Evaluation of composts for production of sod and groundcover crops /

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EVALUATION OF COMPOSTS FOR PRODUCTION OF SOD AND GROUNDCOVER CROPS

A Thesis Presented

by

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Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE

September 1995

Department of Plant and Soil Sciences

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DEDICATION

To my husband, David T. Lashway, whose love, understanding, and encouragement have made everything possible.

ACKNOWLEDGMENTS

I wish to express my sincere appreciation and gratitude to Dr. Allen V. Barker for his continuous support and encouragement during my research. I believe I could not have chosen a better advisor or master's program.

I would like to thank Dr. Wesley R. Autio, Dr. Douglas A. Cox and Kathy Ready for their helpful advice, and special thanks to Kelly Ponte for her dedication and concern for my research.

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CHAPTER I

INTRODUCTION

Disposal of municipal solid wastes has become a large-scale problem in the United States. Current methods of disposal into landfills and incineration are becoming obsolete due to lack of landfill space, high costs, pollution, and state and federal regulations. Continued production of yard wastes, paper, and biosolids has forced municipalities to seek alternatives for dealing with their waste disposal. Composting can serve as an alternative method and is an important component in management of solid-wastes (Cisar and Snyder, 1992).

Composting is the decomposition of organic wastes into a soil-like material. Compost made from municipal solid waste or any biological waste may be incorporated into large-scale agricultural use (Bevacqua et al., 1993; Hyatt, 1995, McConnell et al., 1993) and also may serve as a medium for container growing of crops (Bugbee and Frink, 1989). Depending on the physical and chemical composition, compost can be used as an organic fertilizer, a potting media, or as a soil amendment. The effects of compost on plant growth will determine ultimate agricultural value and use.

Compost has many benefits. Composts applied to land have increased soil calcium, phosphorus, potassium, and magnesium concentrations and soil organic matter (Mays and Giordano, 1989) and have stimulated root growth (Cisar and Snyder, 1992). Composts have induced favorable effects on soil porosity, aggregate stability (Pagliai et al., 1981), and have suppressed plant diseases (Hoitink and Fahy, 1986; Logsdon, 1990). Composts produced from municipal solid waste (MSW) are richer in nitrogen and phosphorus than most agricultural soils (McConnell et al., 1993). The high nutrient quality of biosolids sources increases their potential value in composts for agricultural use. In addition, biosolids contain organic nitrogen which is less likely to leach into ground water than chemical nitrogen fertilizers (Chaney, 1990a). However, the elemental composition of municipal biosolids is still a cause of great concern and has limited their acceptability especially for food and feed crop production. Subsequently, the concern has caused research to focus around risk estimates for compost use (Dyer and Razvi, 1987; Guidi et al., 1990; Chaney, 1990a; Chaney, 1990b). Source separation and regulation of acceptable levels of potentially toxic elements help to protect the public (Rosen et al., 1994).

Proper methods of preparation are necessary to produce stable, valuable composted products (Richard, 1990). Factors such as time of composting, composition, separation methods, aeration, and moisture content are a few of the important considerations in producing a mature and valuable composted product (Hachicha, 1992; Hughes, 1980; Kubota and Nakasaki, 1991). Methods for assessing compost maturity are essential, for unstable compost has inhibited plant germination and growth (He et al., 1992; Inbar, 1990; Zucconi et al., 1981a; Zucconi et al., 1981b). Results from research may be misinterpreted if a compost is assumed mature when in fact the compost is immature. The value of a commercial compost for agricultural use will be impossible to determine if the product is unstable. It is therefore necessary to establish standards for compost maturity as well as composition and then for potential usage based on these assessments.

Composts used in agriculture, horticulture, landscaping, or land reclamation should have specific chemical and physical requirements based on the ultimate use of the compost (Gouin, 1991; Walker and O'Donnell, 1991). Factors such as ammonium concentration, soluble salts, temperature, maturity, pH, C/N ratio, moisture content, odor, and nutrient availability should have different standards for different agricultural uses.

Use of compost from various compositions of biological waste, yard waste, and municipal solid wastes in the production of mint and sod-grown crops can be a demonstration of the suitability and safety of compost for agricultural use. Utilization of compost for production of mint and sod-grown crops represents a large potential use to commercial and noncommercial markets (Cisar and Snyder, 1992). Results obtained from such studies may be transferred to other crops. Information will be gained on the impacts of different composts on transplant growth, crop germination, growth, quality, and N status. These kinds of information are essential for the assessment of the effects of composts on any crop.

The focus of this research is to demonstrate production of mint transplants and grass and wildflowers sods in composts as potential large-scale uses of compost. Composts were produced from cocomposted municipal solid wastes, autumn leaves, and cocomposted cranberry waste and chicken manure. Mint transplants and grass and wildflower sods were evaluated in the greenhouse and outdoors in plots on black plastic and in the field. Composts were used as a mulch or incorporated into the soil surface. The capacity of composts to provide nitrogen nutrition for plant growth, to establish stands, and to increase harvest weights was assessed. Other standard analysis of the composts included ammonium, nitrate, total N, salinity, pH, bulk density, and water content. Chemical analysis focused on ammonium concentrations in compost for assessing maturity of compost.

The first experiments were conducted in the greenhouse with mint transplants and a mixture of wildflower seeds. Changes in nitrogen status and electrical conductivity in the composts were assessed. From these results, it was apparent that closer investigations of ammonium and soluble salts were necessary. Wildflowers and grass were grown in composts treated $(NH_4)_2SO_4$ and $Ca(NO_3)_2$ to simulate different maturities and salinities of composts. The effects of varying ammonium-N and electrical conductivity on seed germination and plant growth were assessed. Based on the results that showed declines in compost ammonium within 7 to 14 days after application, the effects of delaying seeding after compost application on germination of seeds and growth of grass were investigated. In the field, studies to determine the effects of compost application on wildflower and grass germination and seedling growth were conducted. Field studies had two methods of compost application, incorporation of compost into the top 2 inches of soil and application to the surface as a mulch. During the first season of field studies, it became apparent that weeds had to be controlled in order to get seedling establishment. These results led to the production of sods in outdoor frames over plastic. The plastic surpressed weed growth and provided a system where the only nutrition for crop growth was from the applied media. Results from the field and plastic lined frames indicated that a N-rich compost and some kind of weed control are essential for production of high quality crops and for a greater diversity of wildflowers.

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CHAPTER II

GROWTH OF PEPPERMINT AND WILDFLOWERS IN SEVERAL TYPES OF COMPOST

Abstract

To evaluate compost as a medium for production of herbs, peppermint (Mentha piperita L.) in a greenhouse experiment was grown in flats of compost. The composts were made from mixed municipal solid wastes (MSW) (one high in NH_4^+; one low in NH_4^+), biosolids-woodchips (one mature, one immature), agricultural wastes, autumn leaves, and yard wastes. The agricultural, leaf, and yard-waste composts were mature. In a separate experiment, a mixture of wildflowers was sown into the same sources of composts that were used in the mint experiment. Shoot growth of mint was recorded in each compost after an 8-week growth period. Wildflower germination and growth were measured in each compost after 3 weeks and 19 weeks. Ammonium and nitrate concentrations, electrical conductivity, and pH of composts were determined at the initiation and weekly during the mint experiment. Mint shoot growth was vigorous in each MSW, mature biosolids, agricultural, and leaf composts. Except for the leaf compost, these media were fertile in nitrogen. Growth of mint in immature biosolids-woodchips compost and in yard-waste compost was inhibited relative to growth in the other composts. High initial ammonium concentrations and high salinity in immature biosolids-woodchips compost were responsible for the inhibited growth. Ammonium concentrations in immature biosolids-woodchips compost decreased with time due to nitrification and ammonia volatilization. The limited growth in the yard-waste compost was attributed partly to its low nitrogen content. Results indicate that a mature compost with good availability of nitrogen is required for mint production. The response of wildflowers after 3 weeks was similar to that of the mint transplants with good germination in MSW that was stored in bags, mature biosolids, agricultural, and leaf composts; however,

germination of wildflowers was hindered in MSW compost that was stored in a pile. After 19 weeks, wildflower growth was better in agricultural compost or immature biosolids-woodchips compost than in the other composts. The lowest dry weights of wildflowers were produced using mature biosolids compost.

Introduction

Composting of municipal and agricultural wastes is important in management of solid wastes. Composting reduces the volumes of wastes entering landfills and gives a product that is useful in production of agricultural crops (Hyatt, 1995). Grower acceptance of composts from nonagricultural sources has been slow. Inert materials, such as shredded plastic and glass, have spoiled the appearance of some municipal composts, limiting their acceptance in agricultural practices. Separation of inert materials from the compostable organic materials has improved grower acceptance of municipal composts. The concerns about lead, cadmium, zinc, and other metals in composts are alleviated also by separation of metal-containing materials from the compostable materials (Hoitink and Keener, 1993). Federal regulations govern the composition of composts that are to be used in agricultural activities helping to ensure that composts are low in unwanted elements (Federal Register, 1993).

Compost maturity is a another principal factor in determining whether or not a compost is acceptable for crop production. High ammonium concentrations such as those occurring in immature N-rich composts can inhibit plant growth (Barker and O'Brien, 1993; Inbar et al., 1990; He et al., 1992;. In mature or immature composts, high salt concentrations can inhibit plant growth (Cisar and Snyder, 1992). Failure of seeds to germinate or of transplants to grow in compost has been attributed to high soluble salt concentrations and less frequently to high ammonium concentrations (Mitchell, 1994). High ammonium in compost is likely more of a factor in the inhibition of plant growth than previously assessed (see Chapters III, IV, and V).

The objective of this study was to evaluate the suitability of solid waste composts of different compostable materials for herb and wildflower sod production. Composts of varying maturities and compositions were evaluated. Maturation of composts allows for dissipation of soluble salts and ammonium. Salts can be leached, and ammonium is volatilized or nitrified during aging. Mint plants were chosen for study because of their values as a culinary herb, ground cover, and bee attractant (Ayers et al., 1987) whereas wildflower sods were chosen because of their values in erosion stability, roadside beautification, and habitat and food for wildlife (Ahearn et al., 1991).

Materials and Methods

Composts (Table 2.1) were from mixed municipal solid wastes including biosolids (MSW1 and MSW2; Delaware Solid Waste Authority, Dover, Delaware), biosolids and woodchips (BIO30 and BIO90; Springfield, Mass., Wastewater Treatment Plant), cocomposted cranberry fruit pomace and chicken manure (AGR; MassNatural, Westminster, Mass.), autumn leaves (LEAF; Springfield, Mass., Wastewater Treatment Plant), and yard wastes (YARD; Earthgro, Lebanon, Conn.). Composts were received in July 1992 and were stored in piles or in bags. Storage of mixed MSW compost in plastic-mesh bags (MSW2) depleted ammonium relative to that in MSW compost stored in piles (MSW1). Ammonium concentrations varied in the biosolids-woodchips composts due to different durations of composting, 30 days (BIO30) or 90 days (BIO90). On September 29, 1992, three uniform-sized mint plants were transplanted into individual plastic flats (25 cm wide x 50 cm long x 5 cm deep) filled with 4.0 kg of the different composts and arranged in 4 randomized complete blocks in a greenhouse at Amherst, Massachusetts.

Ammonium (distillation, Bremner, 1965), nitrate (specific ion electrode, Barker, 1974), total N (Kjeldahl-N, Bradstreet, 1965), and electrical conductivity (Richards, 1954) of extracts (2:1 v:w, water:medium) of composts were measured as a function of time. Samples were taken at the initiation of the experiment and after 1, 2, 3, 4, and 8 weeks. At 8 weeks, mint shoots were harvested, and dry weights were recorded. Total N was determined on the dried mint tissues (Bradstreet, 1965).

In a second experiment that was setup on October 20, 1992, a mixture of wildflowers (Northeastern mixture, W. Atlee Burpee Company, Warminster, PA) was sown into 13 rows into each (25 cm wide x 50 cm long x 5 cm deep) flat filled with 4.0 kg of compost. The composts used and the experimental design were the same as those used in the mint experiment. Germination of wildflowers was indexed visually (0 to 13; 0 = no germination and 13 = all 13 rows fully established) after 3 weeks of growth. Wildflowers were harvested after 19 weeks and dry weights were recorded. Nitrogen, pH, and conductivity determinations were not repeated in this experiment, relying on the results above for those determinations.

Results

Mint

Three mint plants of equal size were transplanted into 7 different composts. Compost nitrogen, pH, and salinity were assessed to determine their impact on mint transplant growth.

