DECOMPOSITION AND EFFECT ON pH OF VARIOUS ORGANIC SOIL AMENDMENTS

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Abstract.--Decomposition and effect on soil properties and seedling growth of peat, sewage sludge, shredded cones, and 20-year-old slash pine sawdust were tested in field plots installed in a forest nursery in north Florida. After 18 months, the loss rates of organic material at, respectively, the 22.4, 44.8, and 89.6 mt/ha additions were as follows: 62, 51, 51% for peat; 51, 54, 44% for sludge; 51, 68, 68% for cones; 73, 53, 50% for sawdust. Peat lowered soil reaction by 0.3 pH unit for each 1% increase in organic matter. Cones and sawdust lowered pH slightly after 12 months. Sludge increased pH from 5.7 to 6.5 initially, then reduced it to 4.8 after 3 months.

Additional Keywords: Organic matter, soil reaction, forest nursery soil, organic amendments.

Forest nursery managers currently use cover crops, exogenous organic materials or often a combination of both in an attempt to maintain soil organic matter (OM) levels (Davey and Krause 1980).

The declining availability at low costs of conventional amendments such as wood residues prompts a search for alternate sources of organic materials. Once a grower locates an adequate supply of a promising material, pragmatic questions arise concerning application rates, decomposition rate or residence time, and effects on seedling and soil chemical properties.

Full-scale field tests of various amendments consume space and effort, whereas greenhouse pot trials are subject to regimes of soil, temperature, leaching and moisture quite different than those of the field. Accordingly, a field microplot method was designed to study both thevalue of such a procedure and the performance of four common organic materials applied at three rates. The points of interest were decomposition rates, effects on selected soil properties, seedling growth, mycorrhizal development, and incidence of charcoal root rot. This paper focuses on decomposition rates and effect on soil reaction.

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MATERIALS AND METHODS

Study Area

The study was conducted at the Container Corporation of America forest tree nursery near Archer, Florida. The soil in the study compartment is classified as Millhopper sand (loamy, siliceous hyperthermic Grossarenic Paleudult). Prior to clearing and grading as a nursery in 1970, the area had been successively cultivated, abandoned, and planted to slash pine (*Pinus elliottii* var. *elliottii* Engelm.). Mean July and January monthly temperatures are 27° and 14° C, respectively. Annual precipitation averages 1240 mm, most of which occurs in summer and winter.

Experimental Design and Conduct

The materials tested were peat, 20-year-old pine sawdust that had been exposed to normal weathering, municipal sewage sludge, and shredded pine cones. The peat was obtained from a commercial peat mine, 45 km distant. Activated sewage sludge was obtained from drying beds at the University of Florida waste treatment facility. Sawdust and cones (both principally from slash and loblolly pine) were obtained from the St. Regis Paper Company nursery near Lee, Florida. The application rates tested were 22.4, 44.8, and 89.6 mt/ha (dry weight), which would approximate 1, 2, and 4% increases above the native OM level of 1%. The chemical characteristics and particle size distribution of the materials tested are listed in Table 1.

The microplots consisted of plastic, 19-liter (5 gal.) buckets. Roughly 60% of the surface area of the sides and bottom of each bucket was perforated by 5 cm diameter holes to insure natural soil water drainage.

Several cubic meters of unfumigated topsoil from an area adjacent to the study were piled and mixed with a front-end loader and tractor. An appropriate amount of soil and organic material were mixed in a portable cement mixer. Samples for analysis were removed; then two buckets were filled with the mixture. Twenty-eight buckets were prepared in this manner, representing 4 materials x 3 rates x 2 replicates + 4 controls. After arrangement in a completely random fashion, the buckets were buried to the rim in a 14-m section of a nursery bed. The buckets were sturdy enough to withstand removal and replacement for successive crops.

