EFFECTS OF COMPOSTED ORGANIC MATERIALS ON THE GROWTH FACTORS FOR HARDWOOD AND SOFTWOOD TREE SEEDLINGS

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INTRODUCTION

This project was a demonstration of the effects of compost on the growth of hardwood and softwood tree seedlings. There is intense interest in identifying cost-effective means to improve the revegetation of severely disturbed sites. The standard method of revegetating these types of sites generally involves seeding and/or planting, fertilizing, and mulching. For erosion control and revegetation, grass seed, pine seedlings, chemical fertilizers, straw and machine-blown pulp mulches are commonly used.

This report was a cooperative effort by the U.S. Forest Service, U.S. Department of Interior Bureau of Indian Affairs' Cherokee Forest Branch and the Office of Solid Waste, Environmental Protection Agency (EPA). Two mountainous sites were used on the Cheogh Ranger District of the Nantahala National Forest and one in the adjoining Qualla Cherokee Reservation in western North Carolina with permission of the Cherokee Tribal Council. This effort was funded under Interagency Agreement No. DW12936577-01-0.

STUDY DESIGN

This study tested the hypothesis that the use of composted products from organic materials has practical uses in forestry related applications and has the potential to improve the growth of tree seedlings in severely degraded soils. During December 1994, a group of tests were initiated on three damaged (i.e. compacted or severely eroded) sites to compare a standard straw mulch to three different composts used as mulches (i.e. biosolids, yard, and municipal solid waste). Although pines have been developed for consistent characteristics, both softwood and hardwood seedlings were used to provide a greater variety of tree seedling responses. White pine, chestnut oak and Chinese chestnut seedlings were planted. The conifer seedlings were 8-10 inches high and the hardwood seedlings (both oak and chestnut) were 24-30 inches high in 1994. Seedling growth and response of natural vegetation were monitored from December 1994 to the summer of 1998. Comparisons of ground cover, soil erosion, growth and survival data, and soil nutrient values showed distinct differences in the four treatments.

Mulch materials were generally applied two-inches thick. Yard compost was shredded leaves, grass, tree trimmings, etc. donated from Compost Central of Charlotte, N.C. The commercial cost in 1994 was $10/cubic yard. Biosolids compost was wastewater sludge donated from the City of Lexington, N.C. The commercial cost in 1994 was $21/cubic yard. Municipal solid waste (MSW) was mixed municipal solid waste donated from Bedminster Corporation of Sevierville, Tenn. The commercial cost in 1994 was $10/ton or $5/cubic yard. Straw was standard baled straw from Robbinsville, N.C. with a cost $4/bale, which equates roughly to $12/cubic yard.

DESCRIPTION OF TEST PLOTS

Cheogh Clearcut Site #1: A yellow pine/upland hardwood site had been clearcut by the sale to a commercial timber company. All residual vegetation was cut near ground level with chainsaws following the logging. The logging slash and debris were pushed off the test site with a bulldozer. Most of the topsoil and some of the organic duff (i.e. partially decomposed twigs, leaves, etc.) were retained. The ridgetop site had eight test plots 12 feet wide by 32 feet long on the southeast face, and eight identical plots on the northwest face. The 50 Year Site Index (i.e. the average height growth of trees in 50 years of a site) was 75 feet for shortleaf pine and 68 feet for upland oaks. Slopes averaged 30-35%. Soil samples were taken at 4-5 inches depth prior to the test applications for nutrient assessment. All four mulching materials were used as a 2-inch mulch on the sixteen test plots. Thirty white pine seedlings were planted in four tests with different mulches on each site of the ridge making a total of eight plots. Each of the 480 hardwood seedlings were planted in holes approximately 6 inches in diameter and 12 inches deep made by a hand-held power auger. Each tree was marked with a color-coded wire flag (Figure 1).