Compost nitrogen. Immature biosolids-woodchips (BIO30) compost had high initial ammonium concentrations (1,560 mg N/kg dry wt) (Figure 2.1). The initial ammonium level in MSW1 from piles was 550 mg N/kg. All other composts had average initial ammonium concentrations of less than 85 mg N/kg. Ammonium in BIO30 compost decreased sharply in the first 3 weeks to about 500 mg N/kg and then fell slowly to about 100 mg N/kg at 8 weeks. In MSW1 compost, ammonium declined to less than 85 mg N/kg within 7 days. Nitrate in the composts varied with time in the BIO30, MSW1, MSW2, and AGR composts, with peak concentrations appearing in the third week (Figure

2.2). The appearance of these peaks correlate with the dissipation of ammonium.

Total N in the composts did not change with time, remaining at the levels shown in Table 2.2 for each compost. Total N was highest in immature BIO30 compost (3.64 %) and lowest in LEAF and YARD composts (0.68 %).

Compost pH. The pH of immature biosolids-woodchips (BIO30) was the lowest in the group of composts and decreased slightly from 4.96 to 4.64 during the 8 weeks of the experiment. The low pH and its decline are apparent indications of immaturity. The acidity of the mature composts did not change with time, remaining in the range of pH 5.5 to 6.7 (Table 2.2).

Compost salinity. Electrical conductivity varied with kind of compost and during the experiment (Figure 2.3). Conductivity increased to a peak of 8 mmho/cm at 4 weeks in the BIO30 compost. In MSW1 and AGR composts, conductivity reached peaks of approximately 3 mmho/cm after 2 to 4 weeks. In the remaining composts, conductivity also varied with time, but not to the extents detected in the BIO30, MSW1, and AGR composts. The changes in conductivity appear correlated with nitrate accumulation in the media.

Mint growth. Abundant shoot growth occurred with plants in composts of mixed municipal solid wastes (MSW1, MSW2), mature biosolids (BIO90), agricultural wastes (AGR), or leaves (LEAF) (Table 2.2). Shoot growth of plants in immature biosolids (BIO30) or yard-wastes (YARD) compost was limited relative to growth in the other composts.

Mint nitrogen. Mint grown in BIO30 compost had the highest total N in shoots (Table 2.2). Mint grown in MSW1 or AGR composts had significantly higher total N than plants grown in MSW2, BIO90, LEAF, or YARD composts.

Wildflowers

Germination of wildflowers after 3 weeks was excellent in AGR, BIO90, MSW2, or LEAF compost (Table 2.3). Wildflower germination was hindered by MSW1, BIO30, or YARD composts. Wildflowers grown in AGR or BIO30 compost had higher harvest weights than wildflowers in the other composts. Although wildflowers germinated well in BIO90, shoot harvest weights were minimal after 19 weeks of growth.

Discussion

The failure of transplants to grow or of seeds to germinate in composts has been attributed to salinity and to high ammonium concentrations in the composts (He et al., 1992; Inbar et al., 1990; Cisar and Synder, 1992). Frequently, growers have noted that a second transplanting or reseeding after the first failure leads to successful crop establishment. The success with the second planting or reseeding has been attributed to the dissipation of salts from the medium and occasionally to the loss of ammonium from the medium. The mint experiment indicates that both processes, loss of salts and loss of ammonium, are important in successful establishment of stands in composts, but that high concentrations of ammonium seem to be the limiting factor to successful crop production in immature N-rich composts (see Chapters III, IV, V).

Initial ammonium-N in immature, N-rich composts, such as the MSW compost aged in piles (MSW1) and the immature biosolids-woodchips compost (BIO30), was 500 to 1500 mg/kg dry wt. Ammonium declined with time to about 100 mg N/kg after treatments were initiated. A longer period of decline was needed for the BIO30 to fall to apparently nonphytotoxic levels than for the MSW1, because of the much higher level of ammonium in the BIO30. At least 3 weeks should lapse between application of immature biosolids composts, such as BIO30, before planting should occur, whereas with composts with less ammonium and higher alkalinity, such as mature MSW, a delay of 1 week between compost application and planting seems sufficient. Aging in piles does not permit rapid dissipation of ammonium, so N-rich composts stored in piles for less than one year may be high in ammonium.

Ammonia volatilization is likely a principal process for N loss from composts, such as MSW with a relatively high pH. Volatilization likely was low from BIO30, which was acidic (pH 4.8) (Mills et al., 1974). Nitrification may account for some of the dissipation of ammonium with time. The peaks at 3 weeks indicate an accumulation of nitrate from nitrification. The most marked changes in nitrate concentration occurred in the BIO30 compost, which also showed a fall in pH with time, further indicating that nitrification proceeded (Street and Sheat, 1958). The decline in nitrate concentration in compost after 3 weeks was due likely to leaching, absorption by plants, or to denitrification.

Conductivity in BIO30 peaked around 4 weeks in time before declining. By the time of the appearance of the peak nitrate concentrations, plants were well established. Richards (1954) reports that 12 mmho/cm in saturated extracts, or about 8 mmho/cm in 2:1 water:medium extracts, inhibits germination and growth of perennial ryegrass (*Lolium perenne* L.). The conductivities in this study indicate that soluble salts in most of the composts were not sufficiently high enough to inhibit growth. Only the maximum values with BIO30 were in the phytotoxic range.

Growth of mint plants in the BIO30 and YARD composts was 50 % to 60 % of that in the other composts. The initial high concentrations of ammonium and high conductivity are probable causes of the inhibited mint growth in BIO30 compost. The low dry weights recorded in the YARD compost likely were due in part to lack of available N, although LEAF compost with a similar percentage of total N produced good growth. The inhibitory effect of this YARD compost was reported also by Barker (1993).

Total N concentrations in mint shoots were not a good index for assessment of growth responses to the composts. Plants with restricted growth tended to have higher than expected N concentrations, perhaps indicating a concentrating of N in the stunted plants. The toxic effects of high ammonium in the immature biosolids composts were reflected by high N in shoots. On the other hand, N level in the shoots of plants grown in YARD compost, which was inhibitory to growth, was in the middle of the range of N concentrations in shoots.

The responses of wildflowers to the different composts after 3 weeks were similar to those of the mint transplants. Seeds germinated well in AGR, BIO90, MSW2, or LEAF compost. Germination and growth were hindered in MSW1 compost. Wildflower growth was limited in BIO90 compost even after excellent germination. Based on the results of the mint experiment, germination of wildflowers likely was hindered by high initial ammonium concentrations in BIO30; but during 19 weeks of growth, ammonium dissipated, and wildflowers produced excellent shoot biomass due to the available nitrogen. Poor growth in YARD and LEAF composts likely was due to insufficient available nitrogen.

A mature, N-rich compost is essential for production of mint and wildflowers. Biosolids or farm manure composts will be N-rich relative to leaf or yard-waste composts. Maturity is difficult to assess without chemical analyses or growth trials with the compost. Generally, a mature compost has cooled to ambient temperatures in piles, due to moderation of microbial activity after decay of compostable materials. Undecayed fragments, other than woody materials, should be absent in mature composts. The hazards of immature composts are ammonium toxicity in N-rich composts, N deficiency in leaf and yard-waste composts, or possibly salinity in all kinds of composts. Aging is the best curing process for immature composts. Aging in piles conserves N, but aging in mesh bags, plant containers, or on land for a few days gives rapid amelioration of problems with immature composts. Ammonia is the nitrogenous component lost rapidly from mesh-bagged or spread composts, leaving behind the organically combined N that mineralizes to support crop growth.

Concluding remarks

Composts varied in their capacities to support growth of plants under greenhouse conditions. Compost maturity and nitrogen contents appear to be the major factors affecting plant growth in composts. High salinity is often cited as a factor inhibiting plant growth in composts. High ammonium concentrations appear to contribute to salinity and to toxicity in immature nitrogen-rich composts and was assessed to be the responsible factor causing poor establishment of crops in reports on research with municipal solid waste (MSW) composts.

The next step in my research was to attempt to simulate the high ammonium and salinity of immature composts by adding ammonium or nitrate salts to MSW compost depleted of ammonium during storage and to a leaf compost naturally low in ammonium and soluble salts. A series of experiments were run in the greenhouse, growing wildflowers and ryegrass in these simulated immature composts. In these experiments, ammonium or nitrate salts were added at seeding, and ammonium and nitrate contents were monitored as a function of time. Seedling establishment and plant growth were measured in response to the salt applications and changes with time. Results of three experiments follow, with experimentation becoming more refined with each ensuing experiment.

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Table 2.1. Sources and handling of composts used for production of mint transplants.

Type	Symbol	Source	Handling in storage
Mixed MSW	MSW1	Delaware	Pile
Mixed MSW	MSW2	Delaware	Plastic-meshed bags
Immature biosolids-woodchips	BIO30	Massachusetts	Pile
Mature biosolids-woodchips	BIO90	Massachusetts	Pile
Agricultural	AGR	Massachusetts	Pile
Leaf	LEAF	Massachusetts	Pile
Yard wastes	YARD	Connecticut	Plastic-film bags

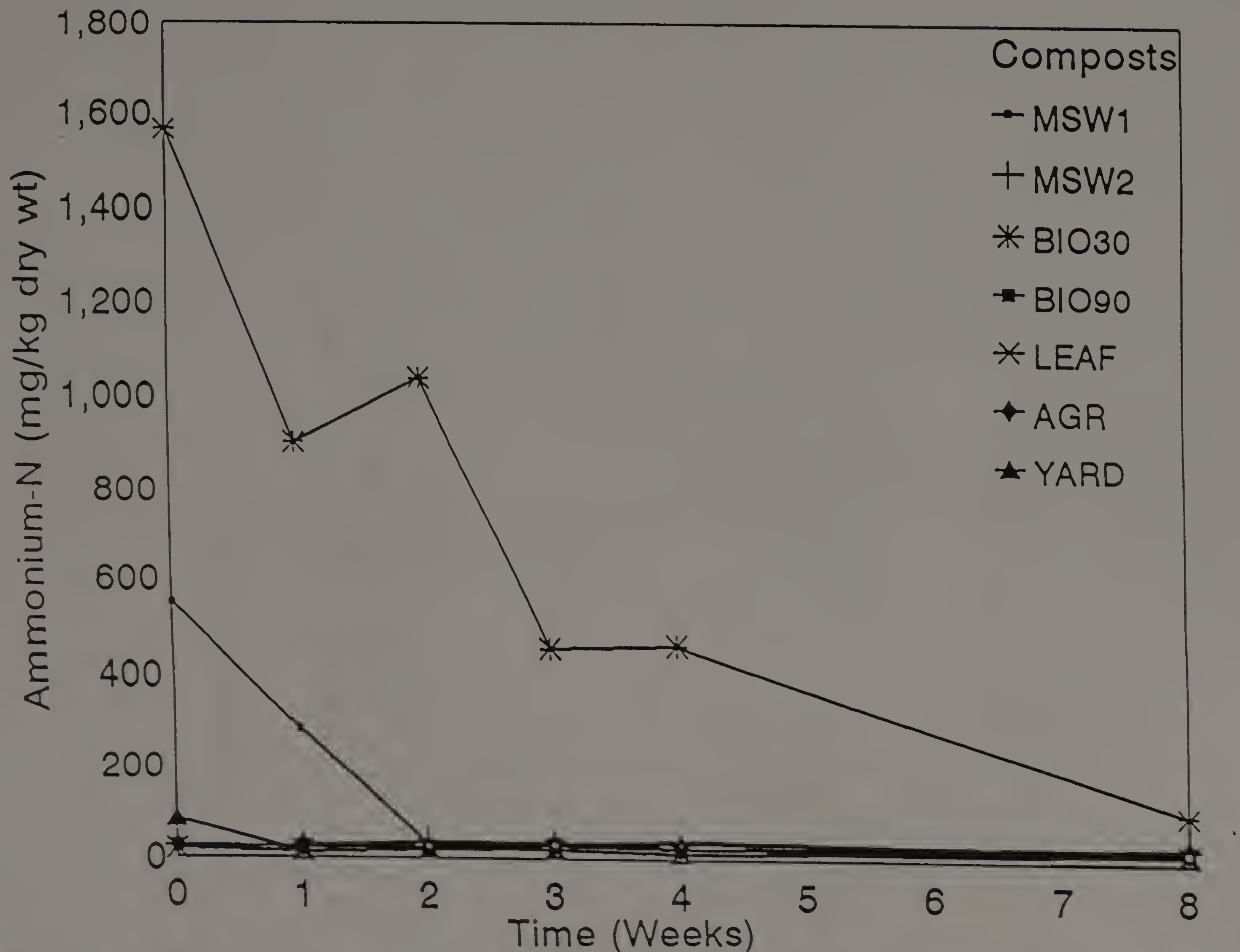

Figure 2.1. Variation in ammonium-N in compost with time after application of composts in flats. MSW1 = L*, Q*, BIO30 = L*, Q*, all others NS.
Trends: L = linear regression, Q = quadratic regression, * = significant ($P \leq 0.05$), NS = nonsignificant ($P > 0.05$).

