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Composition of Animal Manure Compost and Utilization Implications

John P. Chastain, Ph.D., Associate Professor

Department of Agricultural and Biological Engineering, Clemson University, Clemson SC USA, jchstn@clemson.edu

Caleb C. Frase, Undergraduate Student

Department of Agricultural and Biological Engineering, Clemson University, Clemson SC USA,

Kathy P. Moore, Ph.D., Director of Analytical Services

Agricultural Service Laboratory, Clemson University, Clemson SC USA,

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Abstract. *Six compost products were obtained for the purpose of evaluating the plant nutrient, carbon, and organic matter contents. The composts included in the study were a yard waste compost (containing no animal manure), two cow manure based products, mushroom compost (containing manure and straw), and two compost products that contained 25% and 33% separated swine solids. The carbon sources used ranged from wood waste to cotton gin trash. Statistical analysis indicated that the nutrient contents of the compost products were significantly different depending on whether or not animal manure was included in the mix, the type of manure used (cow vs. swine), and the amount of manure included in the mix. The organic matter content (VS/TS) ranged from 0.289 to 0.540 indicating high levels of decomposition. The two products with the lowest organic matter contents (0.289 and 0.366) had the highest values of C:N (18.5 and 24.6), indicating that C:N was not a reliable indicator of compost stability.*

Nutrient balancing calculations were used to estimate the constituent application rates resulting from the use of the compost products for erosion control blankets, and to provide the pre-plant N, P_2O_5, and K_2O requirements for tomatoes. It was concluded that the amount of compost used in a compost blanket mix should be determined based on the major plant nutrient contents, and the fertilization recommendations for roadside turf. The data and nutrient balancing calculations for tomatoes point out that application recommendations based on a prescribed volume (blanket depth) or mass per unit area (t/ha) are not useful. Instead, compost application rates need to be determined based on analysis of the plant nutrients in a compost product, soil-test results, the nutrient requirements of the crop to be grown, and the amount of material required.

Keywords. Compost, plant nutrients, land application, erosion control

Introduction

Compost is a valuable soil amendment that contains organic matter, nitrogen, phosphorous, potassium, and most of the critical minor plant nutrients (e.g. Ca, S, Mg, Cu, and Zn). Adding compost to soil is one of the fastest ways to increase soil organic matter and improve soil quality. The nutrient composition of most compost products are such that they serve as a good source of P, K, and minor nutrients with only small amounts of plant available nitrogen (Chastain et al., 2005; Cooperband, 2002). Complete reviews of the benefits of using compost are provided by Cooperband (2002) and Rynk, et al. (1992).

The concentration of plant nutrients in a compost product will depend on the nutrient content of the source materials, and the management of the composting process. Many of the plant nutrients such as P and Zn will be conserved during the composting process. Soluble plant nutrients (K, NO_3-N) can be lost if the composting facility is not constructed and managed so as to prevent leaching of nutrients by excess water (Chastain, et al., 2005). Organic-N will be mineralized to ammonium-N and can be lost by ammonia volatilization if conditions are not conducive to conserve soluble-N by nitrification.

Most application recommendations are based on the addition of a specified volume or mass of compost. A common recommendation for landscape or horticultural use is to spread 1.3 to 7.6 cm layer of compost, and then incorporate to a depth of 15 cm (e.g. Cooperband, 2002). Another recommendation is to surface apply compost at rates of 6 to 160 t/ha (Ozores-Hampton and Obreza, 1998). A more strict recommendation is to apply no more than 3.3 cm or 112 t_{DM}/ha to garden areas with incorporation prior to seeding or transplanting (Rynk, et al., 1992). Several extension publications recommend application of compost at agronomic rates for horticultural use (e.g. Cooperband, 2002; and Rynk, et al., 1992). However, only a few publications provide a calculation procedure, and the information required to apply compost at agronomic rates for a particular crop (e.g. Rosen and Bierman, 2005).

Compost blankets have been shown to be effective in reducing runoff and erosion from bare soil following roadway construction in several states including Georgia, Iowa, Texas, and Virginia (Glanville et al., 2004; Mukhtar et al., 2004; Persyn et al., 2004; Risse and Faucette, 2003; and Tyler, 2001). Compost blankets vary in composition from compost only, compost-soil mixtures, and compost-mulch mixtures. Blanket depths range from 2.5 to 10 cm. The best reduction in runoff and soil loss was observed for 5 to 10 cm blankets (Persyn et al., 2004). Compost blankets also improved the success rate for establishment of permanent roadside turf to provide long term stabilization of the soil (Risse and Faucette, 2003). In a few cases, compost was applied at the agronomic rate for roadside turf establishment (Mukhtar et al., 2004). However, application rates were typically based on the desired blanket depth for soil protection.

In practice, compost products are rarely spread at agronomic rates based on crop needs. As a result, it may be possible to apply major plant nutrients in extreme excess of the agronomic rate, and to apply elements such as Cu and Zn at amounts in excess of agronomic and regulatory limits.

The objectives of this paper are to (1) measure the major and minor plant nutrients contained in a variety of compost products, and (2) evaluate common compost utilization recommendations with respect to agronomic and regulatory limits.

Experimental Methods

Six different compost products were included in the study. Four of the materials were obtained from a local retail garden center. One bag was purchased of each product (about 57 cm^3/bag). The other two were products from an experimental swine manure treatment system designed by scientists at the USDA-ARS Coastal Plains Research Center (Florence, SC), and tested in North Carolina. About 28 cm^3 was obtained of each of these products.

Two of the commercially available composts were competing brands of composted cow manure and wood waste. Other source materials were not specified. Each product had a very dark brown or black color and emitted no foul odors. These two products were identified as CMCA and CMCB.

Mushroom compost (MC) is another readily available soil amendment in South Carolina. Mushroom compost is the material that remains after mushroom harvest. It is typically composted manure and straw. Mushroom compost had a much stronger odor than any of the other products.

Yard waste compost (YWC) was included in the study for comparison. The main ingredients of composted yard waste were grass, leaves, wood waste and other plant debris. This product did not contain manure.

