Fertilization Practices in Greenhouse Tobacco Seedling Production: A Survey

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ABSTRACT

Production of tobacco (*Nicotiana tabacum* L.) seedlings in greenhouses has become increasingly popular in the southeastern USA. In the most common system, styrofoam flats float on a bath of nutrient solution. A survey was conducted in 1993 and 1994 in South Carolina to determine the nutrient concentration of the solution after the plants were removed. Extension agents collected 183 samples from their growers on an anonymous basis. The samples were analyzed for NO$_3$-, NH$_4$+, PO$_4$-, SO$_4$-, K$^+$, Ca$^{2+}$, and Mg$^{2+}$ by ion chromatography. The analytical results show that most growers are following extension fertility recommendations; however, a few growers are heavily overfertilizing. The overfertilization may be an incorrect grower response to growth-limiting factors other than nutrient supply. The extension agents can use this information to better work with growers on their fertility practices. Residual PO$_4$- concentrations suggest that P recommendations were too high, but new fertility programs have successfully lowered the residual P concentrations. The results also show that current methods of waste nutrient disposal should be adequate.

**SOUTHEASTERN TOBACCO** (*Nicotiana tabacum* L.) producers are increasingly adopting greenhouse technology for production of transplants. For the most part, these greenhouses use a technology referred to as the float system (Rideout et al., 1994). Briefly, this system involves constructing wooden frames on the floor of the greenhouse. At the beginning of each season, the frames are lined with plastic sheeting and filled with nutrient solution formulated with water-soluble horticultural fertilizers such as 20-8.7-16.6 (N-P-K) at a rate sufficient to provide 100 mg L$^{-1}$ N, 15-2.2-12.5 (N-P-K) at a rate sufficient to provide 250 mg L$^{-1}$ P, or 20-4.4-16.6, 16-1.7-13.3, or 15-2.2-12.5 at a rate sufficient to provide 100 mg L$^{-1}$ N (Gooden et al., 1991). Based on P nutrition research results, the fertility recommendation was changed to 15-2.2-12.5 or 16-1.7-13.3 at a rate sufficient to provide 250 mg L$^{-1}$ N in 1994 (Rideout et al., 1994). In addition, the number of producers using greenhouses for seedling production greatly increased during this time.

The objective of this study was to determine the residual nutrient concentration in as many greenhouses as practical. From the residual concentration, we planned to make inferences concerning grower adherence to recommended practices, and to determine what additional educational efforts were needed. In addition, measuring residual concentrations over a wide area aided in identification of any potential environmental problems from waste nutrient disposal.

**MATERIALS AND METHODS**

**Sample Collection**

The survey was conducted in the South Carolina counties of Darlington, Georgetown, Horry, and Williamsburg in 1993 and in Georgetown, Horry, and Williamsburg in 1994. Samples of waste nutrient solution were collected by county extension agents at the time seedlings were removed from greenhouses for transplanting. In 1993, 109 samples were collected, and 74 samples were collected in 1994 (Table 1). Samples were identified only by county and a sequence number, and not by grower name, to increase participation in the survey.

Waste nutrient solution samples were collected in plastic bottles at, or as soon as possible after, seedling removal from the greenhouses. Samples were stored frozen at -18°C until analysis. The dimensions of the float beds and nutrient

solution depth were also measured so that total solution volume and nutrient quantities could be calculated.

Samples were analyzed for $\text{NO}_3^-$, $\text{NH}_4^+$, $\text{PO}_4^{3-}$, $\text{SO}_4^{2-}$, $\text{K}^+$, $\text{Mg}^{2+}$, and $\text{Ca}^{2+}$. A Dionex DX100 ion chromatograph fitted with either an AS4A (anions) or a CS12 (cations) separator was used for all analyses. Results were expressed on an elemental basis of all nutrients. Nutrient solution $\text{N}$ was calculated as the sum of $\text{NO}_3^-$ and $\text{NH}_4^+$. In some cases, there was a lag of a few days between plant removal and sampling. To reduce error due to resulting solution evaporation and to allow comparison between greenhouses, actual solution volumes were calculated using nutrient solution depth measured at sampling. Nutrient concentrations were corrected to the normal working volume of each particular size greenhouse, assuming the initial solution level to be the industry standard a 10-cm depth. Measuring actual solution volume also facilitated calculation of the quantity of nutrients in each greenhouse.