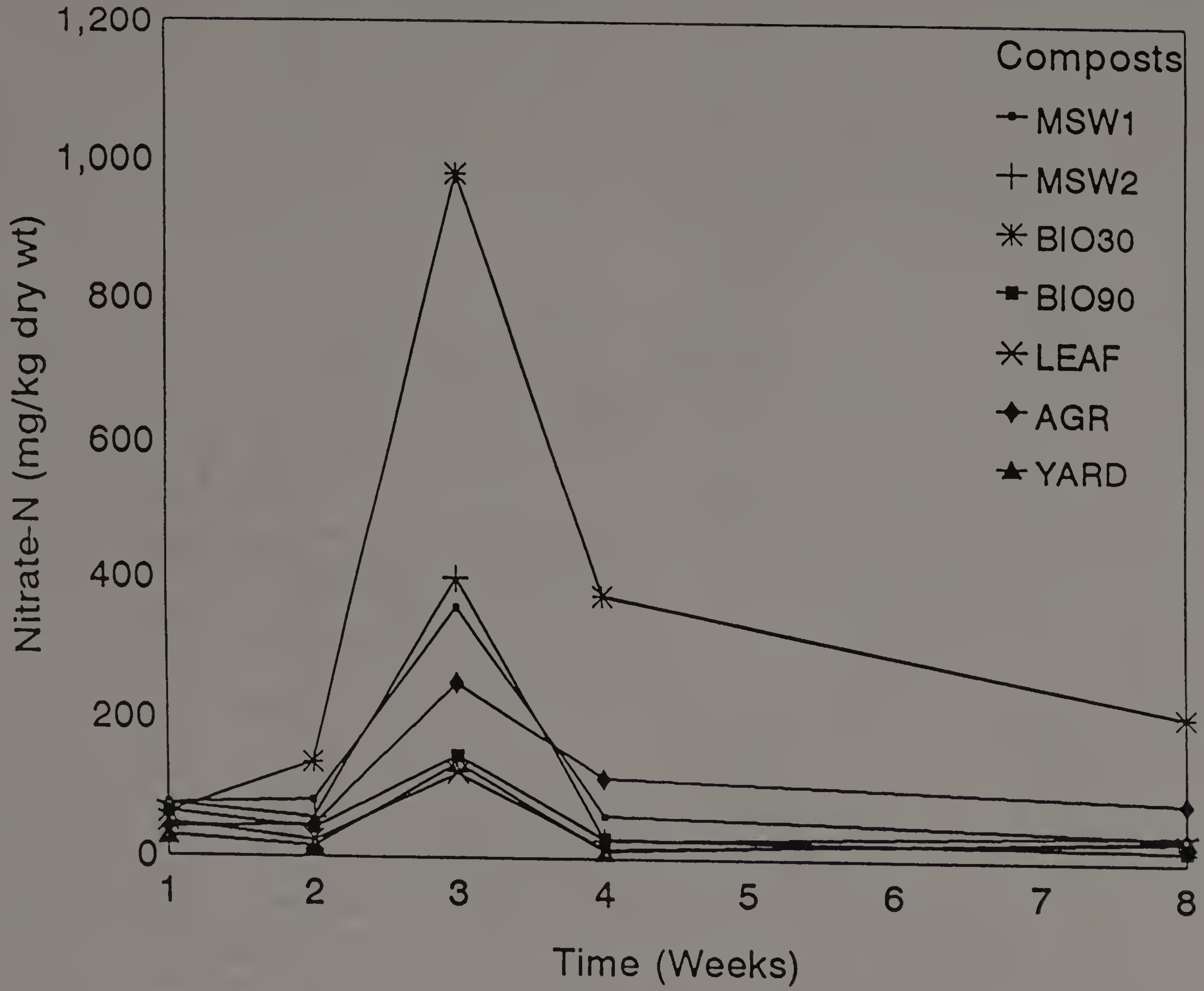

Figure 2.2. Variation in nitrate-N in compost with time after application of composts in flats. MSW1 = L*, Q*, MSW2 = L*, Q*, BIO30 = L*, Q*, AGR = L*, Q*, all others NS.
Trends: L = linear regression, Q = quadratic regression, * = significant ($P \leq 0.05$), NS = nonsignificant ($P > 0.05$).

Table 2.2. Mean compost pH and total N during an 8-week period and mint dry weights and total N at 8 weeks of growth.

Type of Compost	Measurements			
	Compost[z]		Mint	
	pH	%N	Dry wt.[y]	%N
MSW1	6.74a	1.03c	35a	2.52b
MSW2	6.69a	1.01c	32a	1.63c
BIO30	4.84d	3.64a	17c	3.27a
BIO90	5.54c	1.40b	34a	1.85c
AGR	6.40b	1.48b	30ab	2.73b
LEAF	6.37b	0.69d	34a	1.77c
YARD	6.71a	0.67d	22bc	2.08c

Within columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).

[z]Total N and pH of composts did not vary with time, with the exception of BIO30 which fell from pH 4.96 to 4.64 over the 8-week period of the experiment.

[y]Grams per flat (1250 cm^2).

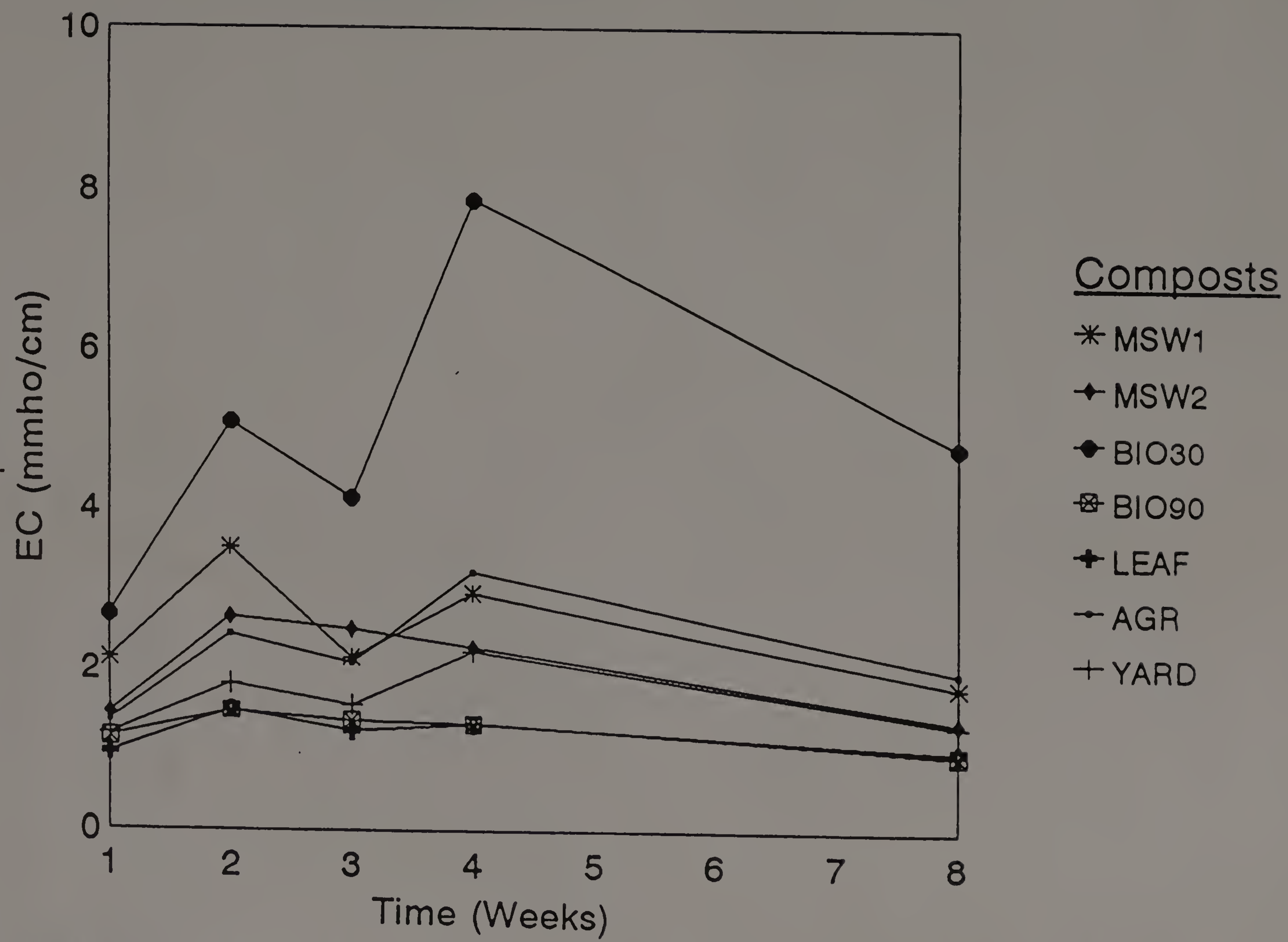

Figure 2.3. Variation in electrical conductivity in compost with time after application of composts in flats.
MSW1 = L*, Q*, MSW2 = L*, Q*, BIO30 = L*, Q*, AGR = L*, Q*, all others NS.
Trends: L = linear regression, Q = quadratic regression, * = significant ($P \leq 0.05$), NS = nonsignificant ($P > 0.05$).

Table 2.3. Mean wildflower germination at 3 weeks after sowing and mean harvest weights at 19 weeks of growth.

	Wildflowers	
Type of compost	Germination[z]	Dry wt.[y]
MSW1	2.50e	16de
MSW2	8.75c	24cd
BIO30	6.25d	30b
BIO90	10.75b	9e
AGR	12.00a	40a
LEAF	7.75c	15de
YARD	5.50d	18cd

Within columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).

[z]Germination measured by visually indexing seedling emergence 0 to 13; 0 = no emergence, 13 = all rows fully emerged.

[y]Grams per flat (1250 cm^2).

CHAPTER III

EFFECTS OF COMPOST AMMONIUM AND SOLUBLE SALTS ON WILDFLOWER PRODUCTION

Abstract

Failure of seeds to germinate or plants to grow has been associated with high concentrations of ammonium or soluble salts in the media. This experiment was conducted to determine changes in ammonium and soluble salts in compost with time and their impacts on plant growth. Northeast wildflower mixture was seeded into ammonium-depleted municipal solid waste (MSW) or leaf composts and into MSW or leaf compost with 1,150 or 2,300 mg N/kg (dry weight) from $(NH_4)_2SO_4$ or $Ca(NO_3)_2$. Seeding occurred on the day that composts were treated and applied to the flats. Ammonium-N and nitrate-N concentrations and electrical conductivity were measured on the day of seeding and at various times during a 77-day period. Germination or growth was assessed after 7, 14, 21, 28, 35, and 56 days from seeding, and plants were harvested and dry weights recorded after 77 days of growth. Ammonium-N in compost declined with time whereas nitrate-N and electrical conductivity increased then decreased with time. In composts amended with 1,150 or 2,300 mg N/kg from $(NH_4)_2SO_4$, ammonium concentrations inhibited seed germination and plant growth. Electrical conductivity indicated that soluble salts in composts with 1,150 or 2,300 mg N/kg from $Ca(NO_3)_2$ or with 2,300 mg N/kg from $(NH_4)_2SO_4$ were sufficient to inhibit seed germination and plant growth. Ammonium salt had a less enduring effect than calcium nitrate likely as the result of losses of ammonia from the medium.

Introduction

In agricultural or horticultural industries, maturity and composition of compost greatly influence compost utilization. High concentrations of ammonium and soluble salts can result from different compositions and maturities of compost (He et al, 1992; Inbar et al, 1990). Since high ammonium or soluble salts in compost can inhibit germination and growth (Barker, 1993a, 1993b; Barker and O'Brien, 1994; see Chapters II, VI), it is essential to determine ammonium and soluble salt concentrations in compost to ensure successful utilization. If composts have high ammonium or soluble salt concentrations, ammonium can be dissipated by volatilization, or by nitrification, and soluble salts can be diminished by leaching, by plant uptake, or by denitrification. Ammonium-N and soluble salts can decline within 7 to 10 days to levels that no longer inhibit growth (see Chapter VII, Mitchell et al., 1994). Therefore, it is critical to know the composition and maturity of compost particularly if composts are applied immediately before seeding.