Two compost products were obtained from the centralized compost facility operated under the direction of Vanotti et al. (2005). One was a mixture of 1 part separated swine manure solids, 2 parts cotton gin trash, and 4 parts wood chips (SGTW). The other product was composed of 1 part separated swine solids and 2 parts cotton gin trash (SGT). The swine solids for each product were obtained from a separation system that included pretreatment with a polymer and a mechanical press. Use of the polymer to enhance the separation process yielded solids with a relatively high nutrient content. A project report by Vanotti et al. (2005) provides a complete description of the composting system.

Sampling and Quantities Measured

Each of the compost products was emptied into a large plastic container, and was well-mixed. Three, 2 L samples were taken from each compost product for constituent analysis, and measurement of bulk density. Three replicate analyses were performed for each compost product.

Three compost sub-samples for each product were sent to the Agricultural Services Laboratory at Clemson University to determine the concentrations of the following: total nitrogen (total-N), total ammoniacal nitrogen (TAN = NH_4^+-N + NH_3-N), nitrate-N, total P (expressed as P_2O_5), total K (expressed as K_2O), calcium, magnesium, sulfur, zinc, copper, manganese, sodium, and carbon. The organic-N content was calculated as: Org-N = Total-N - TAN - NO_3-N. The laboratory procedures used for compost constituents is provided by Moore (2004).

Total solids, volatile solids, and fixed solids were measured in the Agricultural, Chemical, and Biological Research Laboratory in the Department of Agricultural and Biological Engineering at Clemson University using standard oven-drying techniques (APHA, 1995). Each of three sub-samples was dried in an oven at 105ºC for 24 hours. Total solids content was determined after the sample was allowed to cool in a desiccator. Fixed solids content (ash) was determined by incinerating the dried solids in a furnace at 550ºC for 2 to 3 hours, allowing the sample to cool in a desiccator, and determining the sample mass. Volatile solids were calculated as the difference between the total and fixed solids.

The density of the compost was calculated from measurements of the sample mass and volume. An aluminum container was used to measure the mass and volume of a sample. The volume of this container was determined by adding de-ionized water until the water level was even with the top of the container. The volume of the container was 323 mL with a standard deviation of ±1.71 mL. The density of the compost products was determined by filling the calibrated container with a well-mixed sample, measuring the mass of the sample and container, and dividing the sample mass by the container volume. Three replications were performed for each compost product.

Results and Discussion

Three samples of each of the six compost products was analyzed to determine the concentrations of the TS, VS, C, bulk density, and the previously defined plant nutrients and minerals. Many of the constituent concentrations were reported on a wet basis, and were converted to a dry basis (percent of dry matter) prior to statistical analysis. Wet bulk density measurements were converted to dry matter densities (BD_{DM}) by multiplying the wet value by the dry matter fraction (F_{DM}). The VS content was expressed as a fraction of the dry matter (VS/TS). The carbon content of the compost products were compared as a fraction of the volatile dry matter (C/VS) and using C:N. The means are given in Table 1 for each compost product.

Table 1. Nutrient content, organic content, and dry matter densities of the six compost products. Means with the same letter are not statistically different.

	CMCA[1]	CMCB[2]	MC[3]	YWC[4]	SGTW[5]	SGT[6]		
	---------------------- Means, Percent Dry Matter Basis ----------------------						S_P [7]	LSD[8]
Org.-N	0.87a	0.71a	0.71a	1.26	2.01	3.11	0.0923	0.16
TAN	ND[9]	ND	ND	ND	ND	0.12	0.0200	0.07
NO_3-N	ND	ND	ND	ND	0.28a	0.27a	0.0099	0.02
Total-N	0.87a	0.71a	0.71a	1.26	2.30	3.49	0.0927	0.16
P_2O_5	0.64a	0.51ab	0.57ab	0.25b	2.11	5.55	0.1915	0.34
K_2O	0.51a	0.41ab	0.60a	0.32b	1.03	2.15	0.1062	0.19
Ca	0.77	2.25b	2.73b	1.70c	1.39c	2.48	0.2939	0.52
Mg	0.29a	0.18	0.30a	0.29a	0.51	1.50	0.0530	0.09
S	0.20a	0.20a	0.45c	0.16a	0.39c	0.92	0.0526	0.09
Zn	0.012a	0.008a	0.011a	0.013a	0.070	0.171	0.0061	0.011
Cu	0.008a	0.005a	0.011a	0.004a	0.064	0.195	0.0059	0.010
Mn	0.025a	0.010	0.037	0.091	0.023a	0.059	0.0033	0.006
Na	0.087a	0.072ab	0.136	0.011	0.080ab	0.068ab	0.0118	0.021
C	15.91a	13.03ab	17.43ab	23.24d	25.97d	28.50d	3.22	5.74
F_{DM}[10]	0.404a	0.498b	0.544	0.431	0.388a	0.489b	0.0095	0.017
VS/TS	0.381a	0.498b	0.366a	0.289	0.473b	0.540	0.0193	0.034
C/VS	0.417a	0.267a	0.480ac	0.804	0.550ace	0.529ace	0.0891	0.159
C:N	18.2a	17.8ab	24.6	18.5ab	11.3e	8.2e	3.38	6.0
BD_{DM}[11]	282a	233	296a	202	172	282a	13.84	24.6

[1] CMC A = composted cow manure and wood waste A

[2] CMC B = composted cow manure and wood waste B

[3] MC = mushroom compost

[4] YWC = yard waste compost

[5] SGTW = 1 part separated swine solids: 2 parts cotton gin trash: 4 parts wood chips

[6] SGT = 1 part separated swine solids: 2 parts cotton gin trash

[7] S_P = pooled standard deviation

[8] LSD = least significant difference at the 95% level

[9] Not detected

[10] Dry matter fraction, kg_{DM}/kg sample

[11] Bulk density of the dry matter, kg_{DM}/m^3

A one-way analysis of variance (Steel and Torrie, 1980) was used to calculate a pooled variance for each of the 19 compost characteristics defined in the table. The least significant difference using the 95% level of probability was calculated from the pooled variance as: LSD = $t_{0.025,edf}$ $(2\ S_P^2/r)^{0.5}$. Where, edf represents the error degrees of freedom (12), and r is the number of replications per treatment (3). The LSD values were used to test for difference between treatment (type of compost) means for each of the compost characteristics. The values for S_P and LSD are given in the table.

