THE NCSU HORTICULTURAL SUBSTRATES LABORATORY

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Each day we are facing new challenges in floriculture. Most growers are very aware of the current emphasis being placed on water quality, water conservation, and the reduction of runoff from agricultural industries. Another issue that reaches beyond floriculture and affects society as a whole is solid waste management and waste product utilization. Here at N.C. State, these issues are being addressed in an inimitable fashion. Faculty within the Department of Horticultural Science have combined their expertise and formed a powerful research unit, the Horticultural Substrates Laboratory.

Creation of the Horticultural Substrates Laboratory

For some time, the Department has housed experts in horticultural substrates (*for those of you like myself who are behind the times, "growth medium" is passé and "substrate" is the correct term for the "stuff" around your plant roots*): Dr. Bill Fonteno has been specializing in physical properties of horticultural substrates, particularly the mixes used in floriculture; Dr. Ted Bilderback also researches physical as well as chemical properties of substrates, primarily for use in container nursery production of ornamentals; Dr. Stu Warren has expertise in amending native soils for landscape use and is also involved with fertilization practices in the landscape and in nursery production; and Dr. Paul Nelson is renowned as a leading authority in floriculture crop nutrition and has a great interest in pursuing alternative fertilization practices for plant production. These four faculty members are assisted in the horticultural substrates laboratory by four technicians and three graduate students. This core of researchers banded together, integrating the strengths of each program into a center of excellence for substrates research. Though in its infancy, the interaction works well; sharing of facilities, sometimes labor, and a constant dialogue of shared ideas allows the group to address issues that no one member could approach alone.

Grower Issues and Research Goals

Any plant/water/fertilizer issue that is related to the below ground portion of a crop is a concern of the substrates research group. The issues being addressed and the corresponding research goals can be broken into two groups, those relating to physical properties of a substrate and those relating to chemical properties of a substrate.

Chemical properties of a substrate are concerned with plant nutrition, fertilization practices, and nutrient retention in the container. In the past, most chemical properties research dealt with these issues without addressing how physical properties of the substrate affected plant nutrition. It is hard to separate physical from chemical properties because they are so interrelated. For example, watering habits (based on drainage and water holding of a substrate) drastically affect nutrient levels in the substrate solution.

The physical properties of a substrate are equally important to growers, yet are less understood than chemical properties. A substrate is needed to supply anchorage for the plant, moisture and oxygen to the roots, and to serve as a reserve for plant nutrients. Physical properties dictate how rapidly the container will drain, how often watering is needed, and to a certain extent, how available nutrients will be to plants.

So what are the issues being addressed by the substrates laboratory? How are the horticulture industries--floriculture production, nursery production, and landscape management--benefiting from the projects? How is society in general benefiting from this work? Listed below are two major issues and what is being done to tackle the problems involved.

Water quality/water conservation/runoff/groundwater contamination. It is only a matter of time until growers will be forced to change their fertilization and irrigation habits. The amount of water used in production and the quantity of fertilizer running out of the container after a watering must be reduced. In the simplest terms, the goal is to keep the nutrients in the container, reduce the amount that escapes into the environment, and reduce water use in general.

Paul Nelson's research targets nutrient uptake efficiency as a major goal (Figure 1). Part of Paul's research has immediate and direct application for the industry. The applications portion of Paul's program attacks the nutrient runoff problem using three different strategies: **1) Develop slow release fertilizers that will supply constant, uniform, low levels of plant nutrients.** Slow release fertilizers are currently available, but they do not release as uniformly as required to prevent "peaks and valleys" in nutrient concentrations in the substrate solution. Plant roots really do not require 200 ppm nitrogen. If we could supply 14 ppm N (1 mmol) constantly to the roots, never allowing the concentration at the root surface to drop below 14 ppm N, the crop could draw ample nitrogen for growth. Dr. Nelson's lab group is involved in evaluating nutrient sources that may supply ample nitrogen uniformly over the entire production time of a crop (~12 weeks, as for pot mums). Some of the materials being evaluated include composted