Data Analysis

Concentration distributions were determined for $\text{N}$, $\text{P}$, $\text{K}$, $\text{Ca}$, $\text{Mg}$, and $\text{S}$. A series of six concentration ranges were established for each nutrient. Ranges were manually chosen on an individual basis to best display the range in concentrations found. The percentage of samples falling into each range was determined using the chart procedure contained in SAS (SAS Inst., 1982). Data were plotted as the percent of samples in each range. Years were not combined, due to differences in the number of counties and samples in each year.

RESULTS AND DISCUSSION

Nitrogen. In 1993, 73% of greenhouses sampled exhibited $\text{N}$ concentrations in the 0 to 50 mg L$^{-1}$ range (Fig. 1). In contrast, 46% of greenhouses were within this range in 1994 (Fig. 1). The range in concentrations was much greater in 1994, with the highest being 489 mg L$^{-1}$ as compared with 220 mg L$^{-1}$ in 1993.

Starting in 1993, recommended practices specified an $\text{N}$ concentration of 250 mg L$^{-1}$ at 4 wk after seeding (Gooden et al., 1992; Rideout et al., 1994). Fertilizer was not recommended after this point, and the $\text{N}$ concentration should have decreased with time. Results from 1993 indicated that this practice was, for the most part, being followed by growers. This $\text{N}$ application is sufficient to provide good growth without leaving excessive residual $\text{N}$. On average, there was 1.3 kg N left per greenhouse in 1993 (data not shown). Given that solution evaporation is by far the most common disposal method, environmental problems would not be expected if the plastic liner is disposed of in a sanitary landfill. However, there is a potential for environmental contamination if the solution is discharged to ground or surface water.

Levels of residual $\text{N}$ increased greatly in 1994 (Table 1, Fig. 1), leading to the conclusion that recommended levels were being exceeded by a number of growers. One possible explanation may be that $\text{N}$ was being applied in response to poor growth that was apparently caused by cloudy, cool weather throughout much of the month of March. With outdoor seedbeds, a normal and recommended practice is to respond to poor growth by application of $\text{NaNO}_3$ and $\text{MgSO}_4$ to correct for leaching of $\text{NO}_3^-$ and $\text{SO}_4^{2-}$ below the shallow root system of the seedlings. Due to the nature of the float system, leaching cannot occur. It does appear, however, that the practice of $\text{N}$ addition in response to poor growth has made its way into the greenhouse. In particular, this practice seems to be more prevalent in Horry County than in other counties (Table 1). Therefore, educational programs covering the actual causes of poor seedling growth in the greenhouse need to be conducted.

Phosphorus. Concentrations of $\text{P}$ were distributed among most of the concentration ranges in 1993 (Fig. 1). In 1994, residual $\text{P}$ levels were very low (Fig. 1). Before 1994, there was no recommendation specifically for $\text{P}$, and this variation is most likely due to the use of soluble complete fertilizers with varying concentrations of $\text{P}$. In 1994, a new fertility regime, known as the Low Phosphorus Program (Rideout et al., 1994), was released to growers. By reducing $\text{P}$ fertilization to a 16 to 36 mg L$^{-1}$ $\text{P}$ range, seedling height is better and more easily managed. Seedlings exhaust the $\text{P}$ supply in many cases, resulting in a desirable seedling hardening before transplant. A very desirable side effect is that the $\text{P}$ concentration of the waste solution is minimized. The Low Phosphorus Program was the subject of an intensive educational effort in Williamsburg and Georgetown counties in 1994. The low $\text{P}$ residuals for 1994 (Table 1) are most likely the result of widespread acceptance of the new fertility regime.

