EFFECTS OF COMPOST ON THE GROWTH OF FRASER FIR CHRISTMAS TREES IN NORTH CAROLINA

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INTRODUCTION

It has often been said that it is easier to pull a rope than it is to push a rope. The same is true for marketing of recycled materials, including the marketing of compost. It is much easier to market a product that is being pulled through the market by the demand for the product. The purpose of this project was to better quantify the effects of compost on Fraser fir Christmas tree growth in North Carolina as a means of providing a research-based marketing tool to increase demand for compost. North Carolina harvests six to seven million Christmas trees per year from nearly 4,000 acres, which is about 15 percent of the total national Christmas tree output.

The premise for the study was that the addition of compost could have several potential positive impacts on tree production, including faster growth, denser growth, and the potential for suppressing plant diseases. The study was divided into two parts: one part studied the growth effects of compost, and a second part studied the disease suppression qualities of compost. It was expected that the results of this study would have positive lateral effects in increasing demand for compost for other conifer trees grown throughout the State.

LITERATURE REVIEW

Past research does not sufficiently provide practical effects of compost for Christmas tree production, nor does it provide guidelines for appropriate application rates. This research proposal refines past research by limiting the range of compost blends and specifically targets a valuable tree species. Research shows that high blending rates (greater than 30 percent by volume) in most cases do not provide added benefits for plant growth and in some cases hinder plant growth through excessive soluble salt levels and high fertility.

The literature provides sparse information regarding the response of evergreen trees to compost application. There is evidence that some compost will suppress certain plant diseases, but the mechanisms for this suppression and, consequently, the amount or type of compost needed to suppress diseases are not well understood.

Dunlap, et al. (1986) found that Ponderosa pine seedlings responded to compost treatment, with significant treatment effects on height and dry weight, while Douglas fir and noble fir did not show any significant effects. F. R. Gouin (1977) measured the germination and growth of Norway spruce and white pine in response to three levels of screened and unscreened compost compared to an inorganic fertilizer in Maryland. Soils amended with screened compost produced taller seedlings than those treated with unscreened compost. Soils amended with compost had higher levels of pH, phosphorous, and magnesium when compared with those plants receiving inorganic fertilizer. An additional study by Gouin (1993) provides key findings for horticultural crops, including that biosolids compost can effectively provide initial plant needs for both macro and micro nutrients; high application rates of compost can cause soluble salt problems in container-grown plants; mulching conifer seedlings with 112 tons of biosolids compost per hectare stimulated growth; and compost can suppress "damping-off" organisms to the extent that fungicides are not needed.

In a separate study by Hoitink (1997), three mixtures of Technagro™ compost (10, 15, and 20 percent v/v) were applied to seven different species of nursery plants. Results showed that at all locations, most plants treated with the compost grew significantly faster (P=0.05) than the control mixture. Additional work by Devitt, et al. (1991) on periwinkle shows that compost can result in greater plant growth. More recent work by Ingham on strawberries shows that compost can help suppress certain plant diseases. DeCeuster, et al. (1999) suggested that the age of compost could have an effect on disease-suppression qualities.

AREAS OF STUDY

From seed to harvest, the life cycle of a typical Fraser fir Christmas tree is 12 to 15 years. During this time, the tree is transplanted twice prior to harvest. Seeds are initially planted in a seedbed (75 to 120 plants per square foot) where seedlings develop and grow for three years. The seedlings, anywhere from 6 to 12 inches tall, are then transplanted into larger transplant beds. The transplants are kept in the transplant beds for two years, where they reach a height of 16 to 24 inches. From here, the transplants are planted in fields, where they remain for seven to ten years until harvest.

The following two topics were investigated for this research project:

- Study 1 – The response of Fraser fir field transplants to compost
- Study 2 – The effect of compost on the viability of Phytophthora cinnamomi root rot in transplanted Fraser fir seedlings

PROJECT DESCRIPTION AND RESULTS

The compost used in this study was a biosolids-based compost furnished by the City of Morgantown, North Carolina. The compost was well within the USEPA Table 3 limits for pollutants. Additional analysis is presented Tables 1 and 2.