Cheogh Landing Site #2: The second test site was a log landing devoid of all topsoil and the remaining soil compacted by the trucks and tractors used in previous log harvesting. Site #2 was located on top of a ridge about a mile north of Ridge #1 and was surrounded by a yellow pine/upland hardwood stand on an old road where logs had been loaded on trucks (Figure 2). On all eight plots, two inches of mulching materials were turned into the hard-packed soil by use of a disk harrow pulled by a farm tractor. Additionally, on four test plots, a 2-inch surface mulch was applied. Chinese chestnut seedlings were planted into 12-inch holes made by a 6-inch gas-powered auger bit in each of the eight 30 tree seedling test plots. Each of the 240 seedlings were marked with a color-coded wire flag.

Cherokee Old Field Site #3: The third test site was located within the Cherokee Reservation on a rocky north slope that had a marked loss of topsoil. At the bottom of the slope was s small stream. In an old field cleared of brush, Chinese chestnut seedlings were planted into 12-inch holes made by a 6-inch gas-powered auger bit. The four test materials were added as a 2-inch layer to each test plot and turned into the soil with a disk harrow pulled by a farm tractor. An additional 2-inch layer of mulch was added to each of the plots. More intensive data was

collected on Sites #1 and #2 because Site #3 was compromised when a third 2-inch layer of MSW compost was inadvertently spread over the entire test sites including the control site. Although Site #3 could not be used for valid statistical comparisons, it was quite impressive to observe the average of about 3 feet of growth per year in those seedlings that received both turned-under and surface-applied compost, about 3-inches total around each tree.

FINDINGS

Tree Growth – Site #1 and Site #2: White pine: Height and diameter values after three years for all of the composted materials were significantly higher than the values for straw, with the highest in the yard compost. Chestnut oak: Height and diameter after three years were significantly higher in all of the compost plots compared to the straw plots (Figure 3) with the highest in the MSW compost. Chinese chestnut: At the log landing, similar to chestnut oak, the height and diameter of the Chinese chestnut tree seedlings were significantly greater in the MSW compost (Figure 4).

Survival – Site #1 and Site #2: The survival rates after three years of growth exhibited certain mixed results. There was a good survival rate for tree seedlings after planting, regardless of treatment. Among white pine seedlings, the 3 types of compost-treated plots averaged 93% survival and the straw-treated plots averaged 92%. All of the hardwood seedlings survived the first year very well but declined rapidly in the second and third years. However, this survival pattern is typical of most hardwood species. The survival rates of hardwoods among the composts averaged 69% and the survival rate in the straw plots were 77%. The survival rates of the Chinese chestnut seedlings were impeded by chestnut blight infection and the damage due to a tree-fall across the yard compost plots. Even with the disease and physical damage, the survival in the straw plots and in the compost plots both averaged 63%. Among the three composts, the highest rate of Chinese chestnut survival was 75% in the biosolids compost plots and the lowest was in the yard compost plots due to damage by the wind-thrown tree. Before the storm damage, the straw plots showed the lowest survival.

Herbaceous Ground Cover – Site #1 and Site #2: Herbaceous volunteer cover was estimated by the percent of ground surface area covered for each plot six months after the initial planting. The average cover for each type of mulch was: biosolids compost at 95%, yard compost at 80%, MSW compost at 60%, straw at 50% and an untreated control on Site #1 at 45%. The natural vegetation by herbaceous plants on the biosolids compost was remarkable in the first growing season with many plants well over five feet in height. The negative height growth of tree seedlings in the biosolids plot in Site #1 measured after the first growing season could have been due to that dense herbaceous cover shading the seedlings (Figure 5). In all of the composted plots, the vegetation showed a deeper green color with few yellow hues compared to the straw plots (Figures 6 and 7). There was no visible soil erosion in any of the compost or straw plots

during the first year after planting. However, erosion was apparent during the first year in the untreated areas. In the second and third years, similar trends were noted except that the erosion was visible in the straw plots as well as the untreated areas. None of the three compost plots showed any signs of erosion over the three years of observation. Serially dated photographs of each test site showed heavier vegetation cover on all of the compost sites compared to the straw plots.