Plant Nutrients and Sodium in Compost

The results shown in Table 1 indicate that the plant nutrient value of a compost product depended on the source materials. The plant nutrient content of the two compost products that contained cow manure (CMCA and CMCB) were not significantly different except for Ca, Mg, and Mn. The total-N, P_2O_5, K_2O, Zn, and Cu concentrations in mushroom compost were not significantly different from the cow manure based products. The type of manure used for the mushroom compost was unknown, but cow manure is often the N-source, and may be the reason for the similarities. Yard waste compost was significantly higher in N than the cow manure based composts, but lower than the products that included separated swine manure. Yard waste compost was lower in P_2O_5, K_2O, and Na than most of the animal manure based products. The Zn and Cu concentrations of yard waste compost were not significantly different from mushroom compost or composted cow manure. The two compost products that used separated swine manure (SGTW and SGT) as the N-source contained significantly higher concentrations of all major plant nutrients as compared to the other products studied. The compost that was composed of 33% separated swine manure and 67% cotton gin trash (SGT) was significantly higher than all other products in all major and minor plant nutrients. The nutrient contents of the compost products were significantly different depending on whether or not animal manure was included in the mix, the type of manure used, cow vs. swine, and the amount of manure included in the mix, 25% vs. 33%.

Nitrogen in compost is almost exclusively in the organic form. The only compost products that had measurable amounts of soluble-N (TAN and NO_3-N) were the two products that used separated swine solids (SGTW and SGT) as the source of N. The majority of the soluble-N in these two products was in the nitrate form, which indicates that oxygen levels were maintained at sufficient levels to drive much of the ammonium-N released by organic-N mineralization to nitrate before it was lost as ammonia gas.

High sodium content in a compost product can be detrimental for some plants (Cooperband, 2002). The lowest sodium content, 0.011%DM, was for the yard waste compost. The Na concentration for the animal manure based products ranged from 0.068%DM for the product that contained 33% swine manure (SGT) to 0.087%DM for CMCA. The Na content of mushroom compost was 1.7 to 2.0 times greater than the Na content of any of the animal manure based compost products.

Two of the most common types of cow manure used for composting are screened dairy manure solids, and dry manure scraped from an outside lot. Composition data for the cow manure used to manufacture the two cow manure based compost products were unknown. However, similar data were available to provide a range of probable values for comparison. Data for the separated swine manure solids were presented by Vanotti et al. (2005). Concentrations of major plant nutrients, Zn, and Cu in uncomposted solid dairy and swine manure are compared with the compost products included in this study in Table 2.

The N content of the compost products were much lower than the comparable uncomposted materials. This was expected since it is common for about 50% of the N to be lost from compost windrows (Chastain et al., 2005), and the majority of the nitrogen in the compost mixes came from the animal manure. Increasing the amount of separated swine solids in the compost mix from 25% to 33% increased the N in the compost by about 50%.

There was no general relationship between the concentrations of P_2O_5 and K_2O in fresh solid animal manure and the P_2O_5 and K_2O concentrations of the compost products. Contribution of P and K from the plant materials used as the carbon source obviously had an impact on compost quality. In some cases, the dry matter associated with the carbon source may have diluted the concentrations of P and K.

The copper and zinc contents of animal manure compost were consistently lower than the typical concentrations of these elements in the corresponding fresh solid manure used in the compost mixes. It is believed that the plant material (cotton gin trash and wood waste) in the compost mixes contributed very little Zn or Cu. This would cause the Zn and Cu contributed by the animal manure to be diluted.

Table 2. Comparison of major plant nutrient, zinc, and copper concentrations in animal manure based compost products and typical values for uncomposted solid manure.

	Screened Dairy Manure Solids [1]	Scraped Outside Lot[2]	Cow Manure Compost[3]	Separated Swine Solids[4]	SGTW[5]	SGT[6]
	------------------------------- Percent Dry Matter Basis -------------------------------					
Total-N	1.22	2.29	0.79	5.32	2.30	3.49
P_2O_5	0.75	1.20	0.58	4.03	2.11	5.55
K_2O	0.46	2.14	0.46	0.65	1.03	2.15
Zn	0.015	0.015	0.010	0.30	0.070	0.171
Cu	0.025	0.005	0.007	0.32	0.064	0.195

[1] Solids from inclined screen separator, F_{DM} = 0.203 (Chastain, et al., 2001a)

[2] Manure scraped from an outside dairy feedlot and stored as a solid, F_{DM} = 0.33 (Chastain and Camberato, 2004)

[3] Average values of CMCA and CMCB in Table 1

[4] Nutrient content of the separated swine solids used to make SGTW and SGT (Vanotti et al., 2005)

[5] SGTW = 1 part separated swine solids: 2 parts cotton gin trash: 4 parts wood chips

[6] SGT = 1 part separated swine solids: 2 parts cotton gin trash

Organic Matter, Ash, and Carbon Content

The ratio of the volatile solids to the total solids content (VS/TS) was used as a measure of the organic matter content of the compost products (Table 1). The organic matter concentrations ranged from 0.289 for the yard waste compost to 0.540 for the compost that was composed of 33% separated swine manure (SGT). The value of VS/TS for fresh manure ranges from 0.69 to 0.84 (Chastain et al., 2001a and 2001b). Low values of organic matter indicate high levels of decomposition, which is a desirable characteristic for compost.

Low organic matter indicates high levels of fixed solids (1-VS/TS), or ash. The ash content of these compost products ranges from 46% to 71% of the dry matter.

The means given in Table 1 indicate that 26.7% to 80.4% of the organic matter (VS) was carbon. The highest carbon content was for the yard waste compost and the lowest value was for one of the cow manure based products (CMCB). The C/VS values of four of the six compost products (CMCA, MC, SGTW, and SGT) were not significantly different, and the overall mean for these materials was 0.494.

A recent case study by Chastain et al. (2005) indicated that C:N is not a good measure of compost stability. All of the compost products in this study were well decomposed as indicated by low organic matter contents (VS/TS), and a dark brown or black color. All products had a very low odor except for the mushroom compost. However, the products with the lowest organic matter contents (0.289 and 0.366) had the highest C:N values (18.5 and 24.6, Table 1). The lowest values of C:N, 8.2 and 11.3, were for the products with the highest nitrogen contents and contained significant amounts of NO_3-N (SGTW and SGT). These results support the observation made by Chastain et al. (2005) that low C:N values are only observed when the composting system is managed to minimize losses of soluble-N from the product. The ratio of carbon to nitrogen is not a reliable measure of compost stability.