STUDY 1 – THE RESPONSE OF FRASER FIR TRANSPLANTS TO COMPOST

Field-grown trees (previously transplanted trees) in a permanent field location were treated with four rates of compost as mulch (0, 2.2, 4.4, and 8.8 gallons per tree, which corresponds to application rates of 0, 0.5, 1.0, and 2.0 inches of compost on the soil surface, respectively). The experiment was initiated on March 31, 1999 in a plantation of Fraser fir Christmas trees in Ashe County, North Carolina. Spacing of trees was five feet by five feet, and trees had been in the field for about four years. Average tree height was about four feet. Standard cultural practices included annual shearing. Biosolids compost from the City of Morgantown, North Carolina was spread in a circle around each tree out to the drip-line of the crown.

TABLE 1 – Compost Analysis

% Total Solids	49.0
% Volatile Solids	67.3
% Total Kjeldahl Nitrogen	1.8
Carbon-to-Nitrogen Ratio	21.1
Bulk Density (lb/yd^3)	1,168
Conductivity (mmhos/cm)	8.4
% Total Nitrogen	4.07
% Phosphorus	1.81
% Potassium	0.44
% Sulfur	0.91
% Magnesium	0.31
% Calcium	1.03
% Sodium	0.16
Boron (ppm)	17
Iron (ppm)	20,161
Manganese (ppm)	415
pH	7.0

TABLE 2 – Bacterial and Fungal Biomass Analysis

Parameter	Level	Rating
Total fungal to total bacterial biomass	0.03	Poor
Active to total fungal biomass	0.16	Low
Active to total bacterial biomass	0.14	OK
Active fungal to active bacterial biomass	0.03	Poor

The experimental design was a randomized complete block with six replications and four compost rates. Each plot consisted of 20 trees (five trees by four trees). Excluding controls (no compost), all plants received compost. Trees received no inorganic fertilizer during the experiment. Measurements were made on the interior six trees in each plot, with perimeter trees acting as a border between plots. In two plots, to ensure having six good measurement trees, it was necessary to begin with 24 trees rather than 20 trees.

The following measurements were made on September 1, 1999 in each plot:

1. Number of leaders emerging from the top node
2. Length of the best leader
3. Number of lateral buds on the best leader
4. Number of subterminal buds at the apex of the best leader
5. Average diameter (mm) of the best leader two centimeters above its base
6. Bud density on the best leader = 3) 2
7. Twig length in upper crown*
8. Length and weight of a single needle from the branch used in #7*
9. Foliage color: 1 (light) to 4 (dark green)

**See description of "Twig sampling in upper crown."*

Soil samples were collected in each plot and composited (Replicates 1 through 3 and 4 through 6). Two six-inch cores were taken in each plot underneath the compost near the drip line. Root samples were collected for mycorrhizal analysis.

RESULTS AND DISCUSSION – STUDY 1

Of the measurements that were taken (above), there were no significant differences ($P =< 0.05$) for Variables 1 through 6 and 9. Results for Variables 7 and 8 are described below.

Twig Sampling in Upper Crown (Field Trees). We hypothesized that compost treatment might influence the quantity or quality of foliage. In early September, one dominant branch tip (current-year growth) was taken from a major branch in the second whorl below the terminal of each tree. The following variables were measured on each branch:

1. Length (cm)
2. Number of lateral buds
3. Number of terminal and subterminal buds
4. Needle length at the mid-point of the twig

Needles that were used for measurement of length were taped to three-inch by five-inch cards (one card per plot) and subsequently dried at 65°C and weighed. Twigs and needles were placed on ice, transported to Raleigh, and dried to a constant weight at 65°C. Foliage and wood were separated and weighed for each twig. Foliage density was calculated (foliage weight) twig length) as well as bud density (lateral buds) twig length). Results were analyzed with GLM and regression procedures (SAS Institute, Inc.). After processing the twigs, the foliage was composited within each plot, ground to pass a 40-mesh screen, and analyzed by the North Carolina Department of Agriculture, Agronomic Division. Results were analyzed with GLM and regression procedures (SAS Institute, Inc.).

