

**Annual Report**

**Soil Amendments for  
Roadside Flower Plantings in  
Virginia**

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## **I. Introduction**

The establishment and maintenance of roadside wildflower stands is dependent both upon the inherent productivity of roadside soils and on management practices. Roadside soils are almost always highly disturbed relics of the road construction process and vary significantly from soils that have formed in place. In particular, roadside soils are generally compacted, high in soil strength, acidic, and low in organic matter and plant-available nutrients. Additionally, roadside soils are quite variable laterally due to their disturbed (cut/fill) nature coupled with the normal soil and geologic irregularities encountered when a road corridor slices linearly through what is typically a curvilinear surficial soil/parent material sequence.

The combined influence of adverse soil properties and soil variability in roadside soils has led to irregularities in wildflower growth and bloom display and, in certain instances, to complete stand failures (W. Watson and R. Dove, personal communication). Management practices such as tillage, liming, and fertilization have mitigated these problems to only a limited extent. Land reclamation studies have proven conclusively that a lack of organic matter and organically bound nutrients is the primary property that differentiates drastically disturbed soils from their natural counterparts (Daniels and Haering, 1994; Haering et al., 2000).

Numerous investigations in Virginia and nationally have demonstrated that composts produced from a wide variety of organic materials such as biosolids (sewage sludge), animal manure, and yard wastes can improve soil physical, chemical, and biological properties (Shiralipour et al., 1992; Brosius et al., 1998). The use of organic amendments can reduce or eliminate the need for periodic conventional fertilization and is typically less costly. Finally, and perhaps most importantly, organic amendments can ameliorate local irregularities in surface soil properties. In Virginia, many potentially useful organic amendments are available in each of the Virginia Department's of Transportation (VDOT) districts, and regulatory guidance and financial incentives promote the utilization of these amendments.

The primary goal of this research is to develop a soil amendment strategy that will insure uniform and consistent roadside flower growth, quality, and bloom display from year-to-year. This will be accomplished through the use of organic soil amendments that will reduce soil moisture fluctuations, stabilize the physical/chemical soil environment, provide a slow-release source of N, P, and other essential nutrients, and provide a number of other known benefits such as pathogen suppression and enhanced root/shoot growth. The overall goal of this program is to measure the performance of several species of flowers grown in typical Virginia roadside soils amended with various available organic amendments. The objectives of the research program are:

To evaluate and compare different organic amendments for their relative *long-term* effectiveness at improving roadside soil properties and enhancing wildflower growth and quality.

To evaluate the effect of non-composted (fresh) wood chips and hardwood tree leaves incorporated into roadside soils on flower growth and soil properties.

To compare the use of organic amendments and a promising new foam soil amendment with conventional roadside practices (e.g. the use of inorganic fertilizers/mulch).

This report addresses the specific results of two field and two greenhouse studies that were established between the fall of 1998 and the spring of 2000. The field studies were designed to evaluate the long-term effects of the organic materials that were selected. These included biosolids compost, yard waste compost, cotton gin waste compost, papermill sludge compost, and processed poultry-based fertilizer. The greenhouse studies were designed to augment the field studies. The goal of the greenhouse experiments was to gain information on actual N requirements of some roadside flowers as well as information on how these plants perform with the organic products in a carefully controlled environment.

## **II. Field Research**

### **A) The Effect of Compost Amendments on Performance of Roadside Flowers – Culpeper and Staunton – Initiated Fall, 1998.**

*Objective:* The objective of this on-going study is to determine how amending roadside soils with organic products such as composted biosolids, composted yardwaste, cotton gin waste compost, composted paper mill sludge, and processed poultry-based fertilizer affects the long-term performance of roadside flower plantings in Virginia.

*Justification:* These four organic products are available to most of the VDOT districts, but limited information is available about the effect of these products on roadside flowers. Two flower species, one perennial and one annual, were selected. Tall fescue was also included in the design as the typical roadside vegetation used by VDOT.

*Materials and Methods:* In August 1998, two nearly level sites were selected in Culpeper and Staunton, Virginia. The Culpeper site is located near the exit ramp to route 522/3 North off Hwy 29 in Culpeper County in the Northern Piedmont soil physiographic region. The soil at this site has a clay loam surface texture with a high concentration of coarse fragments. The Staunton site is located in the median of I-81 near Buffalo Creek in Augusta County of the Appalachian Ridge and Valleys soil physiographic region. It's surface soil texture is also clay loam.

Initial soil chemical properties (Table 1) were determined using established procedures for southern U.S. soils (Donohue, 1992). Soil pH, Ca and Mg were adequate for establishment of vegetation because VDOT staff had previously limed the soils. Soils at both sites contained

lower concentrations of P than optimum for plant growth. Soil K concentration was adequate at Culpeper but lower than necessary for optimum plant growth at Staunton.

Table 1. Analysis of the soils used in the study.

Location	pH	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Soluble Salts (ppm)
Culpeper	5.8	8	101	816	120	141
Staunton	6.1	10	25	840	117	90

The study design is a two-way factorial experiment consisting of three plant species and six soil treatments. Plant species were lanceleaf coreopsis (*Coreopsis lanceolata*), corn poppy (*Papaver rhoeas*) and tall fescue (*Festuca arundinaceae*). The soil treatments were composts from four sources, an NPK fertilizer applied according to soil test results, a poultry litter-based fertilizer, AgriCell™ foam, and an unamended control. The composts were produced from: 1) biosolids (+ wood chips), 2) yard waste (+ poultry litter), 3) paper mill sludge, and 4) cotton gin trash. The source of each amendment is listed in Table 2. Each treatment was replicated 4 times. The experimental designs were a randomized complete block at Culpeper and a completely randomized block at Staunton. Individual plots were 100 ft<sup>2</sup>.

Table 2. Sources of amendments applied in Culpeper and Staunton in August 1998.

