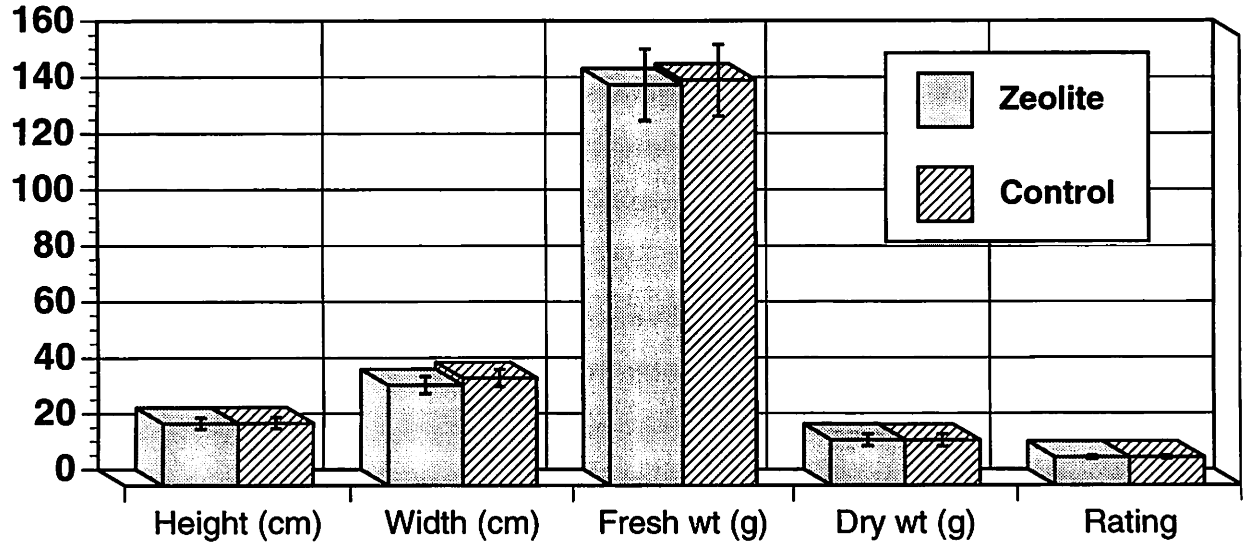

Figure 5. Growth measurements of potted chrysanthemum (one cutting per 4 ½" standard pot) grown with potassium supplied from pre-charged zeolite or from fertilization at each watering with 200 ppm K_2O (control). The lines on the bars indicates the LSD at $\alpha = 0.05$. Leaching of potassium was only 42.6 mg per pot for the zeolite treatment while potassium lost from the control pots averaged 185.5 mg.

many growers. ❷ It would become more difficult to use nutrient stress as a "growth regulator". In other words, growers may not be able to reduce or slow plant growth by withholding fertilizer; its already in the substrate. ❸ Much of the nutrient charge from pre-charging remains in the pots after a three month production cycle and is not utilized by the plants, which is inefficient. However, since the nutrient levels are so low, this continuous supply should not reduce postharvest life due to excess salts and high nutrient levels in the substrate. ❹ It would be difficult for individual growers to pre-charge their own substrate components. Horticultural substrate companies would have to develop this technology and carry out the preparation of specially-treated substrates. Because of these additional steps in the blending of the soilless substrates, substrate cost would be increased for growers.

But consider all of the advantages: ❶ Research has already shown that the amount of nutrients lost through leaching from open crop production systems would be substantially reduced. Therefore, smaller greenhouse operations that cannot afford the equipment costs of closed systems like ebb and flood floors would have an alternative, economically viable method to greatly reduce nutrient runoff. It is also likely that pre-charged substrates would effectively provide nutrients in closed irrigation systems as well as in open systems. ❷ In addition, using pre-charged substrates could simplify or do away with fertilizer applications by growers, and could supply nutrients after plants are purchased by consumers. This may not be as important for a potted chrysanthemum, but it could be of value for plants that consumers would maintain for several months or years, like foliage plants. ❸ And finally, although the substrate would cost more, growers would save money on fertilizers and would likely be able to use the elimination of nutrient runoff as a marketing tool.

Unlike the television commercials that promise the new communications technology that they advertise, we are not ready to make claims that the ideas presented here will be a part of next year's greenhouse fertilization program. But who knows? Two decades ago, many of the biological control methods used today were only academic curiosities. Hopefully, if you ever get an opportunity to support research which pushes the envelope of tradition, or to try a product which defies conventional wisdom, you'll look to the future and . . . imagine the possibilities.

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