Results for Twig Sampling. Because some trees were inadvertently sheared before measurement, the analysis for twig length was conducted only for plots and trees that were not sheared. The number of non-sheared trees in the 0, 2.2, 4.4, and 8.8-gallon treatments was 22, 18, 18, and 24, respectively. Only four of the measured or calculated variables for side shoots appeared to be affected by compost. There was a slight linear increase for total foliage (Figure 1) per branch (g), foliage density (g/cm), and average needle weight (mg). The relationship for lateral buds was quadratic (Figure 2), with highest values for the 2.2- and 4.4-gallon rates, and exhibited great variability. Trees that received standard fertilization (adjacent to experimental plots) yielded results similar to those for the control trees in the experimental plots.

FIGURE 1 – Total Foliage

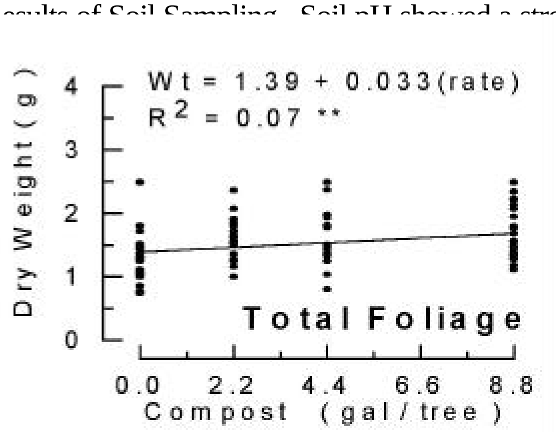


FIGURE 2 – Lateral Buds

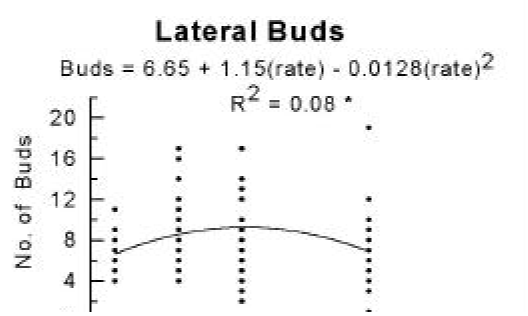
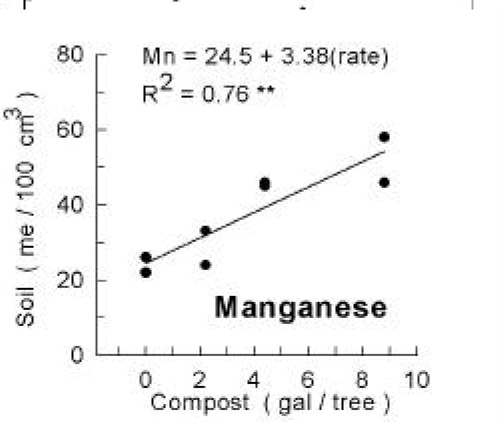