Treatment or Amendment	Source
Biosolids compost (BC)	Harrisonburg-Rockingham Regional Sewage Authority, Mount Crawford, 540-434-1053
Yard waste compost (YWC)	Panorama Farms, Earleysville, 804-989-3846
Paper mill sludge compost (PMSC)	Greif Bros., Amherst, 804-933-4182
Cotton gin trash compost (CGTC)	Commonwealth Gin, Windsor, 757-242-3566
Pelleted poultry-derived fertilizer (PPF)	Harmony Products, Chesapeake, 800-343-6343
AgriCell™ Foam	Enviro Tek Corp, Waterford, 540-882-3630

The existing vegetation was sprayed with glyphosate (2 gal/acre) two weeks prior to seeding. The sites were then roto-tilled six to eight inches deep. The amendments were incorporated by tilling them into the top three to four inches of soil on 8/26/98 at Culpeper and 8/28/98 at Staunton. The laboratory analysis of the properties of each amendment is presented in Table 3.

Table 3. Analyses of soil amendments used in the study.

Compost	Solids (%)	Org C (%)	C:N	TKN* (%)	Org N (%)	NH <sub>4</sub> -N (%)***	P (%)	K (%)	EC** (dS/m)	pH
Biosolids	70	37.8	9.6	3.95	3.14	0.81	2.9	0.25	10.74	6.8
Yard Waste	32	30.3	16.0	1.89	1.88	0.02	0.6	0.65	1.48	7.6
Paper Sludge	58	37.8	22.8	1.66	1.66	0.01	0.6	0.44	1.78	7.4
Cotton Gin	58	23.0	10.5	2.20	2.19	0.01	0.2	0.97	1.50	7.9
Poultry Fertilizer	90	40.98	9.4	4.36	3.96	0.04	1.8	2.79	22.70	7.5

\*TKN = Total Kjeldahl Nitrogen

\*\* EC = Electrical Conductivity (dS/m = mmhos/cm)

\*\*\*NH<sub>4</sub>-N (%) = Ammonium form of nitrogen

Amendments were applied at rates designed to supply 45 lbs/acre of first year Plant Available N (PAN), which is the estimated annual N requirement of wildflowers. Tall fescue N needs are higher than those of wildflowers, but the same rates of amendments were applied to all three species to provide consistent compost application rates. The equation used to estimate PAN from the various organic amendments was:

PAN = (X \* Org-N) + (NH<sub>4</sub>-N), where:

PAN = lbs of plant available nitrogen per dry ton of amendment,

Org-N = lbs of organic nitrogen per dry ton of amendment, determined as TKN - NH<sub>4</sub>-N,

NH<sub>4</sub>-N = lbs of (ammonia + ammonium) nitrogen per dry ton of amendment, and

X = estimated availability coefficient for organic N (x=0.10 for compost).

Nutrient application rates were estimated based on the actual composition of the composts (Table 4). Phosphorus and K rates were variable because the N:P and N:K ratios in the composts were different. The extent of wildflower P and K needs are not known, but establishment of tall fescue required 140 lbs P<sub>2</sub>O<sub>5</sub>/acre at both sites and 160 and 75 lbs K<sub>2</sub>O/acre at Staunton and Culpeper, respectively.

Table 4. Applied plant available nutrients for the first year.

Treatment	Amendment Rate	Estimated Plant Available Nutrients (lbs/acre)		
		Total N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
Biosolids	3 tons/acre (fresh wt)	49	280	12
Yard Waste	33 tons/acre (fresh wt)	54	292	164
Paper Sludge	22 tons/acre (fresh wt)	47	352	134
Cotton Gin	13 tons/acre (fresh wt)	34	69	175
Poultry Fertilizer	3 tons/acre (fresh wt)	44	222	133
AgriCell <sup>tm</sup> Foam <sup>1</sup>	3 inches	Not known	Not known	Not known
15-30-15	300 lbs/acre	45	90	45
Control	Not amended			

The three plant species selected have different characteristics. Corn poppy is a biennial that is seeded each year in the fall, coreopsis is a perennial that often takes two years to become fully established, and tall fescue is a perennial grass that is widely planted along Virginia roadsides. Corn poppy and fescue have higher N demands than coreopsis. Corn poppy and coreopsis were expected to be more sensitive to phytotoxicity produced by un-matured compost than fescue. Seeding rates were 20 lbs/acre of coreopsis, 18 lbs/acre of corn poppy, and 100 lbs/acre of tall fescue, respectively. The plots were rolled after seeding to increase seed-soil contact.

Weeds were controlled with periodic use of 2,4-D (1.4 gal/acre), imazapic (Plateau<sup>TM</sup>, 4 oz/acre), and pendimethalin (Pendulum<sup>TM</sup>, 1 gal/acre). Imazapic was applied in the spring of each year to the poppies and coreopsis. The pendimethalin was applied to both grass and coreopsis in August 1999. In June 1999, vegetation at both sites was mowed to eight inches to control weeds. By this time, the corn poppy had senesced, the tall fescue seed heads had fully expanded, and the coreopsis was not yet tall enough to be damaged by mowing. The corn poppy was replanted in early September 1999, after the plots were sprayed with glyphosate and imazapic and roto-tilled to three inches. The plots were rolled again after seeding.

The performance of the vegetation is being evaluated until spring, 2001 (2-1/2 years). A visual rating system that is frequently employed by turfgrass researchers is used each spring to measure living plant ground coverage density. Soil was sampled in each plot to a depth of 3-4 inches 18 months after soil amendments were applied (March 2000) for determination of pH; Bray-1 P; exchangeable Ca, Mg, K, and acidity; and base saturation.