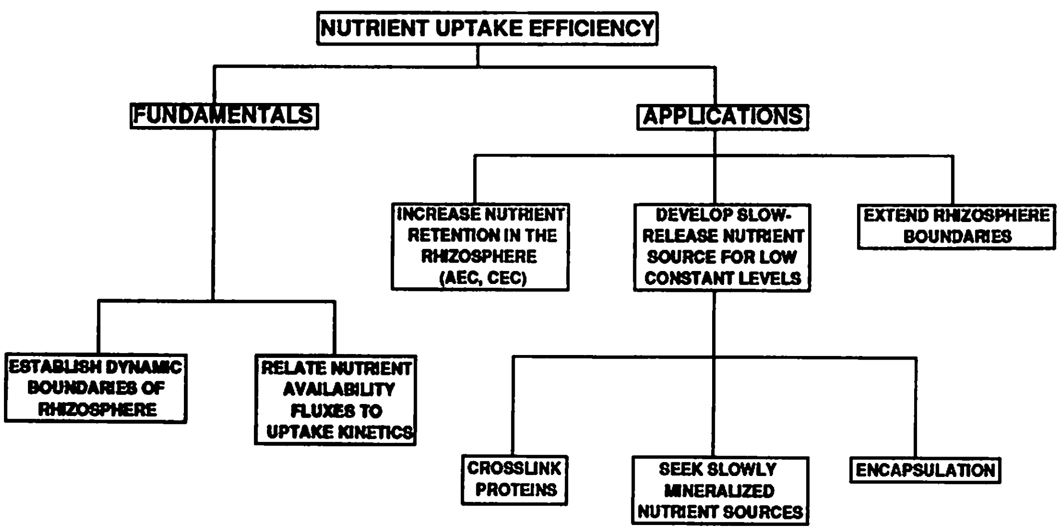

Figure 1. Organizatonal diagram for Dr. Paul Nelson's nutrition research program.

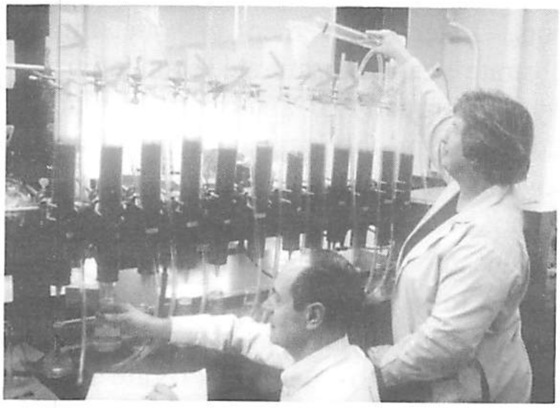

Figure 2. Dr. Paul Nelson and technician Nancy Mingis are measuring nitrogen release from experimental slow-release fertilizers.

poultry litter, bacteria, yeasts, and feather meal (Figure 2). These naturally occurring forms of nitrogen are slowly broken down by nitrifying microbes in the substrate. As the organic nitrogen is "mineralized", it becomes available for plant growth. Another class of slow release fertilizers being developed are complex protein molecules that contain high levels of nitrogen. As the proteins are broken down in the substrate, the nitrogen becomes available for plant use. The third group of slow release materials of interest to Dr. Nelson is microencapsulated mineral fertilizers. **2) Increase nutrient retention in the rhizosphere.** First, a definition for rhizosphere: the rhizosphere is the portion of the substrate within a container from which roots can draw nutrients and water. A large portion of the container volume may hold fertilizer and water, but if the roots cannot pull the moisture and the nutrients from that area, then it is not part of the rhizosphere. One way Dr. Nelson's group hopes to increase nutrient retention is to increase the cation and anion exchange capacity (CEC and AEC) of substrates. This involves evaluating different materials used in the substrate mixes and noting which components "hold" the most nutrients. If more nutrients are retained, less can leach out the bottom of the pot. **3) Extend the boundaries of the rhizosphere.** As mentioned above, only a portion of the container volume is tapped by roots, and a large portion of the nutrients and water in the pot are not available to the plant. How can plants utilize these unavailable nutrients? As water moves through the substrate, it carries nutrients with it. The nutrients outside the rhizosphere would be available, if we could increase the lateral movement of water into the rhizosphere and towards the roots. This is a goal being addressed by Dr. Nelson's group as well as Dr. Fonteno's research group.

Bill Fonteno has been researching physical properties of substrates for many years. His work has led to standard procedures that are used to test the air and water status of mixes produced by many of the substrate manufacturers today (Figure 3). The procedures developed in his laboratory have reduced the turnaround time for physical properties testing from 3 weeks to 48 hours, allowing for quicker response to manufacturers and growers. Bill is continuing this research into standardization of physical properties testing. Another portion of Bill's work deals with reducing fertilizer runoff. Two approaches are being taken to reduce runoff and increase nutrient efficiency: **1) Redesign mixes**

Figure 3. Dr. Bill Fonteno and technician Beth Harden are measuring drainage, aeration, container capacity, and total porosity of greenhouse substrates.