Implications for Compost Utilization

The plant nutrient content of compost varies greatly depending on the materials used to make the compost. The results of the current study indicated that the type (cow vs. swine) and quantity of the animal manure used in the compost mix were important factors.

Compost has been promoted as an excellent source of organic matter and plant nutrients. Recommendations for horticultural use vary from applications of 1.3 to 7.6 cm over the field (e.g. Cooperband, 2002) to application rates of 6 to 160 t/ha (Ozores-Hampton and Obreza, 1998). Application of 2.5 to 10 cm of compost or a compost-mulch mixture has been shown to protect soil following construction and to provide plant nutrients to help establish roadside turf for soil protection (Glanville et al., 2004; Mukhtar et al., 2004; Persyn et al., 2004; Risse and Faucette, 2003; and Tyler, 2001).

One study conducted in Iowa (Glanville et al., 2004) provided detailed information concerning the mass of plant nutrients that were removed from roadside areas by runoff following installation of 5 and 10 cm compost erosion control blankets. Their results indicated that the mass of plant nutrients that were removed from highway embankments that received conventional erosion control treatments (tillage and seeding, or application of 15 cm of topsoil, tillage, and seeding) were 5 to 33 times greater than those treated with 5 and 10 cm blankets of compost.

None of the studies provided information on the constituent application rates that resulted from application of compost based on a prescribed depth (blankets), or amounts per hectare (t/ha).

Estimate of Plant Available N and P in Compost

The nitrogen in compost is predominately in the organic form. However, high-quality products can contain significant amounts of ammoniacal nitrogen (TAN) and nitrate-N. During the composting process a large amount of the organic-N is mineralized to ammonium-N. Consequently, a much smaller portion of the organic-N in a stable compost product will be mineralized in the soil following application as compared to uncomposted manure.

The fraction of the organic-N that will be released to NH_4^+-N is described by the mineralization factor, m_F. Mineralization factors for uncomposted animal manure range from 0.4 to 0.6 depending on species (Chastain, 2006). The mineralization factor for compost can range from 0.06 to 0.12 (Rynk et al., 1992). The recommended value of m_F for compost is 0.12 to be conservative from the standpoint of minimizing potential environmental impacts.

The amount of TAN that will be available for plant use following land application of compost will vary based on the amount applied, and the TS content. The fraction of TAN that is available for plant use is described by a TAN availability factor, A_F. The recommended value of A_F for surface applied compost without immediate incorporation is 0.5.

Nitrate-N cannot be lost from compost following application. Therefore, all of the NO_3-N contributes to the estimate of plant available nitrogen (PAN).

The recommended equation to estimate the plant available nitrogen content of a compost product is:

$$\text{PAN} = 0.5\ \text{TAN} + 0.12\ \text{Organic-N} + NO_3\text{-N}. \qquad (1)$$

The P_2O_5 in uncomposted manure is similar to commercial fertilizer and as a result, all of it is considered available (Chastain and Camberato, 2004). However, the phosphorous in compost is less available. Rynk et al. (1992) indicates that only 25% to 40% of the phosphorous in compost will be available for plant use. The available P_2O_5, was estimated as:

$$AP_2O_5 = 0.40\ P_2O_5. \qquad (2)$$

The upper limit of availability for P_2O_5 (40%) was used to provide a conservative estimate from the perspective of water quality protection.

Comparison of Constituent Application Rates Associated with the Use of Erosion Control Blankets with Agronomic and Regulatory Limits

An erosion control blanket is formed by spreading a 2.5, 5 or 10 cm layer of compost or a compost-mulch mixture on bare soil following final grading of roadside embankments. The embankment is also seeded with a grass mixture, and once established the grass will provide permanent soil protection.

Some of the 5 cm and 10 cm erosion control blankets are a one-to-one mixture of compost and screened mulch. Consequently, a 5 to 10 cm blanket may contain a compost volume equivalent to a 2.5 to 5 cm layer.

A 2.5 cm layer of compost is equal to a material volume of 250 m^3 of compost per hectare. The material application rates and the resultant constituent application rates for a 2.5 cm layer of compost were calculated for each of the compost products using the concentrations and dry bulk densities given in Table 1. The results are given in Table 3.

Table 3. Application rates resulting from a 2.5-cm layer of compost.

	CMCA[1]	CMCB[2]	MC[3]	YWC[4]	SGTW[5]	SGT[6]
Dry Application Rate (t_{DM}/ha) =	70.50	58.25	74.00	50.50	43.00	70.50
Wet Application Rate (t/ha) =	174.50	116.97	136.03	117.17	110.82	144.17
	Resultant Constituent Application Rates					
	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
Total-N	613	414	525	636	985	2468
PAN [7]	74	50	63	76	164	443
P_2O_5	451	297	422	126	907	3913
AP_2O_5[8]	180	119	169	51	363	1565
K_2O	360	239	444	162	443	1516
Ca	543	1311	2020	859	598	1748
Mg	204	105	222	146	219	1058
S	141	117	333	81	168	649
Zn	8	5	8	7	30	121
Cu	6	3	8	2	28	137
Mn	18	6	27	46	10	42
Na	61	42	101	6	34	48
C	11217	7590	12898	11736	11167	20093

[1] CMCA = composted cow manure and wood waste A

[2] CMCB = composted cow manure and wood waste B

[3] MC = mushroom compost

[4] YWC = yard waste compost

[5] SGTW = 1 part separated swine solids: 2 parts cotton gin trash: 4 parts wood chips

[6] SGT = 1 part separated swine solids: 2 parts cotton gin trash

[7] Estimated using equation 1.

[8] Estimated using equation 2.

Although application rates are given for all measured constituents, the discussion will focus on the agronomic requirements of roadside turf. Sample N, P_2O_5, and K_2O fertilization recommendations for roadside turf are given in Table 4.