The objective of this study was to evaluate the effects of ammonium or soluble salts in compost on wildflower seed germination and plant growth. Ammonium sulfate or $Ca(NO_3)_2$ was added to ammonium-depleted MSW compost or leaf compost to establish variable nitrogen concentrations that simulate fresh compost, compost aged in piles, and compost that was stored in bags. Germination or growth of wildflowers was evaluated as a function of ammonium or soluble salt concentrations in the medium.

Materials and Methods

Composts were from cocomposted municipal solid waste (MSW) including biosolids (Delaware Solid Waste Authority, Dover, Del.) or from autumn leaves (Springfield, Mass., Wastewater Treatment Plant). MSW compost was delivered 15 July 1992 and several plastic-mesh bags were filled with this compost and stored outdoors. Such storage allows for depletion of ammonia from the medium. The leaf compost was stored in a pile.

The average ammonium-N and electrical conductivity of the MSW compost after depletion of ammonium were 40 mg/kg dry weight and 3.38 mmho/cm, respectively (5:1, water:medium, v:w, extracts). The average ammonium-N and electrical conductivity of leaf compost were about 20 mg/kg dry weight and 0.50 mmho/cm, respectively. The initial pH was 7.1 for MSW compost and 7.2 for leaf compost. Ammonium sulfate was added to the composts to give ammonium concentrations of 1,150 or 2,300 mg NH_4-N/kg dry weight, restoring the ammonium to the level of aged, piled compost or fresh compost, respectively. These concentrations of N are based on analysis of compost stored in piles or in plastic mesh bags (Barker, A. V., University of Massachusetts, personal communication). Calcium nitrate was added to provide NO_3-N at the same N concentrations as the $(NH_4)_2SO_4$. A sufficient amount of ammonium-depleted MSW compost was not available. The MSW compost with 1,150 mg N/kg with $Ca(NO_3)_2$ had an average ammonium-N concentration of 358 mg/kg.

On 29 January 1993, wildflower northeast mixture (W. Atlee Burpee & Co., Warminster, PA) (Table 3.1) including 4 annuals, 4 perennials and 1 biennial was seeded into 4 blocks of completely randomized flats (25 cm wide x 50 cm long x 5 cm deep) filled with 4.5 kg of compost. Thirteen rows were seeded into each flat. Germination and growth were measured by assessing the number of rows (visual index 0 to 13; 0 = no establishment, 13 = all 13 rows fully established that emerged and grew 7, 14, 21, 28, 35, and 56 days after seeding). After 77 days of growth, wildflowers were harvested and final dry weights were recorded.

Ammonium-N was determined volumetrically on 1M KCl extracts of compost (Bremner, 1965). Nitrate was determined electrometrically in 5:1 (water:medium) extracts (Barker, 1974). Electrical conductivity was measured in the same extracts used for nitrate-N determinations (Richards, 1954). Compost was analyzed for ammonium-N on the day of seeding, and after 7, 14, 21, 28, 35, 49, and 77 days, whereas nitrate-N and electrical conductivity were analyzed on the day of seeding and after 7, 14, 21, 28, and 77 days.

Results

Ammonium in compost

The interaction of compost, nitrogen source, amount of N, and time was significant (Tables 3.2 & 3.3). The high magnitude and persistence of NH_4-N with $(NH_4)_2SO_4$ added to leaf or MSW compost was the principal observation in this interaction. Ammonium-N in composts fell with time after $(NH_4)_2SO_4$ was added (Table 3.4, Figure 3.1). With leaf compost with 2,300 mg N/kg from $(NH_4)_2SO_4$, 1,489 mg NH_4-N/kg were detected initially, and detectable NH_4 declined to 932 mg N/kg, 28 days after treatment of compost. With MSW compost with 2,300 mg N/kg from $(NH_4)_2SO_4$, 1,058 mg NH_4-N/kg were detected initially, and detectable NH_4 declined to 27 mg N/kg, 28 days after compost treatment (Table 3.2).

Leaf compost had higher average ammonium-N (224 mg/kg dry wt) than MSW compost (143 mg/kg) (Table 3.4). Composts (MSW and leaf) amended with $(NH_4)_2SO_4$ had higher average ammonium-N (358 mg/kg) than composts amended with $Ca(NO_3)_2$ (68 mg/kg). Composts amended with 2,300 mg N/kg (450 mg/kg) had higher average ammonium-N than composts amended with 1,150 mg N/kg (162 mg/kg). Composts with no nitrogen added had the lowest average ammonium-N (27 mg/kg).

Nitrate

Compost, nitrogen source, amount of N, and time did not interact to affect nitrate levels (Tables 3.5 & 3.6); however, many of the lower levels interactions and main factors had significant effects on nitrate-N in the media (Tables 3.6 & 3.7, Figure 3.2). After additions of N-containing salts, mean nitrate-N concentration in MSW compost (937 mg/kg) was higher than in leaf compost (641 mg/kg) (Table 3.7). Mean nitrate-N in composts (MSW and leaf) with $Ca(NO_3)_2$ had a higher nitrate-N concentration (1,163 mg/kg) than composts with $(NH_4)_2SO_4$ (693 mg/kg). Composts with 2,300 mg N/kg had higher nitrate-N concentrations (1,398 mg/kg) than composts with 1,150 mg/kg (936 mg/kg).

Nitrate-N concentrations in composts with 1,150 or 2,300 mg/kg from $Ca(NO_3)_2$ increased then decreased 7 to 14 days after application of compost (Tables 3.5 & 3.6, Figure 3.2). Nitrate-N concentrations in composts with $(NH_4)_2SO_4$ were lower than in composts with $Ca(NO_3)_2$ but nitrate-N still increased then decreased with time (Figure 3.2). If $(NH_4)_2SO_4$ was added, nitrate-N in MSW compost increased more rapidly and to a greater extent than in leaf compost (Tables 3.5 & 3.6).

Salinity

Compost, nitrogen source, amount of N, and time did not interact to affect salinity (Tables 3.8 & 3.9); however, many of the lower lever interactions and main factors had significant effects on electrical conductivity of the media (Tables 3.9 & 3.10, Figure 3.3). Conductivity was greater in MSW compost (2.5 mmho/cm in 4:1 water:medium, v:w, extracts) than leaf compost (1.8 mmho/cm) (Table 3.10). Conductivity did not increase more by adding $Ca(NO_3)_2$ (2.3 mmho/cm) than by adding $(NH_4)_2SO_4$ (2.1 mmho/cm). Conductivity in composts with 2,300 mg N/kg (2.9 mmho/cm) was higher than in composts with 1,150 mg N/kg (2.3 mmho/cm). Composts with no nitrogen added had the lowest conductivity (1.4 mmho/cm). Overall, a significant decline in compost conductivity occurred with time (Figure 3.3).

In MSW compost, conductivity increased then decreased 7 days after application of compost (Figure 3.3). In leaf compost, conductivity remained constant before declining 28 days after compost application. Compost conductivity in all levels of N added began to decline 7 to 14 days after application (Tables 3.8 & 3.9).

Stands of Wildflowers

Compost, nitrogen source, amount of N, and time did not interact to affect stands of wildflowers (Tables 3.11 & 3.12); however, some of the lower interactions and main factors had significant effects on stands of wildflowers (Tables 3.12 & 3.13, Figure 3.4). Wildflower stand was better in unamended composts (index 8.9) than in composts with 1,150 mg N/kg (index 7.5) or with 2,300 mg N/kg (index 6.2) (Table 3.13). Stand of wildflowers in MSW compost (index 7.1) was not significantly different from stand in leaf compost (index 7.9), and similar stands occurred in compost amended with $(NH_4)_2SO_4$ (index 8.0) or $Ca(NO_3)_2$ (index 7.1).

Twenty-one days after application of compost to flats, establishment of stands of wildflowers in composts treated with 2,300 mg N/kg was inhibited at 35 days. Sixty-five days after application, stands of wildflowers in compost with 2,300 mg N/kg were no longer different from stands in the unamended composts (Tables 3.12 & 3.13).

Dry weights of wildflowers

Wildflowers were harvested 77 days after seeding, and dry weights were recorded (Tables 3.14 & 3.15). In leaf compost, shoot weights increased with greater amounts of nitrogen added. In MSW compost, shoot weights in N-amended composts were not different from those in unamended composts.

Discussion

Germination of seeds of wildflowers were inhibited by the 2,300 mg N/kg from $(NH_4)_2SO_4$ and by all $Ca(NO_3)_2$ additions. High ammonium concentrations in composts with 2,300 mg N from $(NH_4)_2SO_4$ likely were deemed responsible for hindering germination of wildflower seeds (see Chapters II, IV). Ammonium-N declined to 50 % or less of the originally detected values after 28 to 49 days. In the leaf compost, high ammonium concentrations persisted and inhibited germination and growth longer than in MSW compost. Ammonium likely was dissipated by volatilization and nitrification. Perhaps, microbial activity was higher in the MSW compost than in the leaf compost leading fo more rapid nitrogen transformation.

Additions of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$ increased electrical conductivity. The conductivity indicated that initial soluble salt concentrations in these composts were sufficient to inhibit plant growth (Richards, 1954). Conductivities were equivalent to 10 to 15 mmho/cm in saturated extracts. These levels of salinity would be harmful to crops other than salt tolerant ones. Soluble salts decreased to noninjurious levels after 28 days. Conductivities likely decreased as a result of leaching, plant absorption, and denitrification. In composts amended with $(NH_4)_2SO_4$, volatilization of NH_3 also may have diminished conductivity (see Chapter V).

After 56 days, stands of wildflowers in composts with 2,300 mg N/kg were as good as stands in composts with no nitrogen added. Declines in ammonium-N or soluble salts likely were responsible for the improvement in growth of wildflowers in composts with 2,300 mg N/kg added.

Addition of nitrogen from either salt to leaf compost increased wildflower final harvest weights. This benefit was not apparent with MSW compost. Perhaps the injury was greater in MSW compost or N was lost and not beneficial.

A mature, N-rich compost is essential for wildflower production. Determination of maturity requires chemical analysis and growth trials with the compost. A mature compost generally has low ammonium and has cooled to ambient temperatures in piles. Salinity of compost also is an important factor to assess before determining proper utilization of the compost. High concentrations of salts can cause water relation problems between the medium and the plants.

Concluding remarks

The effects of nitrate salts were more damaging than the effects of additions of ammonium salts. Additions of $(NH_4)SO_4$ or $Ca(NO_3)_2$ increased electrical conductivity to levels that were injurious to plant growth. High salinity is often cited as a factor inhibiting plant growth in composts. However, high ammonium concentrations appear to contribute to salinity and to toxicity in immature composts. Ammonia losses by volatilization rapidly reduced ammonium levels to nontoxic levels and reduced soluble salt concentrations. While the inhibitory effects of nonvolatile salts ($Ca(NO_3)_2$) persist, ammonia volatilization appears to alleviate inhibitory effects of immature composts.

This research attempted to simulate the high ammonium and salinity of immature composts by adding ammonium and nitrate salts to MSW depleted of ammonium during storage and leaf composts. Although, ammonium concentrations in compost declined with time, only about half of the ammonium initially added was detected. Since only about half of the ammonium was detected and not enough ammonium-depleted MSW compost was available, this experiment was repeated using the same experimental design. In the following experiment, ryegrass seed was used instead of wildflower seed, because ryegrass grows more rapidly and uniformly than wildflowers.

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Table 3.1. List of wildflower species in Northeastern mixture.

Common Name	Scientific Name
Annuals	
Bachelor's Button	*Centaurea cyanus* L.
Baby's Breath	*Gysophila elegans* Bieb.
Flax	*Linum perenne* lewisii L.
Biennial	
Dame's Rocket	*Hesperis matronalis* L.
Wallflower	*Cheiranthus allionii* Hort.
Perennials	
Black-eyed Susan	*Rudbeckia hirta* L.
Larkspur	*Delphinium ajacis* L.
Ox-eye Daisy	*Chrysanthemum leucanthemum* L.
Lupin	*Lupinus perennis* L.