Results and Discussion:

### Compost

There was considerable variation between the N levels of the composts, with the biosolids compost (BC) containing about double the percent N of the other composts (Table 3). The BC had a low C:N ratio and a high proportion (i.e., >20%) of N in the NH<sub>4</sub> form, indicating that the compost was not completely stabilized at the time of application. The BC also contained (not unexpectedly) a higher concentration of P and a lower concentration of K than the other composts. The P and K concentrations in the yard waste (YWC) and cotton gin trash (CGTC) composts were typical for composts derived from such feedstocks (Brosius et al., 1998). The paper mill sludge compost (PMSC) also contained concentrations of P and K that were consistent with published values, but the total N concentration of the PMSC used in our study was considerably higher than typical values (Campbell et al., 1995; Jackson and Line, 1997). Our PMSC was produced from a combined primary and secondary sludge that had received additions of NH<sub>4</sub>OH during the digestion process to stimulate microbial decomposition (Evanylo and Daniels, 1999). This resulted in a higher initial C:N ratio of the sludge (40:1) than is normally associated with papermill sludge.

### Other Amendments

The levels of N, P and K in the poultry fertilizer were similar to YWC and PMSC. Both the poultry fertilizer and the 15-30-15 fertilizer had similar N concentrations, but P and K concentrations in the poultry fertilizer were nearly 3 times greater than in the 15-30-15 fertilizer. The AgriCell foam provides some N but also significantly increases soil water holding capacity (Beck et al, 1999). This effect may explain why corn poppy reacted so favorably to this product. The potential for long term N release has also been documented for this product, but the amount and duration of N release is not clear. We have seen positive effects of the foam amendment on tall fescue performance for over two years beyond establishment treatment. The initial growth pattern of poppy and tall fescue with the foam was better than the control and equal to the other amendments.

### Corn poppy

Eight months after seeding (May 1999), the stand density of the corn poppy at Culpeper increased in the order: Foam = PPF ≥ Fertilizer ≥ PMSC = BC ≥ YWC ≥ CGTC ≥ control (Figure 1). Differences in corn poppy density with soil amendment treatments were observed in Staunton by the following spring (March 2000), when ground cover averaged 61% at Culpeper and 74% at Staunton.

### Coreopsis

None of the amendments significantly increased coreopsis density above the control at Culpeper or Staunton seven months after seeding (April, 1999; Figure 2). Coreopsis density averaged 66% at Culpeper and 51% at Staunton. Coreopsis density was decreased by the biosolid and poultry fertilizer at Culpeper and by the poultry fertilizer, as compared to other amendments, in

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<sup>1</sup> The amount of nutrients delivered by this product is not known. The product is sold as a soil conditioner, not a fertilizer. However, AgriCell does release significant N and P over time.

Staunton, 18 months after seeding (March 2000). At Culpeper, coreopsis density averaged 66% and at Staunton 64%, across all treatments. In Culpeper, the density increased in the order: Control  $\geq$  Fertilizer  $\geq$  Foam  $\geq$  CGTC  $\geq$  PMSC  $\geq$  YWC  $\geq$  BC  $\geq$  poultry. This is almost the opposite response to that of corn poppy.

### Tall fescue

The application of the composted yard waste, poultry fertilizer, and foam at Culpeper increased the density of tall fescue above the control in April 1999 (Figure 3). At Staunton, only the foam treated tall fescue was denser than the control at this time. By March 2000, none of the treatments increased tall fescue density above the control at either site. At this time, the average density at both sites was similar, 84% at Culpeper and 81% at Staunton. The densities measured for tall fescue and coreopsis at both sites were similar, unlike those measured for corn poppy.

### Soil Properties

At both locations, the greatest increases in soil extractable P concentration were associated with yard waste compost, biosolids composts, and poultry fertilizer (Table 5, 6), which each supplied nearly 300 lbs P<sub>2</sub>O<sub>5</sub> per acre (Table 4). Surprisingly, the paper mill sludge compost, which supplied the greatest amount of total P (352 lbs P<sub>2</sub>O<sub>5</sub> per acre), did not raise soil P concentration above that of the control, fertilizer, or CGTC treatments. The P in the PMSC was apparently not readily extractable. Composts had little effect on soil pH, which were already adequate, but soil pH tended to be higher with the PMSC and YWC than with the control and/or fertilizer treatments at both locations (Table 5, 6). This was likely due to the higher base saturation and lower exchangeable acidity of the PMSC and YWC plots than in the control and fertilizer treatments. PMSC and YWC increased the soil ppm Ca above the control and fertilizer treatment at both locations. YWC treatment increased ppm K above the control or fertilizer treatments at both locations; but the poultry fertilizer increased the ppm K above the control in Staunton only. The YWC increased the ppm Mg above all other treatments at both locations. Only the YWC increased soil cation exchange capacity at either site. The lower C:N ratios of the BC and the CGTC when compared with the PMSC and YWC may have resulted in greater N mineralization and subsequent acidifying nitrification reactions in the BC and CGTC soils. This in turn may have reduced the liming effectiveness of the organic matter in the BC and CGTC. The foam product did not increase the amount of soil P, ppm K, ppm Ca or ppm Mg when compared to the control. Because of the acidifying effect of the foam, the pH of foam-amended plots was significantly lower than that of the control. Therefore, if foam is used as a soil amendment, appropriate additions of lime are recommended. Percent base saturation was adequate for all treatments. Only the YWC and PMSC significantly increased the % base saturation over the control.

Table 5. Effects of amendments on soil properties sampled at Culpeper in March 2000 averaged across species. Treatment means followed by the same letter are not significantly different at the 5% level according to Student, Newman and Kuels test.

Treatment	ppm P	pH	CEC <sup>2</sup>	ppm K	ppm Mg	ppm Ca	% Base saturation <sup>3</sup>
BC	24bc	6.0b	9.1b	207bc	178b	1151bc	85b
YWC	34a	6.3a	11.5a	299a	249a	1517a	90a
PMSC	14cd	6.4a	9.9b	185c	191b	1417ab	92a
CGTC	14cd	6.1b	9.3b	247abc	204b	1137bc	86b
Poultry Fertilizer	29ab	6.1b	8.9b	282ab	184b	1097c	86b
AgriCell <sup>tm</sup> Foam	17cd	5.8c	9.9b	234abc	187b	1141bc	79c
Fertilizer	16cd	6.0b	9.0b	209bc	183b	1116bc	84b
Control	12d	6.0b	9.1b	205bc	187b	1140bc	85b

<sup>2</sup> CEC=Cation Exchange Capacity. The higher the CEC the more likely the soil is able to hold onto positive ions.