Two-week-old slash pine seedlings were transplanted immediately after installation in mid-June 1980. In 1981, the buckets were in place when the entire bed was operationally sown on May 1. Subsequently, seedlings received the normal operational watering, fertilization, fungicide treatments and weed control. The fertilizer regime consisted of four maintenance applications (postemergent) of 168 kg/ha 10-10-10 in 1980 and only two in 1981. All fertilizer materials had a micronutrient mix of Mn (.2%), Fe (.1%), Zn (.05%), B (.05%), and Mg (.06%). The buckets were lifted at time of harvest and the soil + organic matter mixtures were stored between late February and mid-April 1981.

Table 1. Chemical characteristics and particle size distribution of four organic materials used as nursery soil amendments.

Material	pH	Ash	C	N	C/N	P	K	Ca	Mg	% within each size fraction			
										< 1.0 mm	1.0-2.0	2.0-6.0	>6.0
		----- %-----				---------ppm----------				----------%----------			
Peat	4.5	14	53.7	2.85	18.8	160	90	1250	415	29	20	38	12
Sludge	6.7	24	42.7	5.69	7.5	23900	2750	15500	4690	13	8	34	44
Cones	6.2	1	56.5	0.30	188.3	215	3400	225	405	21	18	35	25
Sawdust	4.5	4	61.6	0.19	342.2	25	55	325	70	22	35	37	6
Soil	5.7	99	0.7	0.02	35.0	44	35	149	9	100	—	—	—

Sampling Scheme

Soil samples were taken before and after the organic matter additions and composite samples at 3-month intervals, including the time between crops. Each composite sample consisted of four cores, 2.5 cm diameter by 30-cm deep, from each bucket.

At harvest, the soil mixture in each bucket was passed through 6 mm hardware cloth to remove all roots. Organic fragments larger than 6 mm were returned to the soil mixture.

Analyses

Soil and plant samples were processed and analyzed following routine procedures. Organic matter was determined by loss-on-ignition after combustion of a 25- to 30-gram sample at 550° C for 8 hours. Soil pH was measured in a 2:1 distilled water-to-soil ratio using a standard glass electrode.

Data analyses were conducted using procedures in the Statistical Analysis System. The change in soil OM over time was characterized by generated equations. Mean soil pH values within sample periods were compared using Duncan's multiple range test.

RESULTS AND DISCUSSION

Organic Matter Decomposition

The patterns of decomposition for the various organic materials and rates of application are described by linear equations (Fig. 1). The overall course of decomposition is linear despite seasonal variations in soil temperature and the disturbance associated with seedling harvest and reestablishment.

After 18 months, the peat treatments had lost 62, 51 and 51% of the amounts applied at the 1, 2, and 4% rates, respectively. This decomposition rate was much more rapid than observed in a large scale field study (Munson 1982) where 22.4, 44.8 and 67.2 mt/ha of peat lost 0, 21, and 19% of the amounts applied during the same time period. Possible reasons for the difference between the two studies are discussed later. The respective similarity in loss rate from the two higher applications within both studies, however, confirms that decomposition rate is roughly proportional to the amount added when this exceeds 22.4 mt/ha.

At the end of 18 months, the sludge treatments had lost 51, 54, and 44%, respectively, of the organic material added at the 1, 2, and 4% rates. These values would suggest that the sludge was more resistant to decomposition than any of the other three materials. A more likely explanation, however, is that decomposition was reduced by the large size and low porosity of the sludge particles. Initial air drying of the sludge produced firm aggregates, 78% of which were larger than 2 mm (Table 1). Hence, the area of soil-sludge contact was limited and exchange of O_2 and CO_2 with soil air restricted.