Table 3.2. Variation in ammonium-N in MSW or leaf compost with time with different amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Time (days)	Ammonium-N (mg/kg dry wt)					
	$(NH_4)_2SO_4$			$Ca(NO_3)_2$		
	Amount of N added (mg N/kg dry wt)			Amount of N added (mg N/kg dry wt)		
	0	1,150	2,300	0	1,150	2,300
			MSW compost			
0	67	481	1,058	54	358	46
7	27	248	1,020	37	494	26
14	47	137	417	45	467	36
21	23	22	275	33	526	38
28	29	24	27	27	258	23
35	21	21	19	27	164	21
49	18	14	19	14	21	17
77	27	23	19	21	15	23
			Leaf compost			
0	27	596	1,489	46	30	36
7	37	461	1,690	23	20	21
14	15	424	1,505	18	60	24
21	18	154	1,565	28	14	11
28	23	67	932	13	14	11
35	9	42	932	10	9	11
49	9	11	194	26	8	10
77	17	9	10	14	9	9

See ANOVA Table 3.3.

Table 3.3. Analysis of variance table for variation in ammonium-N in MSW or leaf compost with time with 3 amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Source	Symbol	Significance
Weeks	W	0.0001
Compost	C	0.0093
N source	N	0.0003
Amount of N	L	0.0001
CxN		0.0005
CxL		0.0001
NxL		0.0001
CxNxL		0.0004
WxC		0.0795
WxN		0.0001
WxL		0.0001
WxCxN		0.0001
WxCxL		0.0002
WxNxL		0.0001
WxCxNxL		0.0007

Table 3.4. Mean ammonium-N concentrations in MSW or leaf compost treated with different amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Amount of N added mg/kg	Ammonium-N detected (mg/kg dry wt)[z]					
	MSW compost			Leaf compost		
	$(NH_4)_2SO_4$		$Ca(NO_3)_2$	$(NH_4)_2SO_4$		$Ca(NO_3)_2$
0	32		32	19		22
1,150	121		288	220		20
2,300	357		29	1,397		17
Trend	L*		Q*	L*		NS
Source mean	170	*	116	427	*	20
Compost mean		143	*		224	

[z]Means over 77-day sampling period. See ANOVA Table 3.3.

*Within composts, sources of N are different by F-test ($P \leq 0.05$), and compost means are different by F-test ($P \leq 0.05$).

L = significant linear regression; Q = significant quadratic regression; * = $P \leq 0.05$. NS = nonsignificant trend ($P > 0.05$).

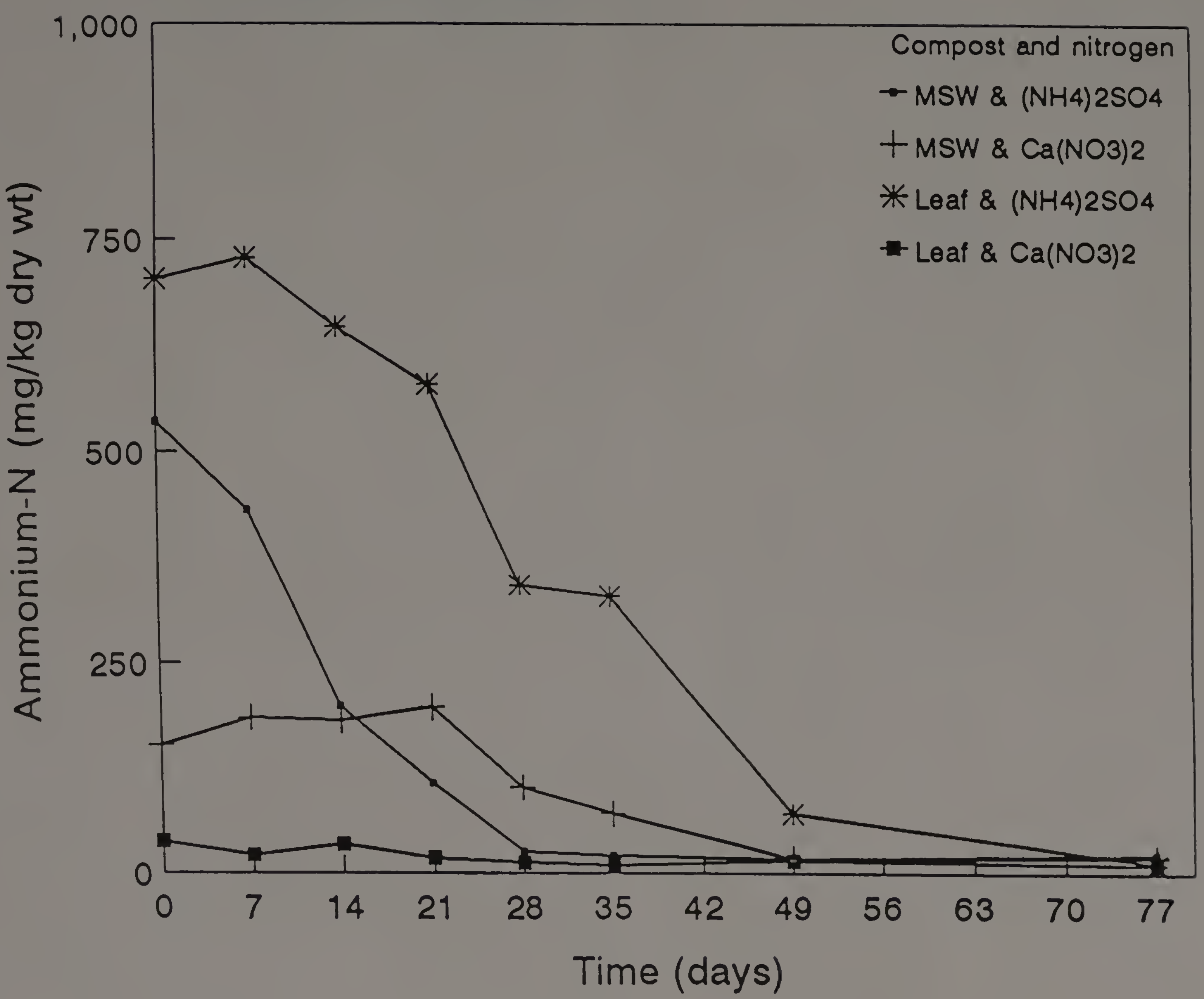

Figure 3.1. Variation with time in ammonium-N in composts treated with $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Table 3.5. Variation in nitrate-N in MSW or leaf compost with time with different amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Time (days)	Nitrate-N (mg/kg dry wt)					
	$(NH_4)_2SO_4$			$Ca(NO_3)_2$		
	Amount of N added (mg N/kg dry wt)			Amount of N added (mg N/kg dry wt)		
	0	1150	2300	0	1150	2300
			MSW compost			
0	580	650	600	804	802	1666
7	650	1334	1540	800	1420	2650
14	890	1240	1645	640	1395	1810
28	176	1120	1695	540	1140	1720
77	66	75	152	70	93	133
			Leaf compost			
0	397	344	495	440	1344	1748
7	512	535	560	453	1760	2690
14	385	775	1650	380	1670	3040
28	415	795	1420	752	2140	2454
77	32	33	27	32	48	268

See ANOVA Table 3.6.

Table 3.6. Analysis of variance table for variation in nitrate-N in MSW or leaf compost with time with 3 amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Source	Symbol	Significance
Weeks	W	0.0001
Compost	C	0.0347
N source	N	0.0086
Amount of N	L	0.0001
CxN		0.0014
CxL		0.2429
NxL		0.0012
CxNxL		0.0330
WxC		0.0038
WxN		0.0067
WxL		0.0001
WxCxN		0.0365
WxCxL		0.8865
WxNxL		0.0025
WxCxNxL		0.0566

Table 3.7. Mean nitrate-N in MSW or leaf compost treated with different amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Amount of N added mg/kg	Nitrate-N detected (mg/kg dry wt)[z]					
	MSW compost			Leaf compost		
	$(NH_4)_2SO_4$		$Ca(NO_3)_2$	$(NH_4)_2SO_4$		$Ca(NO_3)_2$
0	473		570	348		411
1,150	884		970	496		1,392
2,300	1,126		1,595	830		2,040
Trend	L*		L*	L*		L*
Source mean	828	*	1,045	558	*	1281
Compost mean	937		*	641		

[z]Means over 77-day sampling period. See ANOVA Table 3.6.

*Within composts, sources are different by F-test ($P \leq 0.05$), and compost means are different by F-test ($P \leq 0.05$).

L = significant linear regression; * = $P \leq 0.05$.

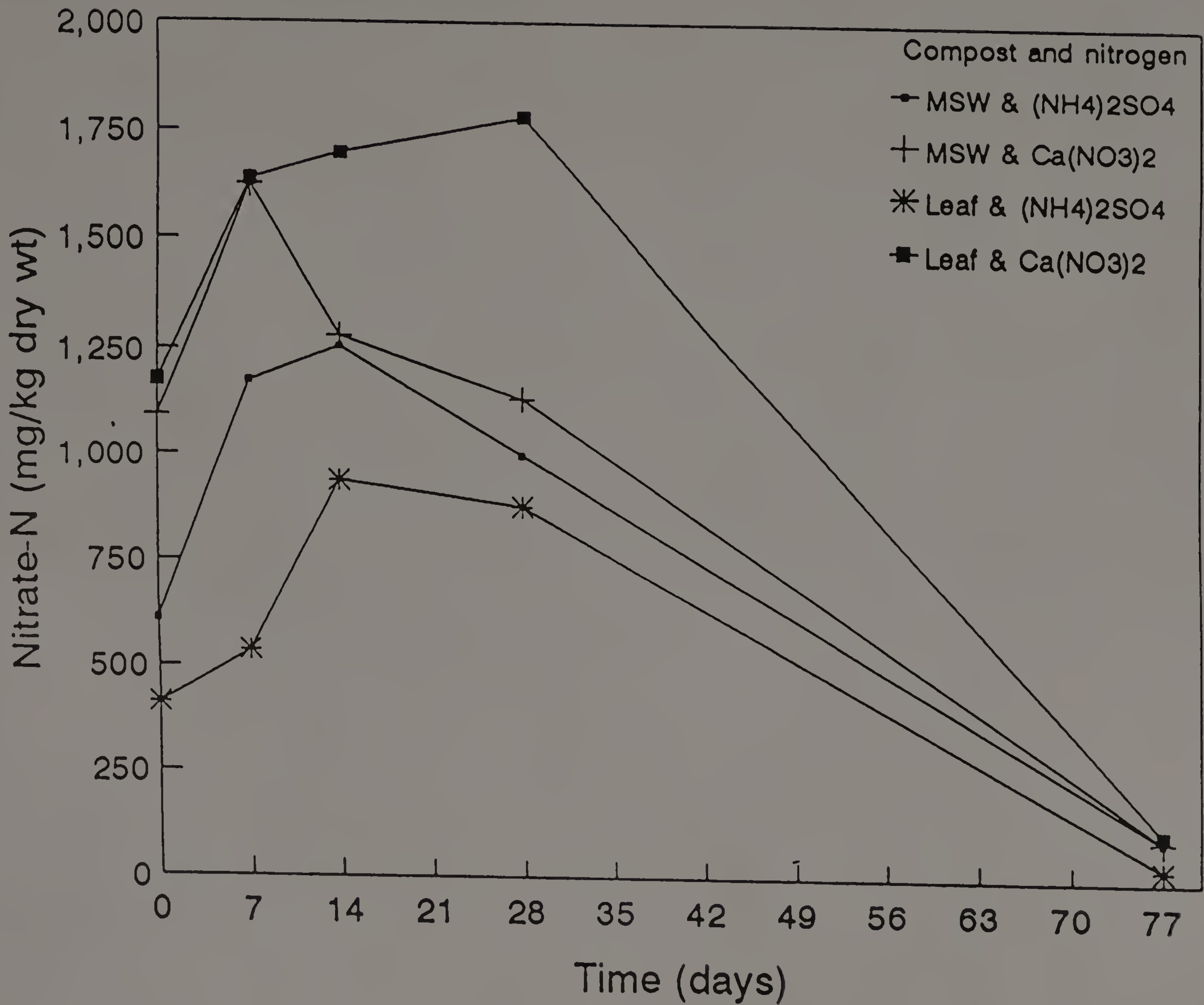

Figure 3.2. Variation with time in nitrate-N in composts treated with $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Table 3.8. Variation in electrical conductivity in MSW or leaf compost with time with different amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Time (days)	Electrical Conductivity (mmho/cm)[z]					
	$(NH_4)_2SO_4$			$Ca(NO_3)_2$		
	Amount of N added (mg N/kg dry wt)			Amount of N added (mg N/kg dry wt)		
	0	1,150	2,300	0	1,150	2,300
	MSW compost					
0	1.7	2.4	2.7	2.6	2.9	3.2
7	1.8	3.6	4.7	3.1	4.1	4.6
14	1.4	2.9	4.4	1.8	3.1	3.5
28	2.1	2.6	2.7	2.2	3.7	3.8
77	0.6	0.8	1.4	0.7	0.5	0.5
	Leaf compost					
0	1.3	1.8	3.3	1.2	2.4	3.0
7	1.1	1.8	3.3	0.9	2.7	3.9
14	1.0	1.7	2.4	1.2	2.1	3.6
28	1.3	2.3	3.2	0.9	2.8	3.5
77	0.4	0.5	0.5	0.4	0.4	0.6

[z]Electrical conductivity measured in 5:1 extract (water:medium).