<sup>3</sup> % Base Saturation = %K + %Mg + %Ca. The base saturation indicates the percent of CEC sites that are occupied by basic cations. An approximate base saturation of 60% or higher is desirable.

Table 6. Effects of amendments on soil properties sampled at Staunton in March 2000 averaged across species. Means for all treatments followed by the same letter are not significantly different at the 5% level according to Student, Newman and Kuels test.

Treatment	ppm P	pH	CEC <sup>4</sup>	ppm K	ppm Mg	ppm Ca	% Base Saturation <sup>5</sup>
BC	40ab	6.1ab	9.7b	68c	173b	1358bc	87ab
YWC	46a	6.3ab	11.5a	119a	225a	1625a	92a
PMSC	22c	6.4a	9.9b	72c	173b	1500ab	91a
CGTC	27bc	6.1ab	9.5b	99ab	175b	1308bc	87ab
Poultry Fertilizer	52a	6.2ab	10.1b	109a	170b	1417abc	87ab
AgriCell <sup>tm</sup> Foam	21c	5.9b	9.2b	66c	154b	1247bc	84b
Fertilizer	28bc	6.1ab	8.7b	88bc	157b	1194c	85ab
Control	21c fix	6.2ab	9.3b	69c	175b	1311bc	88ab

### Herbicides

In March 1999, 2,4-D (1.4 gal/A) was applied to the tall fescue and Plateau<sup>TM</sup> (4 oz/A) was applied to the corn poppy and coreopsis at both sites. One month later Plateau<sup>TM</sup> (same rate) was again applied to the flowers. The herbicides were used to kill henbit (*Lamium amplexicaule*) and purple deadnettle (*Lamium purpureum*) in Culpeper and Canada thistle (*Cirsium arvensis*) in Staunton. The Plateau<sup>TM</sup> reduced, but did not eradicate, the henbit and purple deadnettle populations in Culpeper. Plateau<sup>TM</sup> did little to kill the thistle, unfortunately. The coreopsis appeared to be slightly stunted by the herbicide but later recovered. The corn poppies were not affected. In late August 1999, Pendulum<sup>TM</sup> (1 gal/A) was applied to the coreopsis and 2,4-D (1.4 gal/A) was applied to the grass in both areas to try to prevent the germination of winter annual weeds. The following spring, the weed population in these plots was reasonably tolerable.

<sup>4</sup> CEC=Cation Exchange Capacity. The higher the CEC the more likely the soil is able to hold onto positive ions.

<sup>5</sup> % Base Saturation = %K + %Mg + %Ca. The base saturation indicates the percent of CEC sites that are occupied by basic cations. An approximate base saturation of 60% is desirable.

*Conclusions:* Compost has been demonstrated to be valuable for restoring the productivity of disturbed soils because it improves nutrient availability, water-holding capacity, and soil structure. In this study, the compost effects on plant density were variable and often not better than the control. Extremely droughty conditions during the initial one and half years after plant establishment may have masked expected beneficial effects of the composts. Each plant species performed poorly with the CGTC relative to other compost treatments at same location and sampling time. The most noticeable difference in chemical composition between the CGTC and other composts was the lower rate of P supplied. Conversely, the YWC always resulted in plant densities that were among the best at each location and time of sampling. Similar biological processes create composts, but the characteristics of each will be greatly dependent on the feedstock employed and the degree to which the finished material is allowed to mature. The poppy responded differently than the coreopsis to the two non-compost amendments. The poppy's performance was strongly enhanced with the AgriCell™ Foam and poultry fertilizer; however, the poultry fertilizer reduced the coreopsis' density. The concept of matching compost type to individual plant species is worthy of further investigation.

## **B) The Effect of Leaf Litter and Wood Chips on the Performance of Roadside Flowers – Culpeper – Initiated Spring, 1999.**

*Objective:* The objective is to determine the effect of incorporated leaf litter and wood chips on the performance of roadside flower species.

*Justification:* Wood chips and leaf litter are abundantly available and often end up in community landfills. Both have been used as soil amendments to increase soil organic matter levels (Christian and Evanylo, 1997, Heckman, 2000, King, 1979). The use of this inexpensive material on the roadsides may be of benefit to roadside flower establishment.

*Procedures and Materials:* In the spring of 1999, a nearly level site adjacent to the previous study (section IIA) in Culpeper was selected. The soil properties were the same as described earlier. Leaves were collected in the fall of 1998 from Blacksburg residents and stored in black plastic bags. A mixture of hardwood and softwood chips that were less than six months old was acquired from VDOT, and this mixture was stored in a pile.

The site was sprayed with glyphosate (2 gal/A) to kill the existing vegetation two weeks prior to the amendment application. The soil was roto-tilled four to six inches deep in preparation for the applications of the chips and leaves. On March 24, 1999, dried leaves (5.5, 11.0 and 15.0 wet tons/A) and wood chips (13, 20, 27 tons/A) were applied at three rates. All treatments were replicated four times and arranged in a completely randomized design. The amendments were then tilled into the soil to a depth of six to eight inches where possible, although the high rate of leaves was difficult to incorporate into the soil. The treatments are described in Table 7.

Table 7. Description of leaf litter and wood chips as applied in Culpeper in March 1999. Fertilizer was applied in a split application in March and September 1999.

