Container Substrate Temperatures Affect Mineralization of Composts

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Abstract. Traditional N mineralization studies have been conducted by soil scientists using soils and temperatures found in field production. As temperature, in part, governs the rate of mineralization, and container substrates reach much higher temperatures than do soils, the effect of these elevated temperatures on mineralization must be considered to begin to understand N mineralization in container substrates during production. The N mineralization patterns of three composts [turkey (*Meleagris gallopavo*) litter, yard waste, and municipal waste] were determined under three temperature regimes (45, 25, and 45/25 °C). More organic N was mineralized from composted turkey litter (CTL) than from municipal or yard composts, regardless of temperature. The percentage of organic N mineralized from CTL was greater at 45/25 and 45 °C than at 25 °C.

The use of animal manure as a source of nutrients is an ancient practice. However, because animal production is concentrated near processing facilities, the quantity of manure produced can exceed agricultural crop demand in these areas. Thus, alternative uses are needed for manure, facilitating improved disposal and distribution.

In general, compost is considered to be valuable as an amendment for improving physical properties of container substrates and, to a lesser degree, as a fertilizer source. Compost generally improves the chemical properties of container substrates by increasing pH, cation exchange capacity (CEC), and concentrations of plant-available nutrients. However, most nutrients in compost are not readily soluble and are released as the organic material breaks down. Since the mineralization of organic N to inorganic N is microbially mediated, the rate of nutrient availability is regulated by environmental conditions such as temperature, moisture, and pH (Haynes, 1986). As temperature, in part, governs the rate of mineralization, the effect of container substrate temperature on mineralization must be considered. Additionally, temperature affects the

sequential steps of ammonification and nitrification; therefore, temperature affects the final product of organic N as it is mineralized.

Traditionally, N mineralization studies have been conducted by soil scientists using soils and temperatures (25 to 40 °C) found in field production. However, the temperature of container substrates can reach 40 °C and remain there for a minimum of 7 h·d⁻¹ (Tyler et al., 1993a). The objective of this experiment was to determine the effect of temperature on N mineralization patterns of three composted products.

Materials and Methods

The experiment, a 3 × 3 factorial, consisted of three temperature regimes (chambers) with three composts replicated four times within each temperature regime in a randomized complete-block design. Temperature regimes were constant 25 °C, constant 45 °C, and alternating 45/25 °C for 10 and 14 h, respectively. Composts were all windrow-composted and included a commercial composted turkey litter (CTL) (Sustane 5N–0.9P–3.3K, Sustane Corp., Cannon Falls,

Minn.) consisting of excreta plus litter; a commercial composted yard waste (Eco Products, New Solutions, Charlotte, N.C.) containing leaves, grass, and landscape debris; and a composted municipal solid waste comprising unidentified organic matter (85%), wood (8%), and inorganic matter (7%), provided by Dr. Jim Shelton, Dept. of Soil Science, North Carolina State Univ. Selected chemical and physical properties of the three compost and the three compost-amended substrates are included in Table 1.

For C and N analysis, composts were dried at 60 °C for 24 h and ground to pass a 40-mesh (0.425 mm) screen. Nitrogen and C were determined using a CHN elemental analyzer (Perkin Elmer 2400, Norwalk, Conn.). Each compost was blended with milled pine bark to achieve an equal N content [0.92 g·L⁻¹ N; based on 3.5 g N added to a 3.8-L container] for each treatment to facilitate comparisons between composts. This resulted in 14.4 g turkey litter, 25.5 g yard waste, and 125.6 g municipal waste mixed with enough pine bark to fill each column. All composts and pine bark were screened through a 6.3-mm screen prior to mixing the substrates. Substrate (compost/pine bark mixtures) for each column was mixed separately. No additional amendments were made to the substrates.

Each substrate was placed in a polyvinyl chloride (PVC) column, 30 cm in length and 5 cm in diameter (589 cm³ in volume) with each end sealed with a PVC cap. A 5-mm hole was drilled in each end cap to allow for gas exchange but prevent excessive moisture loss. Columns were tapped twice as they were filled to settle the substrate, saturated with 0.01 M KCl, allowed to drain for 15 min, and placed horizontally in temperature-controlled chambers for the incubation period (16 weeks). An additional column of each substrate was included in each chamber to determine water loss during the course of the experiment.