The other elements of concern are Cu and Zn. In some states (e.g. South Carolina) the same regulatory limits are placed on Cu and Zn in animal manure as are found in the regulations for land application of biosolids (SCDHEC, 2002). High levels of soil-test zinc can have toxic affects on some plants (Camberato, 2003). High levels of Cu in hay can also cause reproductive problems in cows. Once soil-test values of Cu and Zn are excessively high they cannot be reduced since the requirements of plants is so small. Therefore, extremely excessive applications of Cu and Zn are unwise. The regulatory and agronomic limits for Cu and Zn that will be used for comparison to application rates are given in Table 5.

Table 4. Sample recommended fertilization rates for roadside turf establishment.

		Soil Test-P Level				
		Low	Medium	High		
	N		P_2O_5		K_2O	
	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	N/P_2O_5 [3]
South Carolina [1]	135	179	90	45	90[2]	1.50
Texas [3]	112		110		90	1.02

[1] Mylavarapu and Franklin (1997)

[2] Value based on a medium value of soil-test K.

[3] Based on medium soil-test P.

[4] Fertilization rates used for roadside turf establishment by Mukhtar et al. (2004)

Table 5. Application limits for copper and zinc.

	Copper	Zinc
Regulatory Limits		
Ceiling Concentration (%DM)[1]	0.15	0.28
Annual Application Limits (kg/ha)[1]	75	140
Cumulative Application Rate (kg/ha)[1]	1500	2800
Agronomic Limits		
Typical Plant Uptake Rate (kg/ha)[2]	0.022	0.128
Typical Supplement Rates (kg/ha) [3]	9.8	4.5

[1] SCDHEC (2002)

[2] Camberato (2003)

[3] Mylavarapu and Franklin (1997) only needed if soil test is inadequate.

The PAN, AP_2O_5, K_2O, Cu, and Zn application rates resulting from application of 2.5 cm of compost are compared with the agronomic recommendations for roadside turf establishment in South Carolina and regulatory limits in Table 6.

Table 6. Comparison of the PAN, P_2O_5, K_2O, Cu, and Zn application rates resulting from a 2.5-cm compost blanket with agronomic and regulatory limits.

	CMCA[1]	CMCB[2]	MC[3]	YWC[4]	SGTW[5]	SGT[6]
	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
PAN	74	50	63	76	164	443
Applied/Agronomic Limit =	0.55	0.37	0.47	0.56	1.21	3.28
P_2O_5	451	297	422	126	907	3913
AP_2O_5	180	119	169	51	363	1565
Applied/Agronomic Limit =	2.00	1.32	1.88	0.57	4.03	17.4
K_2O	360	239	444	162	443	1516
Applied/Agronomic Limit =	4.00	2.66	4.93	1.80	4.92	16.8
Zn	8	5	8	7	30	121
Applied/Uptake Rate =	62.5	39.1	62.5	54.7	234	945
Applied/Regulatory Limit =	0.06	0.04	0.06	0.05	0.21	0.86
Applied/Supplement Rate =	1.78	1.11	1.78	1.56	6.67	26.9
Cu	6	3	8	2	28	137
Applied/Uptake Rate =	273	136	364	90.9	1273	6227
Applied/Regulatory Limit =	0.08	0.04	0.11	0.03	0.37	1.83
Applied/Supplement Rate =	0.61	0.31	0.82	0.20	2.86	14.0

[1] CMCA = composted cow manure and wood waste A

[2] CMCB = composted cow manure and wood waste B

[3] MC = mushroom compost

[4] YWC = yard waste compost

[5] SGTW = 1 part separated swine solids: 2 parts cotton gin trash: 4 parts wood chips

[6] SGT = 1 part separated swine solids: 2 parts cotton gin trash

The highest quality compost products were made using separated swine manure as the N-source (SGTW and SGT). These products had the highest N, P_2O_5, and K_2O contents. Application of a 2.5 cm layer resulted in 1.21 to 3.28 times the required N fertilization rate, and over 1500 times the P_2O_5 and K_2O fertilization rates. Copper and zinc application rates for these two materials were excessive, and the Cu application rate exceeded the regulatory limit by 83%. A high-quality, nutrient rich compost makes a poor choice for use as an erosion control blanket. Therefore, SGTW and SGT were eliminated from further consideration for use in as a compost blanket.

A 2.5-cm application of the remaining four compost blankets provided only 37% to 57% of the nitrogen needs for roadside turf. However, the available P_2O_5 application rates ranged from 0.57 times the P_2O_5 requirement using yard waste compost to 2 times the P_2O_5 need using cow manure compost. The K_2O requirements of grass were exceeded in all cases. The Cu and Zn applications were only a fraction of the regulatory limits, but still greatly exceeded crop uptake.

The constituent application rates for a 5-cm layer of compost were twice the values given in Table 3. The application rates are compared for the two cow manure based products, yard waste compost, and mushroom compost in Table 7.

Table 7. Comparison of the PAN, P_2O_5, K_2O, Cu, and Zn application rates resulting from a 5-cm compost blanket with agronomic and regulatory limits.

	CMCA[1]	CMCB[2]	MC[3]	YWC[4]
	kg/ha	kg/ha	kg/ha	kg/ha
PAN	148	100	126	152
Applied/Agronomic Limit =	1.10	0.74	0.93	1.13
P_2O_5	902	594	844	252
AP_2O_5	360	238	338	102
Applied/Agronomic Limit =	4.00	2.64	3.76	1.13
K_2O	720	478	888	324
Applied/Agronomic Limit =	8.00	5.31	9.87	3.60
Zn	16	10	16	14
Applied/Uptake Rate =	125	78.1	125	109
Applied/Regulatory Limit =	0.11	0.07	0.11	0.10
Applied/Supplement Rate =	3.56	2.22	3.56	3.11
Cu	12	6	16	4
Applied/Uptake Rate =	545	273	727	182
Applied/Regulatory Limit =	0.16	0.08	0.21	0.05
Applied/Supplement Rate =	1.22	0.61	1.63	0.41

[1] CMCA = composted cow manure and wood waste A

[2] CMCB = composted cow manure and wood waste B

[3] MC = mushroom compost

[4] YWC = yard waste compost

Overall, the yard waste compost was the best choice for use as a 5-cm compost blanket. Nitrogen and P_2O_5 were over applied by about 13%. Potash was over applied by a factor of 3.6. Zinc and Cu were still applied at a fraction of the regulatory limits. It is thought that a one-time application of 5 cm of yard waste compost would not pose a great environmental risk.