Amendment Treatment	Rate of Amendment	Fertilizer Rate (lb/A)	
		March '99	Sept. '99
Unfertilized control	0	0	
Fertilized control	0	150 *	150
Low Leaf Rate (L-leaf)	5.5 tons/A (wet weight)	195 **	195
Medium Leaf Rate (M-leaf)	11 tons/A	343	343
High Leaf Rate (H-leaf)	15 tons/A	461	461
Low Wood Chip Rate (L-chip)	13 tons/A	758	758
Medium Wood Chip Rate (M-chip)	20 tons/A	1114	1114
High Wood Chip Rate (H-chip)	27 tons/A	1469	1469

\* 15-30-15 used

\*\* 46-0-0 was applied to all the leaf and chip treatments

Two split applications of urea were applied in March 1999 and in September 1999 to satisfy both plant N requirements and to provide the estimated rate of N required by microbes to decompose the carbon present in both leaves and wood chips without nitrogen immobilization. This was calculated by applying N to achieve a C:N ratio of 30:1<sup>6</sup>. Phosphorus and K were incorporated in March 1999 (300 lb/A 0-30-15). These experimental rates were used to insure that the N would remain mobile through out the study, but are in excess of what is normally used and are not recommended for a real-life situation.

Garden cosmos (*Cosmos bipinnatus*) (10 lb/A) was seeded in March 1999. In the September 1999, the plots were re-seeded with corn poppy (18 lb/A). Sulfur cosmos (*Cosmos sulphureus*, 10 lb/A) was sown in June 2000. The long-term effect of the organic matter on the performance of roadside flowers will be evaluated for two years (spring 2001) by measuring plant density several times a year and soil chemical properties in the spring of 2001.

Results and Discussion: The first sowing of Cosmos resulted in a poor stand in all plots because of the drought during the summer of 1999. The corn poppy stand that was seeded in the fall of 1999 established successfully.

<sup>6</sup> Example of calculation: For 1000 lb of leaves, N= 1% x 1000 =10lb; C= 54% x 1000 = 540 lb. To attain the desired 30:1 C:N ratio after *in situ* composting, Needed N= 540/30 = 18 lb N. Because the leaves contain 10 lb N/1000 lb leaves, subtract 10 lb from 18 lb. Eight lb N is therefore needed to insure decomposition of the leaves without robbing N from the plants.

Two months after sowing (November, 1999), the corn poppies growing on the two highest wood chip plots (M-chip and H-chip) were significantly less dense than those on the other treatments (Figure 4). However, six months after the corn poppies were sown (March, 2000), all rates of both the leaf and chip treatments were similar in plant density. The control and fertilizer plots out-performed the leaf and chip plots. At this time, no visual N-deficiency symptoms were detected in the poppy crop.

*Conclusions:* There is little to conclude at this time. It appears that the chips and leaves are not doing much to improve the performance of the poppies, but these materials are also not creating a problem. The spring 2001 data should provide more answers. It is clear that if leaves and chips are used as soil amendments additional N is needed for successful stand establishment. How much N to add is not known, especially with high rates of leaves and chips. Heckman (2000) reported that no additional N was required to grow corn. Further study would be required to determine how much N would be necessary for successful stand establishment and to determine the least amount of N that would be required to satisfy the N requirement of both the plants and C decomposing microbes. The benefits from the high rates of leaves and wood chips would be expected to occur in more than several years.

### **III. Greenhouse Research**

The fieldwork presented in this report raised some questions that were important enough to examine more closely in a greenhouse setting:

- 1). Why do the various species of plants perform differently with a particular composted product?
- 2) Why did some of the composts negatively affect plant performance?
- 3) What is the effect of N and pH on the growth of wildflower species in a typical acid roadside soil?

In regard to the first question, the greenhouse environment allows quick screening of the effects of various composted products on different plant genera. In less than three months data can be gathered to indicate the reaction of different species to different composts. The greenhouse work, in comparison to a field study, saves both time and money.

The second question is a concern because we observed that biosolids and paper mill composts hindered the growth and performance of some plant species in the field. In the past, both of these products have been proved beneficial to plant growth. We hoped that the greenhouse work would provide insight into this apparent contradiction.

The third question was asked because of lack of data in the scientific literature concerning the effect of N fertility and soil pH on wildflower species growth. It is generally assumed that these species do not require much N and can grow in very acid soils. A documented understanding of these requirements of these species would help us to understand the response of these plants to compost-amended soils.

All of the greenhouse work described below was done with a C-horizon soil that was high in clay and low in pH, which is common in the Virginia roadside environment. All other factors such as water, air temperature and light were kept at optimum levels. The greenhouse results cannot be applied directly to real-life roadside situations, but they do show what can happen when all inputs are controlled.

## **A) The Effect of Lime and Nitrogen on the growth of *Cosmos bipinnatus*, *Centaurea cyanus* and *Silene armeria***

Objective: The objective was to determine how certain species of roadside flowers respond to N fertilization and to pH.

Justification: The species used in roadside plantings are generally selected for their tolerance to low fertility and pH. However, it is not clear how these species respond to N and lime amendments when grown on typical Virginia roadside soils. The following greenhouse study was designed to quantify the effect of several rates of N and lime on some typical species of roadside flowers.

Procedures and Materials: An acid soil (C-Horizon) was collected from the junction of Rt. 460 business and 460 Bypass to the east of Christiansburg. The soil was air-dried in a greenhouse, screened to less than 2mm, and bulk blended. The soil initially had a pH of 5.1, 3 ppm extractable P, 11 ppm K, 96 ppm Ca, and 30ppm Mg. The control soil (which remained unlimed) was randomly split from the bulk sample. The rest of the soil was bulk-blended with calcium oxide (based on oven-corrected air-dry weights) at the following rates: 0.5x, 1.0x, and 1.5 x the predicted liming requirement (presented as tons/A lime equivalent).

The experimental design was a 5 by 4 factorial for each species, with 4 replications. The rates of N were 0, 20, 45, 90 and 135 kg/ha. The rates of lime were 0, plus three increments based on the total titratable acidity of the soil used (equivalent to 0.5, 1.0 and 1.5 x liming requirements). These 5 x 4 x 4 reps equaled 80 pots per species. The pots were arranged in a completely randomized design in a Virginia Tech research greenhouse and randomly rotated weekly. Species were tested independently, with a total of three species evaluated: *Cosmos bipinnatus*, *Centaurea cyanus* and *Silene armeria*.