Each column was sampled weekly by plugging the end caps, saturating with 0.01 M KCl to displace NH₄⁺ held on the cation exchange sites, allowing 5 min for equilibration, and then draining to container capacity. Leachate volume was measured and a subsample taken for NO₃-N (Calaldo et al., 1975) and NH₄-N (Chaney and Marbach, 1962) analyses using a spectrophotometer (Spectronic 1001 Plus; Milton Roy Co., Rochester, N.Y.). Leachate pH was measured with an Accumet pH meter (Fisher Scientific Co., Fairlawn, N.J.).

Net mineralization rate was defined as the accumulation of inorganic N (NH₄-N + NO₃-N). Losses due to NH₃ volatilization and denitrification were not measured, but were

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Table 1. Selected chemical and physical properties of three composts and compost-amended pine bark substrates.

Compost	Composts			Amended substrates		
	%C	%N	C : N	pH	Mass wetness ²	Db ³ (g·cm ³)
Municipal	6.0	0.4	14:1	5.0	63.7	1.03
Turkey litter	14.9	3.8	4:1	4.7	71.6	0.91
Yard debris	27.9	2.1	13:1	4.6	72.4	0.91

²Equalled [(wet weight – oven dry weight)/oven dry weight].

³Bulk density.

considered minimal under the experimental conditions.

Data were subjected to analysis of variance procedures (SAS Institute, 1985). Mean separations were performed via least significant difference (LSD) procedures at $P \leq 0.05$. Replication within the chamber was used as the error term for the temperature variable; therefore, differences between temperature treatments are only approximations.

Results and Discussion

Carbon : nitrogen ratios of the composts (Table 1) indicated that mineralization should exceed immobilization, resulting in a net release of N into the substrate solution. Nitrification in pine bark substrates can be inhibited when the pH is <4.5 (Niemiera and Wright, 1986); however, pH of all compost/pine bark mixtures in this experiment remained above

5.2. In addition, substrate moisture was within the range (50% to 70% of water-holding capacity) reported to be optimum for ammonification and nitrification in soils (Alexander, 1977).

More organic N was mineralized during the 16-week period in the CTL treatment than in municipal or yard composts, regardless of temperature (Table 2). While composted yard and municipal wastes might be useful for improving the physical properties of container substrates, neither compost would be an adequate N fertilizer in containerized plant production. The percentage of organic N mineralized from CTL at 45/25 (35%) and 45 °C (33%) was greater than at 25 °C (27%). This was expected as ammonification is accelerated at higher temperatures (Haynes, 1986). Percentages of organic N mineralized from CTL in this study were similar to those conducted in soils for similar durations and at similar temperatures (Westerman et al., 1988).

Effects of temperature, compost, and temperature $\times$ compost interaction on $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ content differed over time. From weeks

0 through 5, the source of compost affected $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ content, presumably as the easily mineralizable fractions of each compost were degraded; however, $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$ content were unaffected by temperature and temperature $\times$ compost interaction (data not presented). Nitrogen released from CTL during weeks 0 through 5 arose primarily from mineralization of organic N to $\text{NH}_4\text{-N}$ (Fig. 1).

From weeks 6 through 16, temperature, compost, and the temperature $\times$ compost interaction affected N mineralization (data not presented). At 45 and at 45/25 °C from weeks 6 through 16, ammonification was still the dominant process in CTL (Fig. 2). Optimum temperature for ammonification ranges between 40 and 60 °C (Haynes, 1986). At 25 °C, organic N ammonified to $\text{NH}_4\text{-N}$ was quickly nitrified to $\text{NO}_3\text{-N}$ (Fig. 2). Similarly, nitrification in pine bark substrates was 84% greater at 20 °C than that at 40 °C (Niemiera and Wright, 1987). Maximum nitrification usually occurs between 25 and 35 °C (Haynes, 1986). Presumably, the 45 and 45/25 °C treatments inhibited nitrification in turkey litter-amended

Table 2. Effect of temperature during 16 weeks of incubation on percentage of applied N mineralized from three different composts blended with pine bark having similar N content.