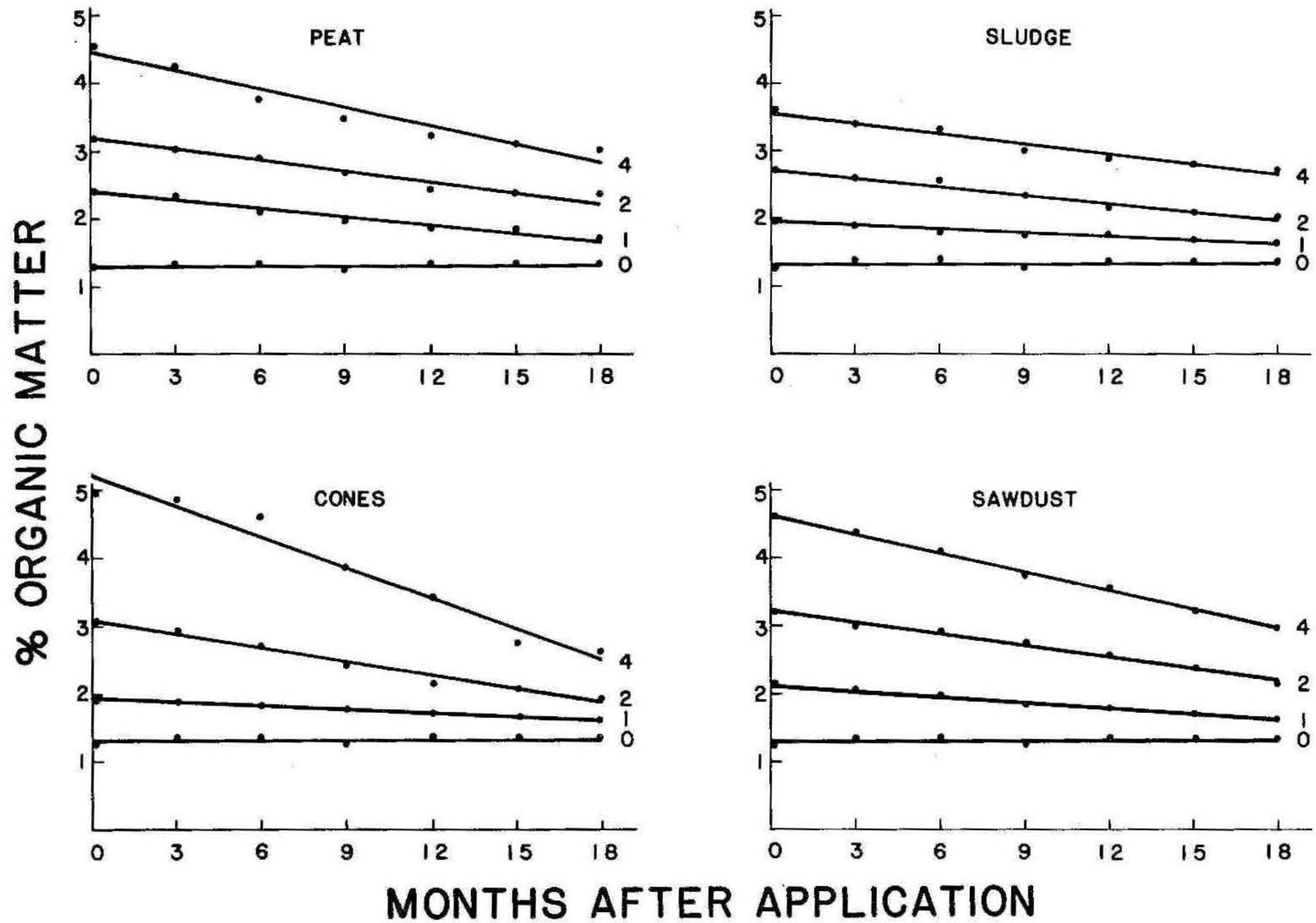

Figure 1. Organic matter decomposition in a nursery soil ammended with four organic materials at three rates. Points are observed values of best-fit lines. 0, 1, 2, and 4 at the end of the regression lines refer to application rates of 0, 22.4, 44.8, and 89.6 mt/ha, respectively. The 1980 crop was harvested in the seventh month.

Laboratory incubation and field studies have shown that decomposition of other sludges is generally more rapid than observed here (Terry et al., 1979; Varanka et al., 1976; Miller 1974). Thus, sludge decomposition rates observed in the present study may be underestimates.