FIGURE 3 – Soil pH



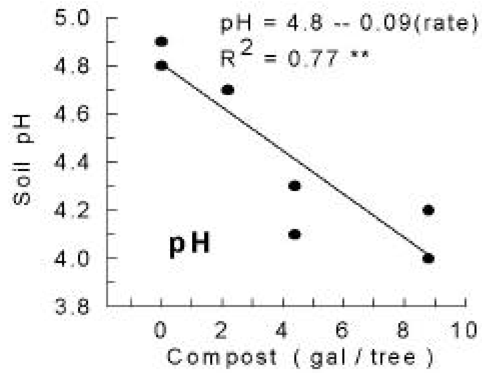


FIGURE 5 – Copper

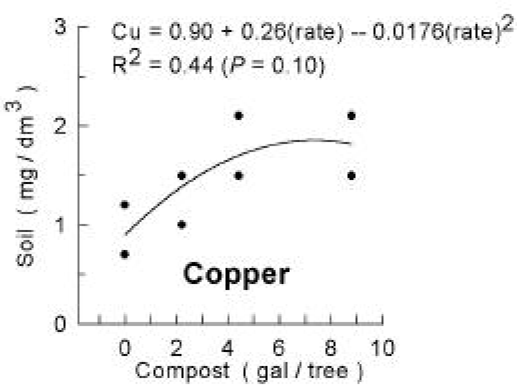


FIGURE 6 – Manganese

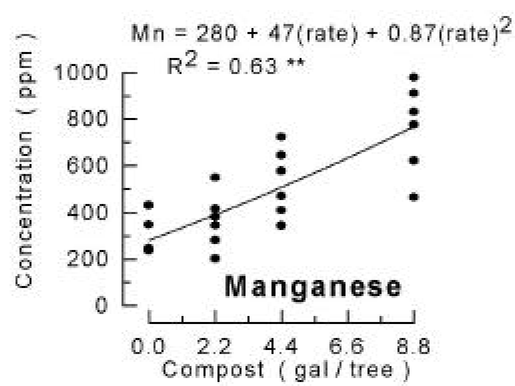
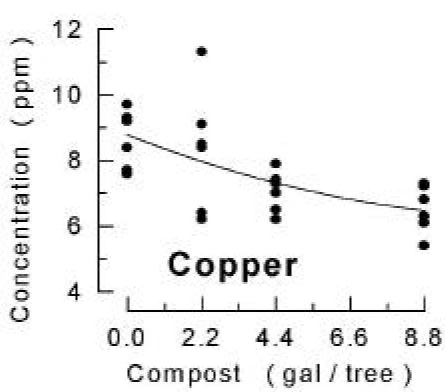


FIGURE 7 – Copper



Variables included in the soil analysis were phosphorous (mg/dm^3); potassium, calcium, magnesium, and sodium (meq/100 cm^3); weight-to-volume ratio (g/cm^3); pH in water, buffer acidity at pH 6.6, sum of cations, and cation exchange capacity buffer (meq/100 cm^3); base saturation (%); manganese, zinc, and copper (mg/dm^3); and humic matter (g/100 cm^3). Regression analysis was also conducted on various soil indices to identify any effects due to compost. Five indices were significant ($P \leq 0.05$) – potassium, copper, manganese, zinc, and pH – and graphs were prepared for these indices, including regressions, R^2 values, and the level of significance.

Results of Foliar Analysis in the Field. For the foliar nutrient concentrations in the field, a regression analysis was conducted to determine if any nutrient concentrations were related to compost rates. Nutrients included in the tissue analysis were nitrogen, phosphorous, potassium, calcium, magnesium, and sulfur (measured in %); and iron, manganese, zinc, copper, and boron (measured in ppm). For any nutrient that was significant ($P \leq 0.05$), a graph was prepared, including the regression, R^2 value, and level of significance. Four nutrients proved significant: nitrogen, phosphorous, manganese, copper, and boron. The regression for boron was significant at P=0.10.

Concentrations of several nutrients in the foliage were affected by compost treatments. Nitrogen and manganese (Figure 6) increased with application rate, whereas phosphorus and copper (Figure 7) decreased. The effect was most dramatic for manganese, which exhibited a steep linear increase with increasing application rate. The most likely explanation is that the pH of the surface soil decreased noticeably at the higher application rates, and manganese is much more soluble below pH 5.3.

The only thing that might be a "red flag" is the unusually high manganese values for the two heaviest rates of compost. Values above 500 ppm often are associated with yellowing of foliage and tend to adversely affect the calcium-to-manganese ratio.