The other three compost products (CMCA, CMCB, and YWC) all resulted in excessive applications of P_2O_5 and K_2O. Application of 5-cm of CMCA and MC provided the N needs for turf establishment within 10%.

Application rates for a 10-cm erosion control blanket are simply twice those given in Table 7. Using these compost products for a 10-cm erosion control blanket would greatly exceed the agronomic limits for all major plant nutrients. Using compost as the only ingredient for a 10-cm erosion control blanket is not recommended.

The results of these calculations indicate that compost would make an excellent component to be combined with screened mulch or possibly topsoil for erosion control blankest for stabilization and establishment of roadside turf. However, using compost alone for 5 to 10 cm erosion control blankets does not appear to be wise from a water quality standpoint. Such compost-mulch or compost-topsoil blends have been suggested by Mukhtar et al.(2004), and these results support their observations.

The amount of compost used in a compost blanket mix should be determined based on an analysis of the plant nutrient content (at least PAN, AP_2O_5, and K_2O) and the fertilization recommendations for roadside turf. The variation in nutrient content between products is too great for published values to be of practical use.

Use of Compost to Fertilize Vegetable and Fruit Crops

Application of compost to field-grown vegetable and fruit crops at depths of 1.3 to 7.6 cm is a common recommendation. The potential benefits include addition of a slow-release form of fertilizer, biological weed control, and suppression of some soil-born plant diseases (Ozores-Hampton and Obreza, 1998; Rynk et al., 1992). However, the nutrient content of the compost product is generally ignored.

Recommended fertilization rates for some common vegetable and fruit crops are given in Table 8. The values provided are for medium soil fertility levels for K, and P_2O_5 fertilization rates for low, medium, and high values of soil-test P (Mehlich 1 extraction). The values in the table were developed for growing conditions and soil testing practices in South Carolina (Mylavarapu and Franklin, 1997). Obtain recommendations for other states, provinces, or regions from local universities, or government agencies.

The relative amounts of N, P_2O_5, and K_2O needed varies depending on the crop and the recommended fertilization practices. For some crops, such as tomatoes, a portion of the N is applied prior to planting with all of the P_2O_5 and K_2O. The remainder of the N is applied in one or more sidedress applications. For a crop such as watermelon, it is desired to apply a portion of all major plant nutrients throughout the growing season. Ratios of N to P_2O_5 and K_2O to P_2O_5 , based on medium soil fertility levels, are provided in Table 8 to facilitate comparison of crop needs with a potential fertilizer source.

Table 8. Fertilization requirements for selected vegetable and fruit crops (Mylavarapu and Franklin, 1997).

		Soil Test-P Level					
		Low	Medium	High			
	N		P_2O_5		K_2O [1]		
Crop	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	N/P_2O_5[2]	K_2O/P_2O_5[2]
Apples	62	67	0	0	50	0.93 [3]	0.75 [3]
Blueberries (2 applications)	22	22	22	0	22	1.00	1.00
Pole Beans - preplant	67	224	168	112	168	0.40	1.00
sidedress	68					0.80	
Cantaloupes	101	135	112	90	135	0.90	1.20
Collards	168	224	168	112	168	1.00	1.00
Peaches	67	112	56	0	56	1.20	1.00
Sweet Corn - preplant	45	112	67	0	101	0.67	1.51
sidedress	123					2.51	
Sweet Potatoes (3 applications)	34	56	45	34	45	0.75	1.00
Tomatoes - preplant	45	280	190	157	224	0.24	1.18
sidedress	112					0.82	
Watermelons (2 applications)	45	67	56	45	67	0.80	1.20

[1] Value based on a medium value of soil-test K.

[2] Based on medium soil-test values of P

[3] P_2O_5 is only needed if soil-test P is low.

The plant nutrient contents of the six compost products were converted to a wet-basis in terms of kg per wet ton (1000 kg) and are given in Table 9. The ratios of PAN/AP_2O_5 and K_2O/AP_2O_5 were included to allow comparison to the needs of a particular crop.

Table 9. Constituent content per wet ton of compost.

Constituent	CMCA[1] kg/t	CMCB[2] kg/t	MC[3] kg/t	YWC[4] kg/t	SGTW[5] kg/t	SGT[6] kg/t
Total-N	3.51	3.54	3.86	5.43	8.89	17.12
PAN	0.42	0.42	0.46	0.65	1.48	3.07
P_2O_5	2.59	2.54	3.10	1.08	8.19	27.14
AP_2O_5	1.03	1.02	1.24	0.43	3.27	10.86
K_2O	2.06	2.04	3.26	1.38	4.00	10.51
Ca	3.11	11.21	14.85	7.33	5.39	12.13
Mg	1.17	0.90	1.63	1.25	1.98	7.34
S	0.81	1.00	2.45	0.69	1.51	4.50
Zn	0.05	0.04	0.06	0.06	0.27	0.84
Cu	0.03	0.02	0.06	0.02	0.25	0.95
Mn	0.10	0.05	0.20	0.39	0.09	0.29
Na	0.35	0.36	0.74	0.05	0.31	0.33
C	64.3	64.9	94.8	100.2	100.8	139.4
F_{DM}[7]	0.404	0.498	0.544	0.431	0.388	0.489
PAN/AP_2O_5	0.41	0.41	0.37	1.51	0.45	0.28
K_2O/AP_2O_5	2.00	2.00	2.63	3.21	1.22	0.97

[1] CMC A = composted cow manure and wood waste A

[2] CMC B = composted cow manure and wood waste B

[3] MC = mushroom compost

[4] YWC = yard waste compost

[5] SGTW = 1 part separated swine solids: 2 parts cotton gin trash: 4 parts wood chips

[6] SGT = 1 part separated swine solids: 2 parts cotton gin trash

[7] Dry matter fraction

The PAN/P_2O_5 ratios of the animal manure based compost products ranged from 0.28 to 0.45. The only compost that contained more plant available-N than P_2O_5 was the yard waste compost. The two compost products made from separated swine manure had roughly the same amount of K_2O as available P_2O_5. All other products contained two to three times more K_2O than AP_2O_5. Except for yard waste compost, all of the compost products provided large amounts of P and K and relatively low amounts of available-N.