Decomposition of the shredded cones proceeded rapidly: 51, 68, and 68% for the 1, 2, and 4% rates, respectively, after 18 months. The 68% loss is the largest of any material applied at 2 or 4%. No explanation can be offered for the lower loss rate at the 1% addition, a reversal contrary to results with the other three materials. Despite the coarse size (Table 1) and outward woodiness of the cone fragments, their internal structure seems susceptible to microbial attack.

Losses after 18 months from the 1, 2, and 4% sawdust treatments amounted to 73, 53, and 50%, respectively. The 73% was the greatest of those for all materials and rates. Loss from the 2% treatment may be compared with results from a laboratory incubation study (Allison and Murphy 1963) in which 2% fresh slash pine sawdust mixed with soil lost 28% of its carbon in 12 months. This would extrapolate to 42% in 18 months, less than the 53% loss observed in the present study.

If the sludge is excluded from comparison because of the particle characteristics discussed earlier, then the other three materials rank as follows in respect to decomposition after 18 months (actual percentages in parentheses):

Application Rate	Ranking
1%	sawdust (73) > peat (62) > cones (51)
2%	cones (68) > sawdust (53) ≃ peat (51)
4%	cones (68) > sawdust (50) ≃ peat (51)

Only the 1% cone treatment deviates from an overall decomposition ranking of 1% > 2% = 4%, within materials, and cones sawdust peat, within rates. Direct comparison of decomposition under actual field conditions is possible only for peat, used in both the field macroplot study (Munson 1982) and the microplots. As noted, decomposition in the macroplots was about 20% after 18 months for the 2 and 3% additions as compared with about 50% for the 2 and 4% rates of the present study. Factors which may have contributed to accelerated decomposition of the latter include a) better mixing of soil and peat that could not be duplicated even by repeated field tillage, b) fragmenting and remixing of the peat particles during the seedling harvest procedure, and c) possible air gaps between the microplot mixtures and surrounding soil which could have led to longer retention of moisture after rain or irrigation. If decomposition of the other materials was similarly accelerated, then the estimated residence times of such amendments should be extended 2-2½ times.

A general conception of the decomposition of green manures is that two-thirds of the added carbon will be respired away during the decay processes, with one-third remaining as part of a more stable organic matter fraction (Brady 1974). Application of this concept to the results of this study may provide a framework for an organic matter maintenance program. The linear extrapolations of the decomposition data to the point in time following application when one-third of the material is left are presented in Table 2. Also included in Table 2 are the adjusted values to compensate for the accelerated decomposition as discussed previously.

Table 2. Time required for decomposition of two-thirds of the applied organic material.

Material	Unadjusted			Adjusted[1/]		
	Application Rate (mt/ha)			Application Rate (mt/ha)		
	22.4	44.8	89.6	22.4	44.8	89.6
	- - - - - - - - - - - - - yrs - - - - - - - - - - - - -					
Peat	1.6	1.9	1.9	3.2	3.8	3.8
Cones	2.0	1.5	1.5	4.0	3.0	3.0
Sawdust	1.4	1.9	2.0	2.8	3.8	4.0

[1/] The unadjusted time periods were extended 2 times to estimate more closely the time required for two-thirds decomposition of the materials under actual field conditions.

From the practical standpoint, these lengths of time (adjusted) may serve as guidelines for application intervals with respect to the various materials and rates. In general, the results of this study would suggest that where maximizing residence time of applied organic materials is an objective, this may best be achieved by frequent applications at the lower rates rather than applications of the same total quantity in larger but less frequent additions.

Soil Reaction

Soil reactions between pH 5 and 6 are generally considered to be optimum for pine seedling production (Armson and Sadrieka 1979). The change in soil pH over the course of a growing season is influenced by nutrient uptake and leaching, by the effects of fertilizers and by addition of bases in irrigation water. As a result of these seasonal influences, comparisons were confined to those between materials and rates within each sampling date.

Reaction of the unamended control soil increased irregularly from about pH 5.7 to pH 6.0 at 18 months (Fig. 2).

Addition of acid peat lowered the pH 0.3 unit for each 1% increase in OM (Fig. 2). This effect persisted over both growing seasons with reaction more or less paralleling changes in the unamended control.