STUDY 2 – THE EFFECT OF COMPOST ON THE VIABILITY OF PHYTOPHTHORA CINNAMOMI ROOT ROT IN TRANSPLANTED FRASER FIR SEEDLINGS

This study was designed to determine the effects of compost on suppressing *Phytophthora cinnamomi,* a plant disease that is an increasing concern in Fraser fir production. Earlier studies have shown that compost can reduce or eliminate certain plant diseases when mixed with the potting media at up to 30 percent of compost by volume.

Four levels of compost by volume (0, 10, 20, and 30 percent) were mixed with potting media. On April 9, 1999, 300 three-year-old Fraser fir seedlings were lifted and graded from a bed at Laurel Springs, North Carolina and heeled into soil in several plastic boxes and buckets. Plants were about one foot tall.

On April 12, 1999, plants were potted into one-gallon pots using a pine-bark medium. No lime or fertilizer was incorporated into the medium. The pH of the planting media was around 5.0. There were 70 pots of each treatment. After potting, plants were watered and placed beneath 50 percent shade. The plants were irrigated twice daily by overhead sprinklers. On June 2, 1999, pots were moved underneath an overhead shade structure, where they were watered three times daily for 30 minutes each time.

In each compost treatment, 30 plants were inoculated with rice grains infested with *Phytophthora cinnamomi* using three holes per pot (about one inch deep), and two grains per hole. Holes were closed and pots watered shortly thereafter. Thirty non-inoculated plants of each treatment were used as controls. Dr. Mike Benson, Department of Plant Pathology, North Carolina State University, cultured and provided the *Phytophthora cinnamomi* for this study.

The experiment was terminated on July 28, 1999. The primary treatment effect was whether the plant was alive or dead. However, early after inoculation with *Phytophthora cinnamomi,* it became clear that nearly all plants subject to the treatment would die. To determine if compost affected growth, the following measurements were made on each non-inoculated plant:

1. Total height
2. Leader elongation in 1999
3. Length of the longest lateral branch in top whorl
4. Length of a single needle from the longest lateral in the top whorl
5. Average stem diameter two centimeters above ground-line

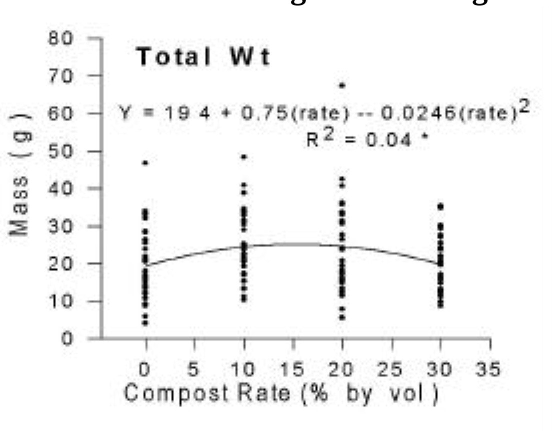
All new growth was removed from the aerial part of each plant. Roots were separated from tops and washed clean of rooting medium. These components, as well as the needle measured in #4 above, were dried at 65^{o}C to a constant weight and weighed for each plant.

RESULTS AND DISCUSSION – STUDY 2

It was hoped that compost might reduce the mortality normally associated with Phytophthora root rot. However, this did not occur. All but a few of the inoculated plants died, with no differences evident among treatments. *Phytophthora cinnamomi* was not deterred by any level of compost.

With regard to the other measurements, results indicate that compost did have an effect on plant growth. In general, the response to compost rate was quadratic, with the maximum for each growth index at 20 to 30 percent, as evidenced in the response for total weight of seedlings (Figure 8).

FIGURE 8 – Total Weight of Seedlings



Values were normally lower for the control (no compost) and for the 30 percent rate, which was similar to the control. However, there was one exception; the average weight of individual needles decreased with increasing compost rate, with the maximum weight in the controls. This result did not carry through into the field experiment, where needle weight increased slightly with increasing levels of compost. Most regressions were statistically significant, but there was tremendous variability, causing the R^2 values to be low. No treatment was included to compare compost to standard fertilization.