Soil Nutrient Values – Site #1 and Site #2: Soil samples were again taken from the center of each of the 24 treated plots in November 1996, nearly two years after the tests were initiated. Control samples were taken at Sites #1 and #2 from an adjacent area within 12 feet of the test plots that were site-prepared, but not treated with compost or straw. Organic component (Hm %): The soil organic component (mean values) in the straw treated plots was 63% greater than the untreated control but the compost-treated plots were 140% greater than the untreated control. In Site #1, the MSW compost showed the highest values, and in Site #2 the yard compost showed the highest values. However, in damaged mountain ridges, variations in soils could occur within the 1200-square-foot test area.

Soil pH: For the control samples, the mean soil pH was 4.65; for the straw plots the mean pH was 4.75; and for the composts, the mean soil pH was 5.1. The greatest gains in soil pH were in Site #2 where the compost was plowed into the soil and additional compost was surface-applied. On Site #2, the straw plot pH was 4.9; the untreated control was 4.7; and the composts averaged a pH of 5.5. A soil pH of 5.5 is considered to be minimum desirable level for growing hardwood trees on these areas, indicating that soil pH was borderline for compost-treated chestnut oak and Chinese chestnut in these mountainous soils.

Soil nutrient values: Phosphorus (P) was not detectable in any of the control samples or in any of the samples taken from the straw-treated plots. The P mean values for all of the compost -treated plots was 23.1, and the highest levels in this group were in the biosolids compost-treated plots. The potassium (K) and calcium(Ca) values for the control and straw samples were virtually the same for all areas and the mean values for the compost-treated plots were approximately twice as high as the control or straw plots. The secondary and micro-nutrient values for magnesium (Mg), manganese (Mn), zinc (Zn), and copper (Cu) were significantly higher in the compost-treated plots. The greatest difference of all the nutrients was in the Zn values where the compost samples showed more than nine times the values of the control and straw plots. It is important to note that the levels of most of the nutrients found in all soil samples were described by the soil scientists as below the desirable levels for nursery and field tree crops. The low P values were labeled as the most critical. None of the nutrient values in any of the plots were raised to the highest acceptable values (see Table 1).

TABLE 1. THE NUTRIENT VALUES OF SOIL*

Value	Straw	Compost	Control
Hm (organics)	0.44	0.65	0.27
pH	4.75	5.1	4.65
P-1	0	23.1	0
K-1	33.0	64.4	29.0
Ca %	12.8	37.7	13.0
Mg %	6.2	10.4	6.0
Mn-1	84.0	90.4	53.5
Zn-1	20.2	182.7	21.0
Cu-1	40.1	100.5	32.0
S-1	146.2	141.1	169.5

* North Carolina Agronomic Division reported as standardized index or percentage of the cation exchange capacity (CEC).

Cherokee Site #3: Each of these plots inadvertently received additional MSW compost over most of the area plots after a severe storm washed the original 2-inch layer of compost downhill in a few areas. The wash-down may have been attributable to the fact that the compost was newly applied and had been screened to 1/4-inch or less rather than the conventional ½-3/4-inch screening size. Although the additional unplanned MSW mulching eliminated the Site #3 data from any valid data comparisons, the results were unexpectedly significant. The median height growth of all of the surviving seedlings after 22 months was 48.1 inches. The average diameter of all the seedlings was 0.81 inches. The overall survival rate was over 76%. The growth in Site #3 was much greater than in the plot at Site #2 originally turned under and surface-mulched with yard compost (Figures 8 and 9). The average tree in the yard-compost plus MSW compost plot was slightly over 100 inches in height and was 0.89 inches in diameter; however, some measured over 180 inches in height and about 1.4 inches in diameter. The height growth across all of the compost test plots was slightly greater than the test plot originally treated with straw only. The straw test plot was accidentally "treated" with a 2-inch layer of MSW compost over the straw. These trees appeared to be sustaining their exceptional growth through the end of the third year, including an average height of 15 feet in the yard/MSW compost plot. In the biosolids test plot (Figure 10), herbaceous volunteer growth continued to be robust after three years, compared to

the control and straw-treated plots, which is consistent with the use of biosolids compost to establish permanent turf.