Comparison of the major plant nutrient ratios of the compost products with the corresponding desired nutrient ratios of vegetable and fruit crops (Table 8) indicates that application of compost to provide the P_2O_5 or K_2O needs of a vegetable of fruit crop is the most sensible. Using compost to provide a portion of the N and all of the P_2O_5 or K_2O, based on soil test, prior to planting and providing the remainder of the N from commercial sources as a sidedress may be the best alternative.

Evaluation of a compost product for potential use for vegetable production involves more that just application rates of PAN, P_2O_5, and K_2O. The other factors that should be considered are the amount of material required, and the amount of Na applied. Application of large amounts of compost can be costly. Therefore, compost products that are rich in nutrients typically cost less to use since less is required per hectare. Addition of large amounts of sodium can be detrimental to a crop, and should be avoided. Copper and zinc application rates should be evaluated based on soil-test results, and the potential toxicity issues.

The benefits and issues associated with using compost as a nutrient source for vegetables can be readily observed by example. Tomatoes were selected for the illustrative example because of its high P_2O_5 requirement relative to total-N needs. Also, spreading compost prior to field preparation would most likely fit easily with current cultural practices (tilling, hill forming, installation of drip irrigation, mulch, and transplanting).

Depending on soil-test results, compost can be applied prior to field preparation to provide the P needs of tomatoes. The dry (DMAR) and wet (MAR) material application rates, blanket depth, and constituent application rates resulting from application of compost to provide 190 kg AP_2O_5 /ha are given in Table 10.

The best compost product for providing the P_2O_5 needs of tomatoes was the compost that contained 33% separated swine manure (SGT). This product required the least amount of compost per hectare (17.5 t/ha), provided a PAN application rate that was closest to the desired pre-plant rate of 45 kg PAN/ha, and the lowest Na application rate (5.8 kg Na/ha).

The worst compost options were the yard waste compost and the mushroom compost. Yard waste compost required an excessive amount of material (440.8 t/ha) to provide the P_2O_5 needs, provided 538% more pre-plant N than needed, and 171% more K_2O than desired. Mushroom compost provided 58% more N than desired, 123% more K_2O than needed, and resulted in 113 kg of sodium per hectare.

The cow manure based products (CMCA and CMCB), and the compost that contained 25% swine manure solids (SGTW) may need to be applied at lower rates. The PAN application rates were higher than desired for all three products. The material application rates for the cow manure based products may prove to be too costly, and 65 to 67 kg Na was applied per hectare. The 25% swine solids compost required less material (58.0 t/ha), but provided 91% more N than desired.

Land application calculations were revised and application rates were determined based on the K_2O requirements for tomatoes (224 kg K_2O/ha). The results are shown in Table 11.

Application of the six compost products based on the K_2O needs for tomatoes indicates that yard waste compost was the only unacceptable product due to the high material application rate (162.4 t/ha), and application of excess PAN (135% more than required).

From the standpoint of matching the pre-plant nitrogen needs of tomatoes, the best products were the cow manure based compost products. The target application rate was 45 kg PAN/ha, and these products provided 46 and 47 kg PAN/ha. Cow manure based compost provided 59% of the P_2O_5 fertilizer recommendation for soils testing medium in P content. Therefore, these products would work well in areas with an elevated level of available P in the soil. The disadvantage of these two products is the high amount of material required (109 to 110 t/ha).

The two separated swine manure products (SGTW and SGT) required the least amount of material and may be the most economical choice. More pre-plant N was provided than desired, but one application provided 42% to 53% of the N required for tomatoes. Perhaps the extremely slow release nature of the N in compost would make such an application acceptable. The K_2O and P_2O_5 provided by SGTW and SGT closely matched crop needs. These two products also added the least amount of salt to the soil.

The calculations provided in Tables 10 and 11 point out that application recommendations based on a prescribed volume (blanket depth) or mass per unit area (t/ha) are not useful. Instead, for application rates need to be calculated based on compost analysis, soil-test results, and the nutrient requirements of the crop to be grown.

Table 10. Application of compost products to provide the P_2O_5 requirement for tomatoes.

	CMCA[1]	CMCB[2]	MC[3]	YWC[4]	SGTW[5]	SGT[6]
MAR (t/ha) =	183.7	187.0	153.2	440.8	58.0	17.5
DMAR (t_{DM}/ha) =	74.29	93.17	83.40	189.91	22.53	8.57
Blanket depth (cm) =	2.63	4.00	2.82	9.40	1.31	0.30
	Resultant Constituent Application Rates (kg/ha)					
AP_2O_5	190	190	190	190	190	190
PAN	77	79	71	287	86	54
Applied / Pre-Plant =	1.72	1.76	1.58	6.38	1.91	1.19
Applied / Total Required =	0.49	0.51	0.45	1.83	0.55	0.34
K_2O	379	382	500	608	232	184
Applied / Required =	1.69	1.70	2.23	2.71	1.04	0.82
Ca	571	2096	2275	3230	313	212
Mg	215	168	250	551	115	128
S	148	186	375	304	88	79
Zn	8.9	7.5	9.2	24.7	15.8	14.6
Cu	5.9	4.7	9.2	7.6	14.4	16.7
Mn	18.6	9.3	30.8	172.9	5.2	5.0
Na	64.6	67.1	113.3	20.9	18.0	5.8
C	11808	12136	14525	44156	5846	2439

[1] CMC A = composted cow manure and wood waste A

[2] CMC B = composted cow manure and wood waste B

[3] MC = mushroom compost

[4] YWC = yard waste compost

[5] SGTW = 1 part separated swine solids: 2 parts cotton gin trash: 4 parts wood chips

[6] SGT = 1 part separated swine solids: 2 parts cotton gin trash

Table 11. Application of compost products to provide the K_2O requirement for tomatoes.