See ANOVA Table 3.9.

Table 3.9. Analysis of variance table for variation in electrical conductivity in MSW or leaf compost with time with 3 amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Source	Symbol	Significance
Weeks	W	0.0001
Compost	C	0.0057
N source	N	0.2383
Amount of N	L	0.0002
CxN		0.2960
CxL		0.4051
NxL		0.2720
CxNxL		0.2546
WxC		0.0425
WxN		0.6052
WxL		0.0002
WxCxN		0.4671
WxCxL		0.3922
WxNxL		0.7090
WxCxNxL		0.5965

Table 3.10. Mean conductivity in MSW or leaf compost treated with different amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Amount of N added mg/kg	Electrical Conductivity (mmho/cm)[z]			
	MSW compost		Leaf compost	
	$(NH_4)_2SO_4$	$Ca(NO_3)_2$	$(NH_4)_2SO_4$	$Ca(NO_3)_2$
0	1.5	2.1	1.0	0.9
1,150	2.5	2.9	1.6	2.1
2,300	3.2	3.1	2.5	2.9
Trend	L*	L*	L*	L*
Source mean	2.4	2.7	1.7	2.0
Compost mean	2.5	*	1.8	

[z]Means over 77-day sampling period. See ANOVA Table 3.9.

*Compost means are different by F-test ($P \leq 0.05$).

L = significant linear regression; * = $P \leq 0.05$.

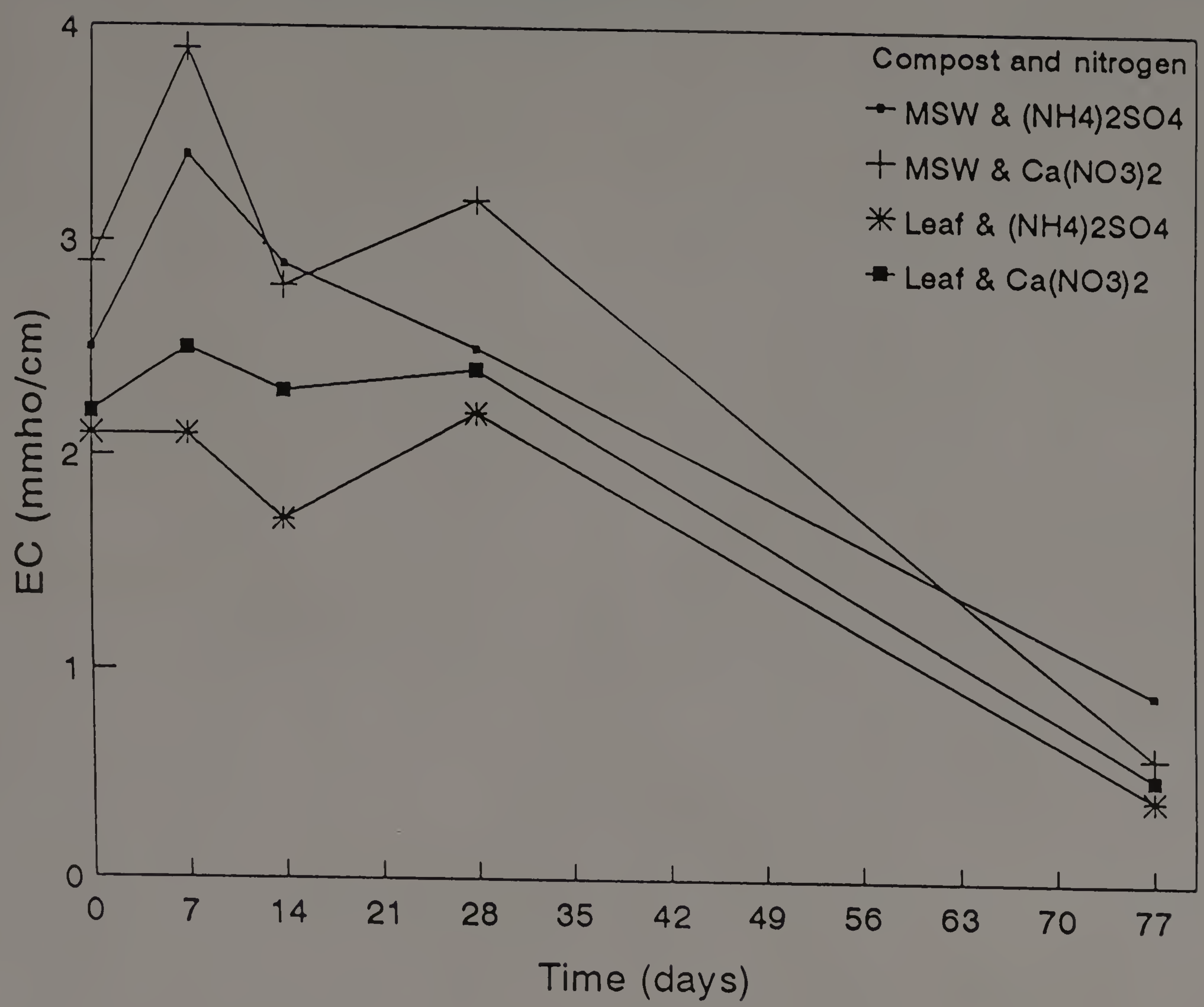

Figure 3.3. Variation with time in electrical conductivity in composts treated with $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Table 3.11. Variation in stand of wildflowers with time in MSW or leaf compost with different amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Time (days)	Stand Establishment (visual index)[z]					
	$(NH_4)_2SO_4$			$Ca(NO_3)_2$		
	Amount of N added (mg N/kg dry wt)			Amount of N added (mg N/kg dry wt)		
	0	1,150	2,300	0	1,150	2,300
			MSW compost			
7	4.6	2.3	3.1	4.0	1.9	1.5
14	6.0	5.6	4.4	4.9	3.1	2.5
21	8.5	5.3	5.4	7.8	3.8	2.6
28	12.0	9.0	7.0	10.0	6.0	4.5
35	12.8	10.5	8.5	12.0	7.8	6.3
56	12.8	13.0	12.8	12.8	11.3	10.3
			Leaf compost			
7	3.3	6.0	2.4	4.0	2.5	3.3
14	5.5	6.4	2.9	5.8	3.5	4.1
21	7.8	9.4	3.9	8.3	5.0	5.9
28	11.0	11.5	6.0	11.3	8.0	8.3
35	11.8	12.0	7.5	11.3	10.5	10.0
56	12.3	13.0	11.8	12.5	12.8	12.8

[z]Visual index 0 to 13; 0 = no stand established, 13 = all rows in flat established.

See ANOVA Table 3.12.

Table 3.12. Analysis of variance table for variation in wildflower stand in MSW or leaf compost with time with 3 amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Source	Symbol	Significance
Weeks	W	0.0001
Compost	C	0.1620
N source	N	0.1955
Amount of N	L	0.0095
CxN		0.0840
CxL		0.1244
NxL		0.0529
CxNxL		0.0899
WxC		0.2817
WxN		0.1917
WxL		0.0001
WxCxN		0.5591
WxCxL		0.4834
WxNxL		0.2663
WxCxNxL		0.4313

Table 3.13. Mean stand MSW or leaf compost treated with different amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Amount of N added mg/kg	Stand (visual index)[z]			
	MSW compost		Leaf compost	
	$(NH_4)_2SO_4$	$Ca(NO_3)_2$	$(NH_4)_2SO_4$	$Ca(NO_3)_2$
0	9.4	8.6	8.6	8.8
1,150	7.6	5.6	9.7	7.0
2,300	6.9	4.6	5.7	7.4
Trend	L*	L*	L*, Q*	NS
Source mean	8.0	6.3	8.0	7.8
Compost mean	7.1		7.9	

[z]visual index 0 to 13; 0 = no stand establishment, 13 = all rows in flat established. Means over 77-day sampling period.

See ANOVA Table 3.12.

L = significant linear regression; Q = significant quadratic regression; * = $P\leq0.05$. NS = nonsignificant trend ($P>0.05$).

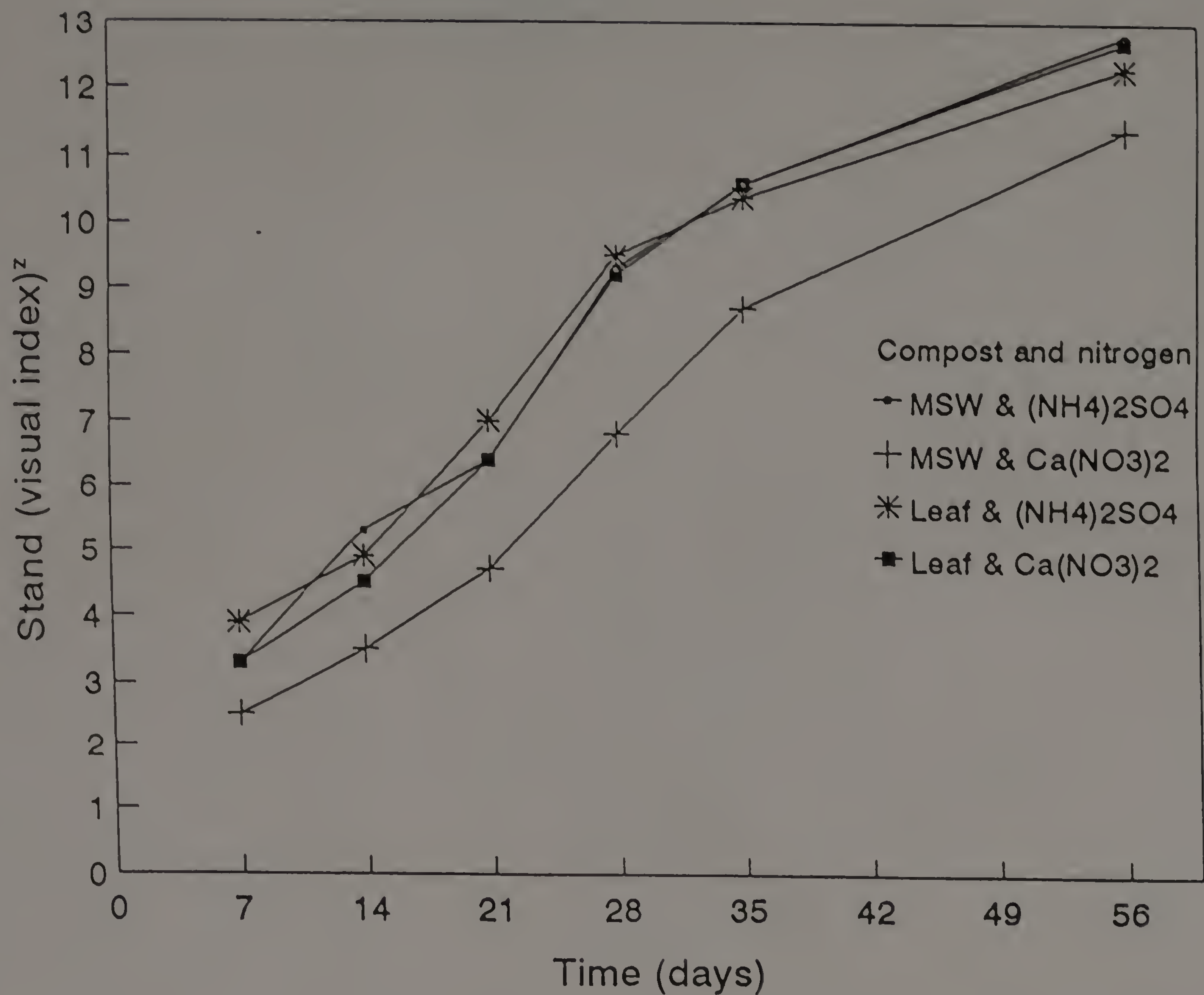

Figure 3.4. Variation with time in wildflower stand in composts treated with $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.
^{z}visual index 0 to 13; 0 = no establishment, 13 = all rows fully established.

Table 3.14. Final dry weights of wildflowers in MSW or leaf compost with 3 amounts of N added.