Plastic 6" Kord™ pots were lined with plastic bags. The pots were filled with 750 g dry soil and watered with tap water to approximately 80% of field capacity. The soil was allowed to equilibrate for 10 days through two wetting and drying cycles. Prior to seeding the soil was mixed in the bags. Fertilizer amendments (reagent grade ammonium nitrate and potassium phosphate monobasic) were added at this time. A fungicide (Subdue Max) was applied at least two days prior to seeding to prevent damping-off. Five to eight seeds were sown on the surface of the soil of each pot. *Cosmos* was seeded on 1/25/99, *Centaurea* on 4/27/99, and *Silene* on

8/16/99. The pots were watered once or twice a day with mist irrigation. Water was also added as needed to maintain 80% of field capacity moisture content, as determined by the pressure plate method, in each pot. Beginning two weeks after seeding the plants were gradually thinned to two to three plants per pot.

During the course of the experiment, halogen lights were used to extend the day to 12 hours. Incandescent light (2 hours/night, 100 watt bulbs) was used to interrupt nights. Insecticides were applied as needed. At the termination of the experiment (8 weeks after seeding), stem height, number of leaves, presence of flower buds and dry weight were measured.

Results: The effect of pH and N varied by species. At soil pH 5.5-5.6 and 7.0-7.3, *Centaurea* and *Silene* had low and similar N requirements for plant growth, although *Centaurea* demonstrated higher N requirements at the more favorable soil pH range of 7.0-7.3 (Figure 5). *Cosmos* grew somewhat better at the higher pH and demonstrated consistently high N requirements than the other two species.

*Cosmos* and *Centaurea* utilized N more efficiently and produced greater biomass as pH was raised from 4.8 to 7.3 (Figures 6 and 7). This pattern was not observed for *Silene* (Figure 8). Figures 6 and 7 show that better growth is possible with increasing N at pH above 5.6. Thus, soil should be limed to pH between 5.6 and 7.0. The optimum soil pH for each species cannot be determined from this study.

Conclusion: Soil pH influences the effect that added N has on plant growth. Plants that are grown in extremely acid soils utilize N less efficiently than those grown in soils with higher pH. This can't be stressed enough. The VDOT manager may obtain a more favorable plant response when these wildflower species are grown in soils that are limed to pH 6.0 to 7.0. Not only is plant-available N increased, other essential elements such as P, Ca, and Mg are also more easily available to the plants. The other factor in this "liming effect" is that aluminum (Al) is rendered immobile in higher pH soils. Al is toxic to many plants (except for Ericaceous plants) and N-transforming microbes.

All the species tested responded to additions of N. However, at lower soil pH levels, low N fertility rates often produced the same growth response as higher N rates. Different plant species also responded in varying ways to the rate of N applied. Although all these species are classified as wildflowers, they certainly did not respond consistently to N fertilization. This was also observed in the greenhouse compost studies (described later).

It should be noted that the soil used in all these greenhouse experiments was quite infertile, with physical properties that are generally not conducive to plant growth. However, this soil is typical of what is often found on the roadside of newly constructed roads. The soil contained little to no organic matter, low P, high clay and high Al. The results of this experiment might not be replicable in a sandy soil, so care should be used in applying this information to different conditions.

**B) The Effect of Composted Organic Materials on the Growth of *Centaurea cyanus*, *Silene armeria*, *Coreopsis tinctoria*, *Ratibia columnifera*, *Sorghastrum nutans*, *Panicum virgatum* and *Schizachyrium scoparium*.**

Objective: To determine how four species of roadside flowers and three species of native grasses respond to soil amendment with different types of composts.

Justification: In the fall of 1998, several types of composted organic material were applied to field plots at Staunton and Culpeper. The following greenhouse study was designed to determine the effect of these composts on roadside flowers under controlled conditions. The composts were applied at the same rates used in the field studies.

Methods and Procedures: The same acid soil that was used in the previous greenhouse study was also used in this study. All of the soil was limed with calcium oxide to bring the pH to 5.1.

The experimental design was 7 treatments with 4 replications. The species were tested independently; all 28 pots per species were arranged in a completely randomized design and randomly rotated weekly. The composts used are described in Tables 2, 8 and 9. A total of eight species were evaluated, *Centaurea cyanus*, *Silene armeria*, *Coreopsis tinctoria*, *Ratibia columnifera*, *Sorghastrum nutans*, *Panicum virgatum* and *Schizachyrium scoparium*. Plastic 6-inch Kord pots were lined with plastic bags and filled with 750g (dry) soil. The pots were then watered with tap water and allowed to equilibrate through two wetting and drying cycles. The soil was mixed in the bags, and the compost amendments were mixed with the soil, also in the bags. The pots were then watered and allowed to go through at least two drying cycles. A fungicide (Subdue Max) was applied prior to seeding. Reagent grade ammonium nitrate and potassium phosphate monobasic were applied in solution at the correct rates to the fertilizer treatment close to the time of seeding. Five to ten seeds were then added sown on the surface soil in each pot. The species were seeded at the following times: *Centaurea cyanus* and *Silene armeria* on 10/19/99, *Coreopsis tinctoria*, *Ratibia columnifera*, *Sorghastrum nutans*, *Panicum virgatum* and *Schizachyrium scoparium* on 1/13/00. The pots were watered once or twice a day with mist irrigation. Water was added manually as needed to maintain soil moisture content at 80% field capacity. Starting two weeks after seeding the plants were gradually thinned to three plants per pot.

During the course of the experiment, halogen lights were used to extend the day to 12 hours. Incandescent light (2 hours/night, 100 watt bulbs) was used to interrupt nights. Insecticides were applied as needed. At the termination of the study stem height and dry weight were measured.

Table 8. Compost Used in the Greenhouse Study, 1999-2000.