	CMCA[1]	CMCB[2]	MC[3]	YWC[4]	SGTW[5]	SGT[6]
MAR (t/ha) =	108.7	109.7	68.6	162.4	56.1	21.3
DMAR (t_{DM}/ha) =	43.96	54.65	37.36	69.97	21.77	10.43
Blanket depth (cm) =	1.56	2.35	1.26	3.46	1.27	0.37
	Resultant Constituent Application Rates (kg/ha)					
K_2O	224	224	224	224	224	224
PAN	46	47	32	106	83	65
Applied / Pre-Plant =	1.02	1.03	0.71	2.35	1.84	1.45
Applied / Total Required =	0.29	0.30	0.20	0.67	0.53	0.42
AP_2O_5	112	111	85	70	184	231
Applied / Required =	0.59	0.59	0.45	0.37	0.97	1.22
Ca	338	1229	1019	1190	302	258
Mg	127	98	112	203	111	156
S	88	109	168	112	85	96
Zn	5.3	4.4	4.1	9.1	15.2	17.8
Cu	3.5	2.7	4.1	2.8	13.9	20.3
Mn	11	5.5	14	64	5.0	6.1
Na	38	39	51	7.7	17	7.1
C	6988	7119	6507	16268	5648	2969

[1] CMC A = composted cow manure and wood waste A

[2] CMC B = composted cow manure and wood waste B

[3] MC = mushroom compost

[4] YWC = yard waste compost

[5] SGTW = 1 part separated swine solids: 2 parts cotton gin trash: 4 parts wood chips

[6] SGT = 1 part separated swine solids: 2 parts cotton gin trash

Summary and Conclusions

Six compost products were obtained for the purpose of evaluating the plant nutrient, carbon, and organic matter contents. The compost products were analyzed to determine the dry matter concentrations of total-total nitrogen, total ammoniacal nitrogen (TAN = NH_4^+-N + NH_3-N), nitrate-N, total P (expressed as P_2O_5), total K (expressed as K_2O), calcium, magnesium, sulfur, zinc, copper, manganese, sodium, carbon, total solids (TS), volatile solids (VS), and ash..

The composts included in the study were a yard waste compost (containing no animal manure), two cow manure based products, mushroom compost (containing manure and straw), and two compost products that contained 25% and 33% separated swine solids. The carbon source used for the cow manure based compost was wood waste. The separated swine solids were mixed with either 67% cotton gin trash, or 25% cotton gin trash and 50% wood chips.

Statistical analysis indicated that the nutrient contents of the compost products were significantly different depending on whether or not animal manure was included in the mix, the type of manure used, cow vs. swine, and the amount of manure included in the mix, 25% vs. 33%.

The most important results are summarized below.

- The total-N content ranged from 0.71%DM for cow manure based compost to 3.49%DM for the mix that included 33% separated swine solids.
- The majority of the nitrogen was in the organic form (87% to 100%).
- All of the animal manure based compost products contained 2.7 to 3.6 times more available P_2O_5 than available N.
- The yard waste compost contained 1.5 times more available N than available P_2O_5.
- All of the compost products contained substantial amounts of all of the minor plant nutrients measured.
- Mushroom compost contained 1.7 to 2.0 times more sodium than all other products.
- The organic matter content (VS/TS) ranged from 0.289 to 0.540 indicating high levels of decomposition.
- The two products with the lowest organic matter contents (0.289 and 0.366) had the highest values of C:N (18.5 and 24.6), indicating that C:N was not a reliable indicator of compost stability.

Compost can be an good source of organic matter and plant nutrients. Application recommendations vary from 1.3 to 7.6 cm for horticultural use, to 2.5 to 10 cm compost blankets to protect bare soil following road construction.

Constituent application rates that resulted from using compost for erosion control blankets were compared with fertilizer recommendations for establishment of roadside turf, and the regulatory limits for Cu and Zn. Compost blanket depths considered were 2.5, 5, and 10 cm.

The results indicated the following.

- A high quality, nutrient rich compost (33% separated swine solids) should not be used for a compost blanket of any depth. Application of 2.5 cm resulted in excessive applications of plant available N, available P_2O_5, K_2O, and Zn. The Cu application rate was 83% higher than the regulatory limit.
- Application of all 5 cm of all compost products included in this study exceeded the agronomic limits for available P_2O_5 or K_2O.
- Yard waste compost was the best product for use as a 5-cm erosion control blanket, since K_2O was the only major plant nutrient applied in excess.
- The results indicate that compost would make an excellent component to be included in an erosion control blanket. However, it should be combined with other materials. The amount of compost used in a compost blanket mix should be determined based on an analysis of the plant nutrient content (PAN, AP_2O_5, and K_2O), and the fertilization recommendations for roadside turf.

Comparison of the major plant nutrients contained in compost with fertilizer recommendations for several vegetable crops indicated that application of compost to provide the P_2O_5 or K_2O needs of a vegetable of fruit crop appeared to be a good alternative.

The benefits and potential issues associated with using compost to fertilize vegetables was studied using tomatoes. Tomatoes were selected because they require a small amount of pre-plant N (45 kg/ha), and large amounts of P_2O_5 (190 kg/ha) and K_2O (224 kg/ha). In addition, spreading compost prior to field preparation would most likely fit easily with current cultural practices.

The constituent application rates (e.g. N, Cu, Zn, Na) resulting from spreading compost at the agronomic rates for P_2O_5 and K_2O were calculated. The results indicated the following.

- The most nutrient rich compost products required substantially lower material application rates (t/ha), and would most likely be more economical to use.
- Application of the most nutrient rich compost product (33% separated swine solids) to provide the P_2O_5 requirement resulted in a slight over application of pre-plant N (19%). It also provided slightly less that the K_2O need, and had the lowest sodium application rate (5.8 kg Na/ha).
- Yard waste compost and mushroom compost were considered to be unacceptable for use on tomato fields if spread at the agronomic rate for P_2O_5. Yard waste compost provided 538% more pre-plant N than required, and mushroom compost provided excess N (58% more than required), and large amounts of sodium (113 kg Na/ha).
- Application of cow manure based compost at the K_2O rate resulted in available N rates essentially equal to the pre-plant N requirements, and provided 59% of the P_2O_5 required for the crop.
- Using yard waste compost at the agronomic rate for K_2O resulted in an over application of available N by a factor of 2.35.

The data and nutrient balancing calculations point out that application recommendations based on a prescribed volume (blanket depth) or mass per unit area (t/ha) are not useful. Instead, compost application rates need to be determined based on analysis of the plant nutrients in a compost product, soil-test results, the nutrient requirements of the crop to be grown, and the amount of material required.

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