Amount of N added mg/kg	Dry wt (g/flat)			
	MSW compost		Leaf compost	
	$(NH_4)_2SO_4$	$Ca(NO_3)_2$	$(NH_4)_2SO_4$	$Ca(NO_3)_2$
0	44	45	33	31
1,150	57	49	65	60
2,300	52	49	60	70
Trend	NS	NS	L*, Q*	L*, Q*
Source mean	51	48	53	54
Compost mean	49		53	

See ANOVA Table 3.15.

L = significant linear regression, Q = significant quadratic regression, * = $P \leq 0.05$. NS = nonsignificant trend ($P > 0.05$).

Table 3.15. Analysis of variance table for variation in dry weight in MSW or leaf compost with 3 amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Source	Symbol	Significance
Compost	C	0.3720
N source	N	0.4024
Amount of N	L	0.0014
CxN		0.2310
CxL		0.0111
NxL		0.1469
CxNxL		0.2142

CHAPTER IV

EVALUATION OF AMMONIUM AND SOLUBLE SALTS ON GRASS SOD PRODUCTION IN COMPOST

Abstract

Inhibition in seed germination and plant growth in some composts have been associated with high concentrations of ammonium or soluble salts in the media. This experiment was conducted to determine changes in ammonium and soluble salts in fertilized-amended compost with time and their impacts on plant growth. Turfgrass (Lolium perenne L.) was seeded into ammonium-depleted municipal solid waste (MSW) or leaf composts and into MSW or leaf composts with 1,500 or 2,300 mg N/kg (dry weight) from $(NH_4)_2SO_4$ or $Ca(NO_3)_2$ simulating immature composts. Seeding occurred on the day that composts were treated and applied to flats. Ammonium-N and nitrate-N concentrations and electrical conductivity were measured on the day of seeding and after 3, 7, 14, 21, and 28 days. Germination or growth was assessed after 7, 14, 21, and 28 days. Ammonium-N in compost declined with time whereas nitrate-N and electrical conductivity initially increased then decreased with time. Ammonium-N from $(NH_4)_2SO_4$ in compost declined by half within 7 days, and as the compost ammonium-N declined, germination and growth of grass increased. Electrical conductivity indicated that initial soluble salts in composts with 1,500 or 2,300 mg N/kg from $Ca(NO_3)_2$ were sufficient to inhibit seed germination and plant growth. In composts with 1,150 mg N/kg from $Ca(NO_3)_2$, germination and growth of grass improved after 14 days, whereas growth in composts with 2,300 mg N/kg from $Ca(NO_3)_2$ was inhibited for at least 28 days. Ammonium salts appear to be lost from compost more rapidly than nitrate salts which have a prolonged inhibitory effect on germination and growth.

Introduction

Depending on the composition and maturity of composts, ammonium or salt concentrations in composts can reach levels that inhibit seed germination and plant growth (He at al., 1992; Inbar et al., 1990). Phytotoxic concentrations of ammonium have been reported in research with immature composts of biosolids and municipal solid wastes (Barker, 1993a & 1993b; see Chapter II). High concentrations of ammonium in compost decline to levels that do not impede growth within 7 to 10 days after compost application (see Chapter VI). The initial phytotoxicity of high ammonium concentrations can be so severe that seeds or seedlings may be damaged and plants may never be able to recover without reseeding or replanting.

Soluble salt concentrations may decline within 7 to 10 days to levels that do not inhibit plant growth (Mitchell, 1994). Much research has focused on soluble salts without taking into account the ammonium concentration in compost. Distinguishing between the two factors is difficult, since soluble salts and ammonium concentrations vary with time (see Chapter II) and simultaneously are affecting growth. One potential means of ensuring lower ammonium and soluble salt concentrations in compost is to apply composts several days before planting and to allow for diminishing of ammonium in the medium by ammonia volatilization, by nitrification, or by both processes (see Chapter V). Soluble salts may be diminished by leaching, by plant absorption, or by both processes. Delaying of planting will allow ammonium and soluble salts to dissipate to levels less likely to inhibit germination and growth.

This experiment evaluated the effects of additions of ammonium and soluble salts to compost on seed germination and plant growth. Earlier studies with a compost of fresh municipal solid waste (MSW) including biosolids noted that this medium was inhibitory to seed germination (Barker, 1993a, 1993b; Barker and O'Brien, 1993, 1994). The ammonium-N concentration in fresh MSW was about 2,300 mg/kg dry weight. In compost remaining in a pile without turning for 2 months, the ammonium-N concentration was about 1,150 mg/kg. Compost that was bagged for a month had 40 to 100 mg NH_4-N/kg. Fresh autumn leaf compost averaged less than 10 mg NH_4-N/kg dry weight. In this experiment, ammonium sulfate or calcium nitrate was added to MSW and leaf composts that were bagged to deplete ammonium from the medium. Germination and growth of perennial ryegrass were evaluated as functions of ammonium or soluble salt concentrations in the medium.

Materials and Methods

Materials, methods, and experimental design for growing ryegrass to determine whether ammonium or soluble salts are inhibiting germination and growth are identical to those used for growing wildflowers (see Materials and Methods in Chapter III).

On 2 June 1994, 'Pennfine' perennial ryegrass was seeded into 13 rows in 4 blocks of randomized flats (25 cm wide x 50 cm long x 5 cm deep) filled with 4.5 kg of compost. Germination and growth were measured by assessing the numbers of rows (visual index 0 to 13; 0 = no establishment, 13 = all 13 rows fully established) that germinated and grew. After 4 weeks of growth, grass was harvested, and final dry weights were recorded.

Ammonium-N was determined volumetrically on 1M KCl extracts of compost (Bremner, 1965). Nitrate was determined electrometrically in 5:1 (water:medium, v:w) extracts (Barker, 1974). Electrical conductivity was measured in the extracts for nitrate-N determinations (Richards, 1954). Compost was analyzed for ammonium-N, nitrate-N, and electrical conductivity on the day of seeding and after 3, 7, 14, 21, and 28 days.

Results

Ammonium sulfate or $Ca(NO_3)_2$ was applied to the composts, and all flats were seeded at the beginning of the experiment. Growth and other parameters were assessed during a time period of 28 days.

Ammonium

Compost, nitrogen source, amount of N, and time did not interact to affect ammonium-N in the media (Tables 4.1 & 4.2); however, many of the lower level interactions and main factors had significant effects on ammonium-N (Tables 4.2 & 4.3, Figure 4.1). Over the 28-day period, leaf compost had higher average ammonium-N (472 mg/kg dry wt) than MSW compost (322 mg/kg) (Table 4.3). Composts (MSW and leaf) amended with $(NH_4)_2SO_4$ had higher average ammonium-N (732 mg/kg) than composts amended with $Ca(NO_3)_2$ (62 mg/kg). Composts amended with 2,300 mg N/kg (768 mg/kg) had higher average ammonium-N than composts amended with 1,150 mg N/kg (366 mg/kg). Composts with no nitrogen added had the lowest average ammonium-N (57 mg/kg).

Ammonium-N in composts fell with time if $(NH_4)_2SO_4$ was added (Table 4.1, Figure 4.1). Mean ammonium-N in the composts (MSW and leaf) with 2,300 mg N/kg from $(NH_4)_2SO_4$ declined from 2,594 mg/kg to 118 mg/kg after 28 days (Table 4.1). Composts with 1,150 mg N/kg from $(NH_4)_2SO_4$ declined from a mean ammonium-N of 1,375 mg/kg to 70 mg/kg after 28 days. Composts initially having less than 100 mgNH_4-N/kg did not change with time. Ammonium-N in composts with $(NH_4)_2SO_4$ varied with amount of N added whereas in composts with $Ca(NO_3)_2$, ammonium-N was low and did not vary with amount of N added (Table 4.3 & Figure 4.1).

Nitrate

Compost, nitrogen source, amount of N, and time did not interact to affect nitrate-N in the media (Tables 4.4 & 4.5); however, many of the lower level interactions and main factors had significant effects on nitrate-N (Tables 4.5 & 4.6, Figure 4.2). Following additions of N-containing salts, mean nitrate-N concentrations over the 28-day period in leaf compost (835 mg/kg) and MSW compost (750 mg/kg) were not significantly different (Table 4.6). Mean nitrate-N in composts (MSW and leaf) with $Ca(NO_3)_2$ had higher nitrate-N concentrations (1,280 mg/kg) than compost with $(NH_4)_2SO_4$ (305 mg/kg). Composts with 2,300 mg N/kg had higher nitrate-N concentrations (1,295 mg/kg) than composts with 1,150 mg N/kg (860 mg/kg). In MSW or leaf compost with 2,300 mg N/kg from $Ca(NO_3)_2$, nitrate-N concentrations were 2,500 mg/kg or 1,995 mg/kg, respectively, and in MSW or leaf compost with 1,150 mg N/kg from $Ca(NO_3)_2$, nitrate-N concentrations were 1,000 mg/kg or 1,725 mg/kg, respectively. Composts with no nitrogen added had the least amount of nitrate-N (220 mg/kg).

A significant decline in compost nitrate-N occurred with time. Nitrate-N concentrations in composts with 1,150 or 2,300 mg N/kg with $Ca(NO_3)_2$ increased then decreased 7 to 14 days after application of compost (Tables 4.4 & 4.5, Figure 4.2). Nitrate-N concentrations in composts with $(NH_4)_2SO_3$ were lower than composts with $Ca(NO_3)_2$ but still increased then decreased with time (Figure 4.2).

Salinity

The interaction of compost, nitrogen source, amount of N, and time was significant (Tables 4.7 & 4.8). The principal observation in this interaction seems to be the high magnitude and persistence of the conductivity with $Ca(NO_3)_2$ added to MSW compost. MSW compost with 2,300 mg N/kg from $Ca(NO_3)_2$ increased in conductivity from 2.6 mmho/cm to a maximum of 3.7 mmho/cm 14 days after application of compost to flats (Table 4.7 & Figure 4.3). Conductivity then declined to 1.1 mmho/cm 28 days after compost application. In leaf compost with 2,300 mg N/kg from $Ca(NO_3)_2$, conductivity increased from 2.4 mmho/cm to a maximum of 2.6 mmho/cm. After 14 days, conductivity in all $Ca(NO_3)_2$-amended composts declined, and after 28 days, conductivities were about 50 % or less of the maximum values (Table 4.7 & Figure 4.3).

Conductivity was greater in MSW (1.5 mmho/cm in 5:1 water:medium, v:w, extracts) than in leaf compost (1.3 mmho/cm) (Tables 4.8 & 4.9). Adding $Ca(NO_3)_2$ (1.5 mmho/cm) increased conductivity more than adding $(NH_4)_2SO_4$ (1.3 mmho/cm). Conductivity in composts with 2,300 mg N/kg (2.2 mmho/cm) was higher than in composts with 1,150 mg N/kg (1.6 mmho/cm). Composts with no nitrogen added had the lowest conductivity (0.4 mmho/cm). Overall, a significant decline in compost conductivity occurred with time.

In MSW or leaf composts, amendments with $(NH_4)_2SO_4$ also increased conductivity (Tables 4.7 & 4.8). With $(NH_4)_2SO_4$, all treatments increased conductivities, until about 14 days, thereafter, compost conductivity declined to about 50 % of the original values at 28 days after addition of salts to the medium.

Stands of grass

Compost, nitrogen source, amount of N, and time did not interact to affect stands of grass (Tables 4.10 & 4.11); however, many of the lower level interactions and main factors had significant effects on stands of grass (Tables 4.10 & 4.11, Figure 4.4). Stand of grass in MSW compost (index 6.1) was better than grass grown in leaf compost (index 4.4) (Table 12). Grass stand was better in composts with $(NH_4)_2SO_4$ (index 6.0) than in composts with $Ca(NO_3)_2$ (index 5.0). Stand of grass was better in unamended composts (index 6.0) than in composts with 1,150 mg N/kg (index 5.4) or with 2,300 mg N/kg (index 4.3).

A significant increase in growth occurred with time (Tables 4.10 & 4.11). These increases were associated with N compositional changes in the media. Germination or growth of grass was assessed at 3, 7, 14, 21, and 28 days after seeding. Seedlings did not emerge until 7 days after seeding. During the first 14 days after application of composts to flats, ammonium decreased and nitrate and electrical conductivity increased. Due to these changes in the compost, it was important to emphasize differences in germination of grass during this 7-to-14-day period.

Grass establishment after 7 days was the best in composts with no nitrogen added and the worst in composts with 2,300 mg N/kg added (Table 4.13). Germination of grass was hindered more in composts with $Ca(NO_3)_2$ than in composts with $(NH_4)_2SO_4$. In compost with $Ca(NO_3)_2$ or

$(NH_4)_2SO_4$, grass germination with 2,300 mg N/kg was hindered more than in compost with 1,150 mg N/kg.