Compost	% Solid	% TKN*	Total Organic Carbon	% Organic N	%NH <sub>4</sub>	% P	%K	Conductivity mmho/cm**	pH
Biosolid	78	3.57	37.75	3.53	.04	2.9	0.21	10.74	6.8
Yardwaste	52	1.98	30.31	1.98	.0004	0.6	0.82	1.48	7.6

Poultry	90	6.44	40.98	6.43	.011	2.1	2.64	22.70	7.5
Paper Mill	46	2.16	37.80	2.16	0	0.5	0.41	1.78	7.4
Cotton Gin	67	2.50	23.04	2.49	.008	0.3	1.2	1.50	7.9

Table 9. Applied plant available nutrients for the first year.

Treatment	Amendment Rate	Estimated Plant Available Nutrients (lbs/acre)		
		Total N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
Biosolids	3 tons/acre (fresh wt)	67	312	12
Yard Waste	33 tons/acre (fresh wt)	123	473	338
Paper Sludge	22 tons/acre (fresh wt)	74	232	100
Cotton Gin	13 tons/acre (fresh wt)	81	120	250
Poultry Fertilizer	3 tons/acre (fresh wt)	208	260	171
15-30-15	300 lbs/acre	45	90	45
Control	Not amended			

*Results:* The two central effects from this study are constant for all the species that were examined: 1) The dry weight of all plant species was greater if they were grown in pots amended with any of the compost products. 2) All species performed better in yardwaste compost-amended pots than pots amended with the other composts (Table 10 and 11). To some extent, these findings support what was observed in the field study.

The cotton gin waste compost generally encouraged substantial growth, while the effect of the composted biosolids was inconsistent. *Centaurea* and the grasses seemed to benefit from biosolids compost. Both inorganic fertilizer and poultry litter-based fertilizer were less effective in increasing plant growth than the composts, and overall, most of the composted materials produced better plant growth than either the fertilized or non-fertilized control. The use of composts generally appears to encourage better growth when these species are grown on low pH, high clay soils.

Table 10. Dry Weight (g) of three plants/pot. (Yardwaste Compost, our best treatment, is in bold)

Amendment	<i>Centaurea</i>	<i>Silene</i>	<i>Coreopsis tinctoria</i>	<i>Ratibia</i>	Little Bluestem	Indiangrass	Switchgrasses
Composted Biosolids	4.24b	0.69c	0.03b	0.03b	0.91b	1.22b	3.07b
Composted Yardwaste	<b>7.67a</b>	<b>2.44a</b>	<b>4.64a</b>	<b>3.97a</b>	<b>12.64a</b>	<b>2.06a</b>	<b>6.00a</b>
Poultry based fertilizer	Not used	Not used	0.04b	0.05b	0.16d	0.07c	1.69c
Paper Mill Sludge Compost	2.73d	1.36b	0.01b	0.02b	0.13d	0.06c	0.73d
Cotton Gin Waste Compost	3.43c	1.61b	0.26b	0.10b	0.35c	0.84b	2.49bc
15-30-15	0.38e	0.22cd	0.02b	0.01b	0.04d	0.05c	0.06d
Control	0.06e	0.02d	0.02b	0.01b	0.03d	0.04c	0.04d

\* Means for all treatments within columns followed by the same letter are not significantly different at the 5% level according to Student, Newman and Kuels test.

Table 11. Height (cm) of plants. (Yardwaste Compost, our best treatment, is in bold)

Amendment	<i>Centaurea</i>	<i>Silene</i>	<i>Coreopsis tinctoria</i>	<i>Ratibia</i>	Little Bluestem	Indiangrass	Switchgrasses
Composted Biosolids	49.3a*	12.8bc	0.5b	3.2b	23.5b	45.7b	60.9b
Composted Yardwaste	<b>55.3a</b>	<b>23.4a</b>	<b>55.6a</b>	<b>33.4a</b>	<b>30.4a</b>	<b>53.6a</b>	<b>71.4a</b>
Poultry based fertilizer	Not used	Not used	1.2b	2.5b	11.3d	12.3c	44.8c
Paper Mill Sludge Compost	44.6a	18.8ab	1.7b	1.9b	11.4d	14.5c	38.7c
Cotton Gin Waste Compost	48.7a	16.6ab	18.8b	4.1b	15.9c	42.2b	56.0b
15-30-15	13.3b	8.5cd	0.5b	0.6b	9.6d	14.0c	10.3d
Control	3.1c	1.0d	0.5b	0.3b	8.4d	11.1c	8.1d

\* Means for all treatments within columns followed by the same letter are not significantly different at the 5% level according to Student, Newman and Kuels test.

Some of the increased plant growth can be attributed to the higher plant nutrient levels provided by the composted materials. Table 12 illustrates how the various composts affected the soil nutrient availability and soil pH. The pH of all the compost-treated soils increased over time, some by nearly 1.0 unit, while the pH of the fertilizer and control soils declined. Phosphorus levels for all the compost-treated soils increased. Yardwaste compost-amended soils had almost 175 times as much P as the control. The K, Mg and Mn levels of the soils increased in all treatments except the biosolid compost. Ca levels increased with all compost amendments. Yardwaste compost produced an overall increase in P, K, Ca, and Mg.

Although some of the improved plant growth can be attributed to the plant-available-nutrients found in the compost products, other compost components promote growth and plant health. These products contain plant growth hormones (personal communication with Dr. Richard Schmidt), promote a biological control of plant diseases (Hoitink and Grebus, 1994), and increase soil water holding capacity and aggregation. We did not attempt to analyze the presence of these factors; thus we cannot completely explain why these plant species showed increased growth with specific compost products.

Table 12. Soil/compost mixture characteristics. Soil pH was measured before seeding, and again eight weeks after seeding *Centaurea cyanus*.