Compost	Temp (°C):	N mineralized (%) ^z		
		25	45	45/25 ^y
Municipal		5.5 ^x	6.5	7.0
Turkey litter		26.5	32.7	34.7
Yard debris		0.7	0.7	0.4

^zPercentage of N mineralized after 16 weeks = $\frac{\text{mg inorganic N mineralized}}{\text{mg organic N applied}} \times 100$

^yDiurnal cycle of 10 h at 45 °C and 14 h at 25 °C.

^xFor comparisons of treatment means within rows or within columns, $\text{LSD}_{0.05} = 2.2$. Temperature $\times$ compost interaction was significant at $P \leq 0.05$.

Fig. 1. Ammonium, nitrate, and total N mineralized from composted turkey litter per week averaged over temperature treatment from weeks 0 through 5.

Fig. 2. Ammonium, nitrate, and total N mineralized from composted turkey litter per week for each temperature treatment from weeks 6 through 16.

substrates, resulting in an accumulation of $\text{NH}_4\text{-N}$.

The initial mineralization rate of N at 23 mg/week (Fig. 1) from CTL dropped to N at 4.5 mg/week by week 16 (Fig. 2), suggesting that CTL alone would not release adequate N to maximize growth in containerized plant production. This is supported by Groves (1995), who reported that *Cotoneaster dammeri* 'Skogholm' and *Rudbeckia fulgida* 'Goldsturm' plants fertilized with CTL were smaller than those fertilized with commercial inorganic fertilizers applied on an equivalent gram of N basis.

While composted yard and municipal wastes may improve the physical properties of container substrates, they do not supply adequate N to serve as beneficial N fertilizers in containerized plant production as also reported by Falahi-Ardakami et al. (1987). In addition,

our data suggest that, depending upon the species, supplemental fertilizer N may be needed to maximize growth of landscape plants in container substrates amended with CTL.

Literature Cited

- Alexander, M. 1977. Introduction to soil microbiology. Wiley, New York.
- Calaldo, D.A., M. Haroon, L.E. Schrader, and V.L. Youngs. 1975. Rapid colorimetric determination of nitrate in plant tissue. Commun. Soil Sci. Plant Anal. 6:71-80.
- Chaney, A.L. and E.P. Marbach. 1962. Modified reagents for determination of urea and ammonia. Clin. Chem. 8:130-132.
- Falahi-Ardakami, A., J.C. Bouwkamp, F.R. Gouin, and R.L. Chaney. 1987. Growth response and mineral uptake of vegetable transplants grown in a composted sewage sludge amended medium. I. Nutrient supplying power of the medium. J. Environ. Hort. 5:107-111.
- Groves, K.M. 1995. Effect of irrigation volume, cyclic irrigation, and nutrient source on containerized plant production. MS Thesis, Dept. of Hort. Sci., North Carolina State Univ., Raleigh.
- Haynes, R.J. 1986. Mineral nitrogen in the plant-soil system. Academic Press, Orlando, Fla.
- Niemiera, A.X. and R.D. Wright. 1986. Effect of liming rate on nitrification in a pine bark medium. J. Amer. Soc. Hort. Sci. 111:713-715.
- Niemiera, A.X. and R.D. Wright. 1987. Influence of temperature on nitrification in a pine bark medium. HortScience 22:615-616.
- SAS Institute. 1985. SAS user's guide: Statistics. Vers. 5 ed. SAS Inst., Cary, N.C.
- Tyler, H.H., K.B. Perry, and S.L. Warren. 1993a. Composted poultry litter: Effect on thermal properties of a pine bark substrate, p. 92-95. In: Proc. Southern Nursery Assn. Res. Conf., 38th Annu. Rpt.
- Westerman, P.W., L.M. Safley, Jr., and J.C. Barker. 1988. Available nitrogen in broiler and turkey litter. Trans. Amer. Soc. Agr. Eng. 31:1070-1075.