to reduce the amount of water that drains from the container. Many of our mixes are very "loose", and water drains out very rapidly. A well-drained substrate allows growers to be "heavy with the hose", watering more often and leaching with every watering without overwatering the plants. We must change our watering habits and reduce the amount of water running out the bottom of the pot. Recently, Dr. Jay Holcomb from Penn State University was visiting Bill's lab to become better acquainted with physical properties testing procedures. In a group discussion of substrates and runoff problems, the above point was made--greenhouse mixes must "tighten up" and growers must reduce their watering (Figure 4). Jay made an important observation that each of us must accept: "This (changes in greenhouse substrates and watering habits) is a major philosophical change in how we grow plants." Growers will have to relearn how to water their plants. Dr. Fonteno's research efforts in greenhouse mix design are crucial for runoff reduction. **2) Increase the amount of unsaturated conductivity in substrates.** As mentioned above, if lateral movement of water could be increased, then the nutrients held outside the rhizosphere could become available to plant roots. Lateral movement of water through a substrate is called unsaturated conductivity. This physical property of a substrate has not been addressed in the past. Increasing lateral movement of water and nutrients in a container has not been a goal in the past. As a matter of fact, unsaturated conductivity has been sacrificed in order to increase substrate drainage. Lateral movement of water is important to plant nutrition, and part of Bill's research efforts are addressing ways of increasing unsaturated conductivity in substrates. Not only would an increase in lateral movement of water expand the rhizosphere, it would result in more uniform moisture distribution in the container reducing the number of pockets of too much and too little moisture in the substrate.

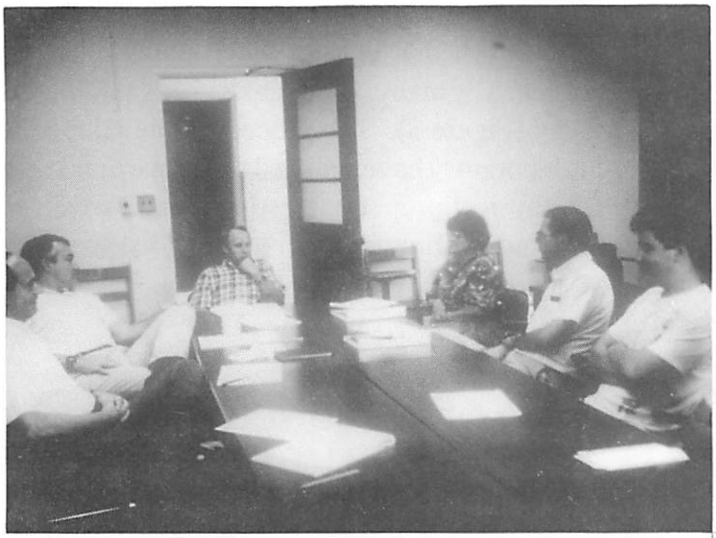

Figure 4. Attenders at a horticultural substrates briefing meeting held this summer included (L–R) Paul Nelson, Bill Fonteno, Ted Bilderback, Penn State graduate research assistant Noreen Khoury, Penn State visiting professor Jay Holcomb, and NCSU undergraduate research assistant Jerome Brewster.

The topic of water quality and reducing runoff is difficult to separate from irrigation systems research. Subirrigation and closed systems such as ebb and flow benches are one alternative to nutrient runoff and excess water use. Bill Fonteno, Roy Larson, and myself are examining different irrigation systems--tube systems, tray systems, and ebb and flow--for poinsettia and bedding plant production (Figure 5). This research will help offer design alternatives to traditional watering/ fertilizing strategies that use tube delivery systems.

The greenhouse industry is not the only facet of horticulture concerned with nutrient runoff. The nursery producers are also reevaluating their fertilizer procedures. Dr. Ted Bilderback's research efforts are centered around keeping nutrients in the container in an outdoor nursery situation. A container nursery does not have the luxury of a greenhouse in having total

Figure 5. Irrigation systems are being tested by Bill Fonteno, Roy Larson, and Doug Bailey for bedding plant and poinsettia production.

control over watering. Nurseries must stick with "loose" mixes to prevent water logging during heavy rain periods. This enhances the need for increased nutrient retention in the nursery substrates. Ted has been testing slow release fertilizers, and he has been evaluating substrate components that resist/reduce nutrient leaching (Figure 6). Probably the biggest leachate problem in nursery production is phosphate loss. Ted's approach to phosphate retention in media is similar to one of Paul Nelson's--increase the nutrient retention of a substrate by increasing the cation and anion exchange capacities. More anion exchange sites for phosphate in the substrate means less will flow out the bottom of the container. In our group discussion with Jay Holcomb, Ted commented: "in today's bark-based nursery mixes, anion exchange capacity is a mute point, but that is changing rapidly." Again, the substrate laboratory group is addressing basic chemical and physical properties of substrates to solve grower problems.

Figure 6. Dr. Ted Bilderback and technician Mary Lorscheider are determining nutrient levels in container leachates and nursery irrigation runoff.