Amendment	pH prior to seeding	pH at harvest	Electrical conductivity Mmhos/cm	P ppm	K ppm	Ca ppm	Mg ppm	Cu ppm	Mn ppm	Fe ppm
Composted Biosolids	4.6	5.7	.199	64.9	20.8	1184.2	94.4	0.7	5.4	7.6
Composted Yardwaste	5.4	6.0	.497	106.8	125.5	2215.5	275.4	0.3	23.5	5.1
Paper Mill Sludge Compost	6.1	6.9	.610	10.1	50.6	1816.2	100.7	0.7	15.4	22.6
Cotton Gin Waste Compost	4.7	5.7	.189	14.4	147.2	1041.7	130.6	0.2	3.6	3.9
15-30-15	5.6	4.7	.066	0.9	44.9	661.5	81.3	0.4	5.6	4.5
Control	5.1	4.8	.079	0.6	42.5	748.7	74.3	0.4	4.7	3.7

Conclusions: The compost utilized in this experiment was tested by A & L Eastern Agricultural Laboratories, Inc. (7621 Whitepine Rd, Richmond, VA 23237, 804-743-9401) in August 1998 and then a year later before the greenhouse study. Table 4 and 9 illustrate that compost nutritional values can change in a year, even though these composts were stored in closed containers. If these composts had stored un-covered on the ground, nutrient levels might have changed even more. In addition to this change in nutrient status with time, composted materials can vary from producer to producer and even from batch to batch. It is very important that composted products be tested before the products are used. The use of a poorly prepared or un-matured batch of compost can result in unexpected and deleterious results.

This study indicated that different plant species react in varying ways to soil amended with different composts. This fact should also be taken into consideration. For example, the yardwaste we used in this experiment was a high quality product, and compost products like this should be sought out and utilized whenever possible.

## **IV. Proposed Specifications for Compost Used on the Roadsides in Virginia**

Table 8 provides our best estimation for specifications on the use of all compost products on the roadsides of Virginia. In addition to the use of compost for roadsides (i.e., flowerbeds, marginal soils reclamation), you may wish to consider using compost as foundations for constructed wetlands and to remediate acid-producing geologic materials. The ranges of the specifications may be slightly altered when used for these purposes.

Related issues that you should consider include the following: 1) Who tests the compost? 2) How often must material be tested? 3) What, if any, certification procedures will be accepted? 4) What are the recommended rates?

Table 8. Proposed Specifications for Compost Used on the Roadsides in Virginia

<b>Compost Characteristic<sup>7</sup></b>	<b>Ranges</b>
pH	5.5 – 8.0
Soluble Salt Concentration	Maximum of 6 dS/m (mmhos/cm) for general purpose; 4 dS/m for planting beds and trees.
Nutrients, N,P,K,Ca,Mg	Must be reported <sup>8</sup>
Water Holding Capacity	Must be hygroscopic
Bulk Density	Must be reported; optimum between 800-1,200 lb/yd <sup>3</sup>
Moisture Content	35 – 55%
Organic Matter Content	Minimum of 35%
Particle Size	Maximum of 1” diameter with less than 10% retained on a ¾” screen
Trace Elements/Heavy Metals	Must meet U.S. EPA Part 503, exceptional quality concentration limits
Stability	Stable to highly stable
Maturity/Growth Screening	Must pass maturity tests or demonstrate its ability to enhance plant growth <sup>9</sup>
Inerts/non-biodegradable	Free of stones and non-organic matter
Weeds	Free from specified noxious weeds <sup>10</sup> and protected from non-noxious weeds.
Meet federal and state health and safety standards	Yes

## **V. Conclusions**

<sup>7</sup> The information presented was compiled from recommendations made by the Composting Council and Black, et al. al., October 1998, Compost Utilization by State Departments of Transportation in the United States, University of Florida Cooperative Extension Service, ENH-125, <http://hammock.ifas.ufl.edu/text/fairs/61151>, 16 pages.

<sup>8</sup> This indicates that the supplier must provide the information

<sup>9</sup> The Dewar Self-Heating or Carbon Dioxide Generation Rate tests as described in the Coalition of Northeastern Governors Source Reduction Task Force’s Model Procurement Specifications are acceptable. Compost tested by the Carbon Dioxide test, which measures compost respiration, will have a limit of no more than 5 mg CO<sub>2</sub>-C/gBVS daily. To test for reheating by use of the Dewar Self-Heating test, the maximum heat rise will be no greater than 20° C above room temperature.

<sup>10</sup> Noxious Weed List: Appendix A.

1. The field studies continue to generate valuable data on the long-term effect of these composted wastes, fertilizers and AgriCell foam on two selected roadside flowers. So far, the overall response is variable. The poppies perform best with AgriCell foam and poultry-derived fertilizer. Composted products did little to improve poppy density, but they did not reduce plant density relative to fertilized controls. The *Coreopsis* density was unaffected by the compost amendments. However, the poultry-derived fertilizer reduced the density of this plant when compared to the control. Results in this study must be assessed with the understanding that the study was only 18 months old when the last data were recorded and that the summer following seeding was very dry. Furthermore, greater growth responses to compost addition would have been expected on typical marginal soils (i.e., soils with low pH and organic matter). The soils used in this study are not characterized as marginal.
2. The wood-chip and leaf litter study is also in its infancy. To date, the lower rates of leaves and chips have not adversely affected plant growth.
3. The general conclusion for the greenhouse studies is that the plants grew better with compost amendments than without compost. Most of the roadside flowers performed better with the yardwaste and cotton gin composts. The native grasses were not as particular and did well on several composted amended soils, but did not respond well to the poultry-derived fertilizer. Soil pH is also an important factor with these plants. Plants grown in neutral pH soils performed better with less N.
4. We also observed in the field and greenhouse studies that different roadside plant species perform better with specific composts. This concept of matching compost type to individual plant species is new and should be considered seriously. For example, in the field, it was apparent that poppy did well with the poultry-derived fertilizer, but poorly with the cotton gin compost. However, coreopsis performed poorly with poultry-derived fertilizer, and fairly well with cotton gin waste.
5. Testing composted waste products before applying to soils is imperative. Composts are created according to certain guidelines, but that does not mean the end product will be the same with each batch. In addition, compost maturity is one of the most important characteristics to consider when selecting a composted material for roadside use. A product that is not totally matured into its final form is inferior and should be used with caution. The by-products of incomplete compost decomposition can have negative effects on plant growth.

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