Potassium. There is no specific recommendation for $\text{K}$ concentration in the nutrient solution. Complete fertilizer is used to supply $\text{K}$. Since most fertilizers used in seedling production have a $\text{K}_2\text{O}$ concentration equal to that of $\text{N}$, the most common concentration is 250 mg L$^{-1}$ $\text{K}_2\text{O}$ (208 mg L$^{-1}$ $\text{K}$). Luxury consumption of $\text{K}$ has been reported for tobacco (Tso, 1990). Variations in the amount of luxury consumption are probably responsible for the wide variation in $\text{K}$ residuals. The lack of very high $\text{K}$ and $\text{P}$ residuals in samples that had high $\text{N}$ residuals (Table 1, Horry County 1994) indicates that complete fertilizers were most likely not being added as a source of supplemental $\text{N}$ in response to poor growth in 1994.

Calcium, Magnesium, Sulfur. No extension recommendations existed during the study period concerning the application of $\text{Ca}$, $\text{Mg}$, or $\text{S}$ as fertilizers. However, $\text{H}_2\text{SO}_4$ and $\text{CaSO}_4$ were recommended to counteract the effects of alkaline water often found in the coastal plain (Rideout et al., 1994, 1995). As a result, $\text{Ca}$ and $\text{S}$ concentrations varied.

Table 1. Mean nutrient concentration of waste nutrient solution by county and year.

<table>
<thead>
<tr>
<th>County</th>
<th>No. of Samples</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>mg L$^{-1}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Darlington</td>
<td>10</td>
<td>33.2</td>
<td>14.4</td>
<td>37.0</td>
<td>19.1</td>
<td>13.0</td>
<td>12.2</td>
</tr>
<tr>
<td>Georgetown</td>
<td>7</td>
<td>12.2</td>
<td>9.2</td>
<td>22.7</td>
<td>12.1</td>
<td>10.3</td>
<td>21.1</td>
</tr>
<tr>
<td>Horry</td>
<td>72</td>
<td>46.2</td>
<td>18.1</td>
<td>52.3</td>
<td>18.1</td>
<td>15.6</td>
<td>53.5</td>
</tr>
<tr>
<td>Williamsburg</td>
<td>20</td>
<td>19.6</td>
<td>16.9</td>
<td>30.5</td>
<td>16.6</td>
<td>4.2</td>
<td>21.7</td>
</tr>
</tbody>
</table>

1994

| Georgetown | 12             | 30.9          | 0.7 | 17.9| 21.5| 17.4| 105.5|
| Horry      | 40             | 161.9         | 5.7 | 44.7| 41.1| 18.9| 319.8|
| Williamsburg | 22          | 40.1          | 2.7 | 25.2| 26.8| 8.7 | 34.4|

Magnesium concentrations were generally low in 1993 (Fig. 2). Grower adoption of low P fertilizers (15–2.2–12.5, 16–1.7–13.3 [N–P–K]), which also contain Mg and Ca (the previously used fertilizers did not contain Mg or Ca), may have resulted in increased Ca and Mg residuals in 1994.

In 1993 and 1994, S concentration in 73 and 62% of samples, respectively, was in the 0 to 50 mg L⁻¹ range (Fig. 2). This range of values occurred in greenhouses located in Darlington and Williamsburg counties (Table 1), where water alkalinity was not a problem. Due to solubility problems with Ca, none of the complete fertilizers used for tobacco seedling production contain S. The soilless mix does contain CaSO₄, but in quantities that may not be sufficient in all cases. There is the potential that S deficiency may have occurred in these greenhouses. It is also possible that S deficiency is being mistakenly diagnosed as N deficiency, resulting in unneeded N application. As a result, South Carolina extension recommendations now include application of MgSO₄ or CaSO₄ to provide 60 mg L⁻¹ S in greenhouses where H₂SO₄ and CaSO₄ are not needed to correct water alkalinity (Gooden et al., 1995).