CONCLUSIONS

Natural vegetation and soil stabilization response were visibly superior in the compost-treated sites. Compost-treated test plots had much more visible natural vegetation response and clearly had no soil erosion and higher soil nutrient values in each of the following three-and-half years after treatment. During the first year after treatment, the biosolid compost plot showed the highest density of natural revegetation of grasses and leafy plants and provided the best protection against soil erosion. After almost four years, all of the compost treatments were shown to be revegetated to a much greater degree than the straw treatments. Soil erosion was non-detectable in all of the compost plots in Sites #1 and #2. Minor soil erosion was visible in the 2-inch straw-treated plots and vegetation recovery was slower and less dense. Soil nutrient values and pH had recovered far better in the compost-treated plots compared to the untreated control and straw-treated plots. The hardwood seedling tests showed mixed results between the four treatments early in the test period, but most of the compost plots resulted in better growth and higher survival rates throughout the three-year test period. All tree seedlings clearly grew larger in height and diameter in the compost plots than in the straw plots. Survival of pine seedlings was also greater in each of the composted plots than in the straw plots.

The results of this project after three-and-a-half years of monitoring show that compost mulching is consistently superior to straw mulching for revegetating severely disturbed sites. Furthermore, results of the combination of disked-under compost plus compost mulching showed both superior survival and growth potential of hardwood and softwood tree seedlings even in soil of borderline nutrient value. In this particular study, the height and diameter growth of white pine trees was greatest in plots treated with yard compost, while the height and diameter of chestnut oak and Chinese chestnut trees was greatest in plots treated with MSW compost. Forestry application benefits were: gained soil rehabilitation, growth of planted seedlings, natural revegetation and in the prevention of soil erosion.

RECOMMENDATIONS

The data produced by this three-year demonstration show that the application of mature compost contributed to a significant accelerated growth of hardwood and softwood tree seedlings when compared with straw and no treatment. The enhanced growth by all three composts could have positive economic implications for public and private tree growers, the lumber industry, the furniture and building construction industries, the biomass/utility/energy industries and the environmental entities dealing with clean air and global warming even though the initial costs of using compost may be greater than straw.

The reproducibility of this study, however, remains to be tested due to the nature of types of composts used in the study. First of all, the mature yard compost used was kept thermophilic (120-140 degrees) for about five months instead of the usual 3-8 days. This process is standard for the company making this compost and was used for the purpose of this study. In addition, the mature MSW compost used was made from mixed municipal solid waste from residential and commercial generators (i.e. compost made from municipal solid waste that has not had recyclables removed). This means that the MSW compost contained a greater diversity of organic materials such as food scraps, paper and other organics. These feedstocks are not usually found in combination in most commercial MSW composts currently being made. It is uncertain what beneficial effects, if any, these factors may have had on the quality and composition of the MSW compost. In addition, the composts used in ths study were analyzed by three laboratories for different compositional characteristics, making comparative analyses of results impractical.

In this study, all three composts (yard, MSW, and biosolids) had a 2% nitrogen (N) level which is more than twice that generally found in most commercial yard waste composts. We recommend that future demonstrations compare these composts to those more commonly found in the marketplace. Additionally, future studies should consider substituting a commercially-valuable hardwood, such as white oak, for the chestnut oak; and that a commercial variety of fruit or nut tree be substituted for the Chinese chestnut. All tree seedling planting and measurements should continue to be under the supervision of experienced forest service personnel. Compost analyses should be done by a single laboratory and that the laboratory meet the standards defined by the U.S. Composting Council.

**Figures and color photographs can be seen on the U.S. EPA website:
http://www.epa.gov/epaoswer/non-hw/compost/trees.pdf**