The results of this study show that this particular compost did not provide protection from *Phytophthora cinnamomi.* Additional research that became available after commencing this study (DeCeuster and Hoitink, 1999) suggests that the age of the compost can make a difference on biological control. Composts that are either too immature or too mature are less likely to suppress disease. Composts that have reduced levels of free nutrients yet still have active populations of microorganisms will be most likely to provide some level of protection. This particular compost had a respiration rate of less than 2 mg CO_2-C/g, which indicates very low microbial activity.

Further studies on this topic should concentrate on the age and the stability of the compost as well as the amount of compost used in the planting mix. For example, a compost that is 0, 30, 60, 90, and 120 days old (after active composting) at various mix ratios (0, 10, 25, and 50 percent, by volume) would provide a better indication of whether compost would have an effect on *Phytophthora cinnamomi* in Fraser firs.

The additional measurements taken in this study were not a part of the original intent or design of the study, yet they do provide an indication that compost can improve the growth of Fraser firs. In the pot study, growth measurements were made only over a seven-week period, yet results were observed. Although there was tremendous variability within each treatment, the results did have some significance. A study specific to the effects on young seedlings would be easy to design, and a longer-term growth study would provide more conclusive results.

CONCLUSIONS

The studies provided mixed results. Although there are clear results in some areas, the project raised additional questions that need further investigation.

With regard to the growth issue, the strongest results are that compost will reduce soil pH, add nutrients and micronutrients to the soil, and affect some nutrient levels in the trees. Also significant, but less predictable, was the response to growth as measured in total foliage, foliage density, and needle weight. Realizing that not all effects of the compost would likely be evident in a single growing season, results over a two-year period would provide more convincing evidence as to the effects of compost.

Results for disease suppression were clear. This compost did not have any impact on the suppression of *Phytophthora cinnamomi* in any of the compost treatments. However, a recent article (DeCeuster and Hoitink, 1999) suggests that the age of compost has a bearing on whether the compost will help suppress plant diseases. The particular compost that was used in this study was very well aged, which is likely the reason that it had no impact on disease suppression in this study. An area of further investigation would be whether differently aged composts would provide different levels of protection from this disease. This issue is important to the extent that compost has been viewed by some producers and users as providing disease suppression in plants. If compost is capable of providing such disease suppression, the circumstances under which it provides protection should be better understood so that this characteristic could be marketed appropriately. This study identifies one set of conditions of compost type, stability, and application where disease suppression did not occur, and this needs to be recognized.

Although this project produced some clearly positive results in using compost on growing Fraser firs, it also uncovers a few areas of concern. The increase in manganese in the soil and in the needles is most likely a result of the lower soil pH with increasing levels of compost. The concentrations of manganese in the needles could be high enough to raise concern about yellowing of the needles, which is not a goal in raising Fraser firs. However, our comparisons of the needles did not uncover any differences in color in relation to amount of compost used. Another area of concern is the decrease in needle phosphorous with the increase in compost. The concentration of phosphorous in the needles was below desired levels in all cases, which suggests phosphorous is deficient regardless of compost use. The drop in pH may have reduced the availability of phosphorous. These areas need further investigation.

There are several changes that would have made the research more meaningful and should be considered in future research efforts. The first is that more than one type of compost could have been used. Understanding the differences between yard waste and biosolids-based compost would be helpful. A second change would be to collect and analyze data over a two-year period rather than just one year. For example, the effects of compost applied in year one on bud development would be more easily measured in shoot growth from those buds in year two. A third area of improvement would be to use compost of different ages in determining the effects of compost on suppressing *Phytophthora cinnamomi.* The compost used in this experiment was well aged, and that could have been a significant reason why the compost did not suppress the disease at any application rate.

ACKNOWLEDGMENTS

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