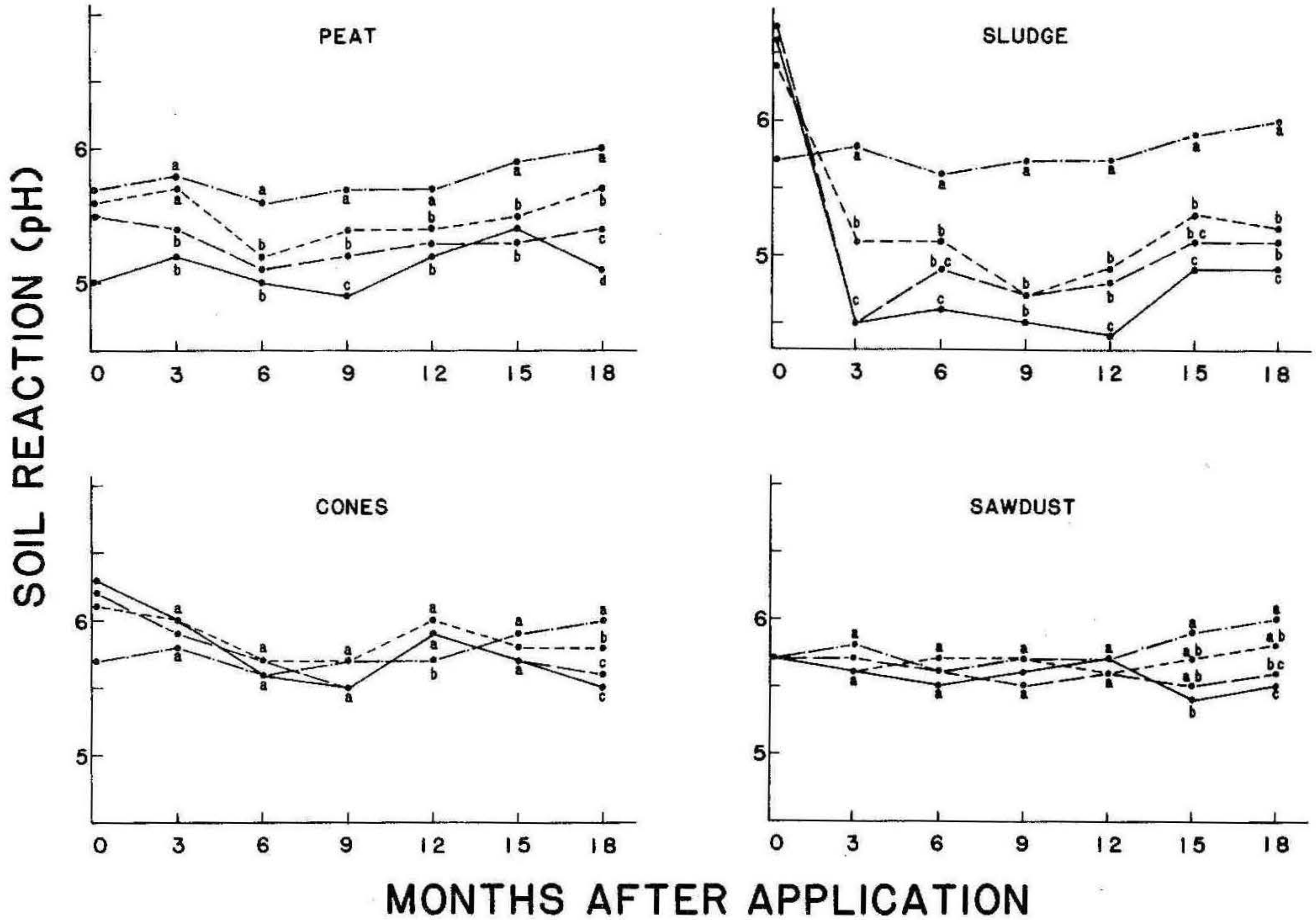

Figure 2. Soil reaction (pH) as influenced by four organic ammendments applied at three rates. The 1980 crop was harvested in the seventh month. Values at each sample period within materials with the same letter are not significantly different (Duncan's, a = .05)