Dr. Stu Warren also deals with nutrition of containerized nursery stock, magnesium availability in particular. Magnesium leaches very rapidly from nursery mixes, resulting in magnesium deficiency during the second year of growth. Stu is analyzing sources of magnesium that are more resistant to leaching than the magnesium released from dolomitic limestone, the traditional source of Mg used today. The most promising material Stu has worked with is the mineral olivine ($MgFeSiO_4$). Olivine breaks down slowly, releasing enough Mg to supply the plant throughout the production cycle. Stu and Ted are evaluating yard waste and poultry litter composts as slow release sources of phosphate for nursery production as a cooperative project. Composted materials may help increase nutrient retention by increasing CEC and AEC as well as serve as a source of plant nutrients. Stu and Ted are also looking at calcined clays as an amendment for nursery substrates. Calcined clays can increase the CEC of the mixes and also increase water holding capacity to reduce irrigation needs.

The horticultural substrates laboratory is addressing water quality issues from many angles for many industries. But this is not the only issue the laboratory is researching. Equally important to both growers and society is the issue of solid waste management.

Horticultural Uses of Solid Waste Materials. The increasing problem of solid waste management affects each of us in our personal as well as professional lives daily. The problem is intensifying and society must be prepared with alternatives to landfill disposal. In case you were unaware, you should know that beginning January 1, 1993, it will be illegal to place any yard trash or plant material in a North Carolina landfill. Currently, items such as leaves and yard debris (including plant material from horticulture industries) account for ~30% of the volume of North Carolina landfills. Where will this material go in 1993? Where will you place your poinsettia stock after you have taken all the cuttings you need? This area of waste utilization is being addressed by the horticultural substrates laboratory. For example, Mecklenburg County has already contacted the members of the substrates laboratory group in regards to composting the large amounts of debris created last year by hurricane Hugo.

We are fortunate at N.C. State to already have in place a strong program in agricultural waste management. Dr. L.M. (Mac) Safley of Biological and Agricultural Engineering has been researching composting procedures for some time. The engineers have the composting technology; the horticultural substrates laboratory have substrates technology. The two areas are being meshed to form alternative uses for the large volumes of organic waste generated by society. Stu Warren is working on the utilization of composts in the landscape (Figure 7). Compost products are an excellent amendment for landscape use as well as in greenhouse and nursery production substrates. The trend of using waste materials in greenhouse mixes can already be seen; materials--rice hulls, peanut hulls--are being used commercially in substrates with good results. Stu Warren and Ted Bilderback are cooperating on the use of compost materials in nursery container media as nutrient sources (mentioned above) as well as an alternative use for solid waste materials. Bill Fonteno is measuring the physical properties of substrates containing composts and other alternative substrate components. In the past, this type of research was based on growing plants in a mix and evaluating growth. This approach took years; many species need to be examined with this approach and each crop takes time. Now that Bill's lab has standard testing procedures, the approach is one of matching a set of physical and chemical property standards. This approach takes only about 6 months when evaluating a substrate mixture. The trend is away from worrying about ingredients. Ingredients are not the issue--properties are. Another solid waste project involves Paul Nelson's work with bacteria as a nitrogen source for plants. Pharmaceutical company waste products include dead bacteria and other microbes that cannot be placed in land fills. Paul is using these materials as nitrogen sources for our industry. In many areas of floriculture technology, universities fall behind the industry with respect to state-of-the-art facilities and equipment. Composting and waste utilization is one area where we are a forerunner.

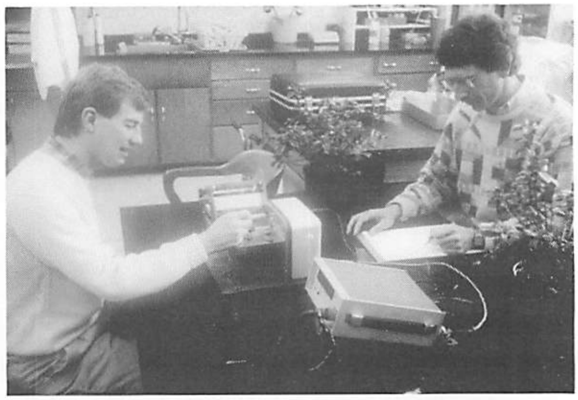

Figure 7. Dr. Stu Warren (right) and technician William Reece are measuring plant growth responses to compost incorporation into substrates.

Benefits of the Horticultural Substrates Laboratory

In a time when agriculture is being criticized for environmental pollution, we are attempting to increase water quality, and we are standing on the edge of an era when we will become an essential user of society's waste products *(talk about environmental stewardship!)* The horticultural substrates group is researching real issues of real concern for our industry; water quality and solid waste utilization being emphasized most. Approached by individual programs, progress in these areas would be slow. However, with the cooperative additive efforts currently underway, perhaps the general public will gain a better appreciation for horticulture in the very near future.