![Graphs showing nitrogen, phosphorus, and potassium concentrations in 1993 and 1994](image)

Fig. 1. Percent of samples within each concentration range of nitrogen, phosphorus, and potassium found in greenhouse samples in 1993 and 1994. Numbers on the x axis indicate concentration ranges.
Survey results indicate that most growers fertilized tobacco seedlings in greenhouses at the level needed by the plants. There were some greenhouses that were heavily overfertilized, either as the result of not following recommended practices or in response to poor growth. Additional educational programs on the causes of poor plant growth are needed.

Average quantities of waste nutrient per greenhouse were 1.3 kg N and 0.6 kg P (data not shown). The most common nutrient solution disposal method is to let the solution evaporate over the summer months (less than 1% of these greenhouses are used for purposes other than tobacco seedling production). Evaporation of the solution results in the nutrients adhering to the liner along with a small amount of soil-less mix. Residual nutrients are then disposed of with the plastic liner, which is replaced every year. As long as the liner is disposed of properly in a sanitary landfill, waste nutrient disposal should not present any environmental problems. Problems could occur if waste solution is dis-

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Fig. 2. Percent of samples within each concentration range of calcium, magnesium, and sulfur found in greenhouse samples in 1993 and 1994. Numbers on the x axis indicate concentration ranges.
charged to ground or surface water, or waste plastic is left outside of the greenhouse where rain could remove some of the nutrients.

The survey methodology used here worked well in providing insight into grower practices. The idea of a survey was well received by both extension personnel and growers. We are not aware of any growers refusing to allow samples to be taken from their greenhouse, and most were interested in the results. Perhaps the methodology used here could be adapted to soil or tissue sampling with other crops.

ACKNOWLEDGMENTS

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REFERENCES


Learning about Riparian Rehabilitation: Assessing Natural Resource and Landscape Architecture Student Teams

Barbara A. Ryder* and Karen S. F. Swoope

ABSTRACT

This case study began as a 6-wk class project between two disciplines that had fundamental differences in terminology, knowledge base, skills, and perceptions. Natural resource students (NR) and landscape architecture students (LA) were teamed up to learn about riparian restoration. The instructors attempted to teach students skills for being effective members of a team. They also taught them rudimentary survey skills. Students completed weekly surveys to assess perceptions of the project, skills acquired through the experience, and the knowledge gained. At the beginning of the project both LAs and NRs felt they had similar individual abilities for working on team projects and had similar experiences with riparian restoration; however, the NRs felt significantly more knowledgeable about riparian ecology. By the end of the project, compared to the NRs, the LAs were significantly more positive about their ability to work as a member of a group. The LAs had caught up to the NRs in their knowledge of riparian ecology. The level of riparian restoration skills, similar for both groups at the beginning, had improved equally for both groups. Instructors felt that all of their course objectives had been met. Student team reports were well written and complete and their posters showed that they had integrated the information presented. Evaluations indicated that the students felt they had learned about the other’s discipline. The student projects were awarded the 1994 Washington State Natural Resource Conservation Service award for volunteerism and provided impetus for a bioengineering grant award from the Washington State Department of Ecology.

It is essential that natural resource science programs prepare college graduates not only with scientific skills and competence in their specific disciplines, but with the ability to think, communicate, and function as part of a progressive, creative interdisciplinary team. The interdisciplinary team is most often the primary decision making unit among natural resource management organizations for addressing land management options and resolving the multiplicity of public interests, social values, and economic concerns.

PROFESSIONAL DISCIPLINES

University natural resource science programs (forestry, range management, wild land recreation management, wildlife management, and water resources) are increasingly faced with the need to adopt curricula that provide opportu-

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Abbreviations: NR, natural resource; LA, landscape architecture; EIS, Environmental Impact Statement.