Control = ____.____.____ Rate 1 = __ __ __ __ __ Rate 2 = ___ ___ ___ Rate 3 = __________

The high base content and reaction of the sludge initially increased the pH of the soil-sludge mixture. This increase was abruptly reversed, however, with the two higher treatments dropping from pH 6.6-6.7 to 4.5 after 3 months. The decrease in reaction during the first 12 months can be attributed to nitrification and rapid leaching of NO_3^- from the sludge, which had a narrow C/N ratio (Table 1). Leaching of NO_3^- also removes equivalent amounts of cations (Raney 1960). After 12 months, the slow rise in reaction is generally similar, although steeper, to that of comparable peat treatments.

The sharp increase in initial pH following addition of shredded cones apparently is due to the relatively high potassium content (.34%, Table 1), coupled with the low exchange capacity of the woody material. The drop in reaction to that of the control after 6 months probably reflects increased exchange capacity, hence lower base saturation, as decomposition occurred (Fig. 2). A lesser pulse of increase at 12 months (early in the second growing season) is unaccounted for, but again followed by a decrease.

Addition of 20-year-old sawdust lowered pH slightly below that of the controls during the first year, and more so between 12 and 18 months.

CONCLUSION

Fifty percent or more of the added OM decomposed in the 18-month study period, regardless of material or rate. The only exception was a 44% loss of sludge applied at the highest rate. In this case, decomposition was likely retarded by coarse particle size as well as drastic changes in the soil chemical environment. Losses from shredded cones, the only material not subjected to prior decomposition, were greater than from the other materials, which in turn were roughly comparable. For each material and rate, decomposition was a linear function of time. In contrast, the OM content of the control soil (1.3%) did not change significantly.

To coordinate decomposition rates and application intervals with the intent of maximizing OM residence time, it is suggested that light applications (22.4 mt/ha) every 3-4 years may be a suitable OM maintenance schedule.

The peat-amended soils maintained a lower reaction during the study period. Sawdust and cones lower pH only slightly after 12 months. Reaction of the sludge-treated plots initially increased to above pH, then dropped below pH 5.0. This decrease was in response to the high content of readily mineralized N in sludge, which resulted in leaching of excess NO_3^- and concurrent losses of cations.

Overall, the OM residence time and response of soil reaction varied with organic material and rate of application. Ideally, the nature of these responses and subsequent effects on seedling development should be determined before the full-scale operational use of any exogenous organic material.

LITERATURE CITED

Allison, F. E., and C. J. Klein. 1961. Comparative rates of decomposition in soil of wood and bark particles of several softwood species. Soil Sci. Soc. Am. Proc. 25:193-196.

Brady, N. C. 1974. The nature and properties of soils. Eight ed. Macmillan Publ. Co., New York. 639p.

Davey, C. B., and H. H. Krause. 1980. Functions and maintenance of organic matter in forest nursery soils. In: Proc. North Am. For. Tree Nursery Soils Workshop, July 28-August 1, 1980, Syracuse, New York.

Miller, R. H. 1974. Factors affecting the decomposition of an anaerobically digested sewage sludge in soil. J. Env. Qual. 3:76-380.

Munson, K. R. 1982. Decomposition, function, and maintenance of organic matter in a sandy nursery soil. Ph. D. Thesis. Univ. of Florida.

Raney, W. A. 1960. The dominant role of nitrogen in leaching losses from soils of humid regions. Agron. J. 52:563-566.

Terry, R. E., D. W. Nelson, and L. E. Sommers. 1979. Carbon cycling during sewage sludge decomposition in soils. Soil Sci. Soc. Am. J. 43:494-499.

Varanka, M. W., Z. M. Zablocki, and T. D. Hinesly. 1976. The effect of digestion sludge on soil biological activity. J. Water Pollut. Contr. Fed. 48:1728-1740.