At 14 days after seeding, trends were similar to those after 7 days with grass establishment being the best in compost with no nitrogen added and the worst in composts with 2,300 mg N/kg (Table 4.13). Establishment of grass was still hindered more in composts amended with $Ca(NO_3)_2$ than in composts amended with $(NH_4)_2SO_4$. However, at 14 days in $(NH_4)_2SO_4$-amended composts, grass establishment was similar to establishment in the unamended composts. In $Ca(NO_3)_2$ amended compost, differences among amounts of N added were still significant at 14 days and remained similar to those after 7 days.

After 28 days of growth, stands of grass with $(NH_4)_2SO_4$ increased, equalling stands of grass in unamended compost (Tables 4.10 & 4.11). Stands of grass with $Ca(NO_3)_2$ increased with time and varied with the amount of $Ca(NO_3)_2$ added to the composts. The more $Ca(NO_3)_2$ added, the more grass establishment was hindered. This result was particularly evident in the first 14 days of establishment (Tables 4.10, 4.11 & 4.12).

Dry weights of grass

Grass was harvested 28 days after seeding, and dry weights were recorded (Tables 4.14 & 4.15). Clipping weights in composts with nitrogen added were greater than those in unamended composts. Grass grown in composts with $(NH_4)_2SO_4$ had higher clipping weights (mean 17 g/flat) than grass grown in composts with $Ca(NO_3)_2$ (mean 10 g/flat). The lowest clipping weights were grown in composts with 2,300 mg N/kg from $Ca(NO_3)_2$. Clipping weights of grass in composts with 1,150 mg N/kg from $Ca(NO_3)_2$ were higher than in composts with no nitrogen added. The highest clipping weights of grass were produced in composts with 2,300 mg N/kg from $(NH_4)_2SO_4$.

<u>Discussion</u>

Seedling emergence was inhibited by $Ca(NO_3)_2$ or $(NH_4)_2SO_4$ and by increasing amounts of N, but after 14 days, germination of grass in compost with $(NH_4)_2SO_4$ did not differ from the unamended flats. During this time, ammonium concentrations in compost decreased. By the seventh day after application of composts to flats, at least 40 % of the applied-ammonium dissipated. The concurrent rise in germination with the fall in ammonium indicates a relation between improved germination and loss of ammonium.

In $Ca(NO_3)_2$ amended compost, germination at 7 days was inhibited relative to the ammonium-amended composts and remained hindered even after 14 days. The conductivity indicates that soluble salts in the composts with 2,300 mg N/kg from $Ca(NO_3)_2$ were sufficient at 14 days to inhibit germination and growth of perennial ryegrass. Richards (1954) reports that 12 mmho/cm (saturated extract) inhibits germination and growth of perennial ryegrass. The maximum values reported here range from 1.9 (1,150 mg N) to 3.7 (2,300 mg N) (5:1 water:medium, v:w, extracts) which were diluted about threefold relative to a saturation extract. Conductivity fell to half the maximum at 28 days after composts were applied to the flats. Persistence of the inhibiting effect of $Ca(NO_3)_2$ was due to soluble salts remaining in the composts for at least 14 days.

Conductivity in composts increased after 7 to 14 days then decreased. This rise in conductivity likely was due to the rise in nitrate and other soluble salts from mineralization. This rise in conductivity was evident particularly in MSW at 2,300 mg NO_3-N/kg, and as a result, growth of grass was hindered.

Addition of $(NH_4)_2SO_4$ increased conductivity in the compost, but these additions did not impede growth or increase conductivity as greatly as with $Ca(NO_3)_2$ amendments. Ammonium was lost by volatilization thereby eliminating the phytotoxicity due to high ammonium or salt concentrations within 7 days. Nitrate is nonvolatile but is lost by leaching, by plant uptake, or by denitrification; these processes failed to reduce salinity below noninjurious levels until late in the experiment.

Grass dry weights after 28 days in amended composts exceeded dry weights in the unamended composts except in compost amended with 2,300 mg N/kg from $Ca(NO_3)_2$. In general, the increased nitrogen in the amendments promoted growth.

The effects of additions of nitrate salts were more ruinous than the effects of additions of ammonium salt. Although high concentrations of ammonium are toxic to plants, ammonium losses by volatilization reduce ammonium levels to nontoxic levels. The inhibiting effects of nonvolatile salts, such as $Ca(NO_3)_2$, persist. It appears that the alleviation of the inhibitory effects of immature composts with time is due to loss of ammonia.

Concluding remarks

Additions of ammonium or nitrate salts affected plant growth. Ammonium in compost declined with time whereas electrical conductivity increased then decreased with time. Ammonium salts appear to be lost from compost more rapidly than nitrate salts which have a prolonged inhibitory effect on germination and growth of ryegrass. Since it appears that ammonia rapidly volatilized from compost, it seems likely that problems due to high concentrations of ammonium could be avoided by applying compost for a period of time before seeding.

The next step in my research was to attempt to delay seeding after compost application so that ammonium concentrations in compost would volatilize to levels that were not injurious to germination and growth.

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Table 4.1. Variation in ammonium-N with time in MSW or leaf composts with different amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Time (days)	Ammonium-N (mg/kg dry wt)					
	$(NH_4)_2SO_4$			$Ca(NO_3)_2$		
	Amount of N added (mg N/kg dry wt)			Amount of N added (mg N/kg dry wt)		
	0	1,150	2,300	0	1,150	2,300
	MSW compost					
0	77	1,267	2,470	60	88	113
3	70	681	2,252	60	82	80
7	74	306	1,245	66	54	88
14	60	60	1,373	53	73	63
21	66	58	72	57	67	68
28	88	66	64	60	64	58
	Leaf compost					
0	53	1,483	2,719	56	73	53
3	42	1,403	2,574	45	70	66
7	45	1,289	1,659	42	69	76
14	65	935	2,283	36	53	57
21	46	247	728	47	50	45
28	53	196	172	48	40	53

See ANOVA Table 4.2.

Table 4.2. Analysis of variance table for variation in ammonium-N with time in MSW or leaf compost with 3 amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Source	Symbol	Significance
Weeks	W	0.0001
Compost	C	0.0324
N source	N	0.0004
Amount of N	L	0.0001
CxN		0.0264
CxL		0.1023
NxL		0.0001
CxNxL		0.1102
WxC		0.1741
WxN		0.0001
WxL		0.0001
WxCxN		0.2066
WxCxL		0.7148
WxNxL		0.0001
WxCxNxL		0.7705

Table 4.3. Mean ammonium-N concentrations in MSW or leaf compost treated with different amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Amount of N added mg/kg	Ammonium-N detected (mg/kg dry wt)[z]					
	MSW compost				Leaf compost	
	$(NH_4)_2SO_4$		$Ca(NO_3)_2$		$(NH_4)_2SO_4$		$Ca(NO_3)_2$
0	72		59		50		45
1,150	406		71		930		57
2,300	1,246		78		1,689		61
Trend	L*		L*		L*		L*
Source mean	574	*	70		890	*	55
Compost mean		332		*		472	

[z]Means over 28-day sampling period. See ANOVA Table 4.2.

*Within composts, sources are different by F-test ($P \leq 0.05$), and compost means are different by F-test ($P \leq 0.05$).

L = significant linear regression, * = $P \leq 0.05$.

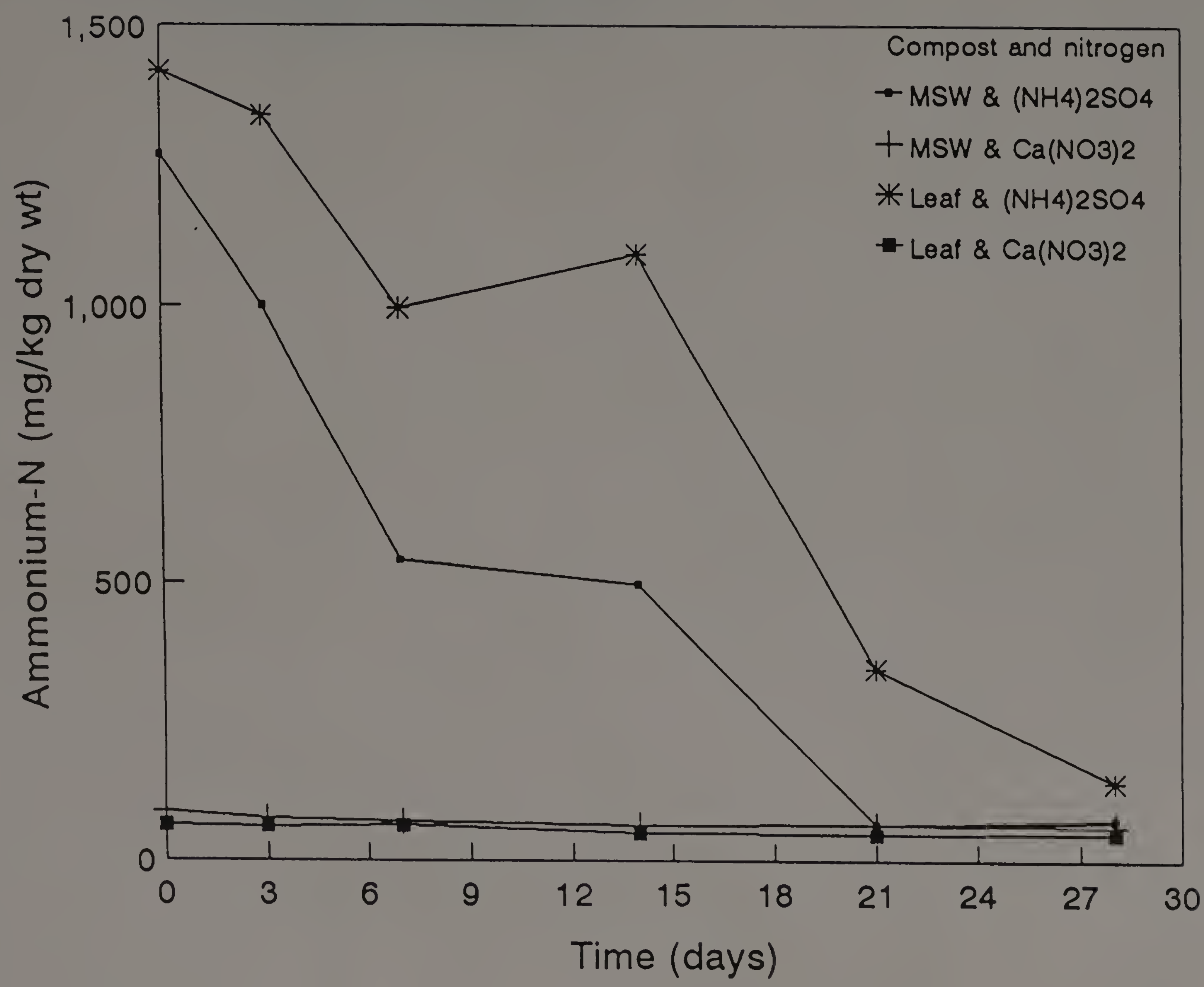

Figure 4.1. Variation in ammonium-N with time for MSW or leaf compost treated with $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Table 4.4. Variation in nitrate-N with time in MSW or leaf compost and with different amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Time (days)	Nitrate-N (mg/kg dry wt)					
	$(NH_4)_2SO_4$			$Ca(NO_3)_2$		
	Amount of N added (mg N/kg dry wt)			Amount of N added (mg N/kg dry wt)		
	0	1,150	2,300	0	1,150	2,300
			MSW compost			
0	305	335	285	205	950	2,190
3	365	395	365	740	1,555	2,890
7	415	860	675	345	1,175	3,190
14	135	810	975	123	1,225	2,925
21	200	390	485	195	815	2,215
28	100	180	80	75	885	1,125
			Leaf compost			
0	190	150	125	190	1,675	2,315
3	225	135	150	250	1,600	2,340
7	225	225	145	245	2,350	1,890
14	105	350	320	155	2,425	2,440
21	170	340	385	180	1,405	1,875
28	85	160	160	75	885	1,125

See ANOVA Table 4.5.

Table 4.5. Analysis of variance table for variation in nitrate-N with time in MSW or leaf compost with 3 amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Source	Symbol	Significance
Weeks	W	0.0004
Compost	C	0.0656
N source	N	0.0001
Amount of N	L	0.0001
CxN		0.0009
CxL		0.0072
NxL		0.0001
CxNxL		0.0121
WxC		0.4095
WxN		0.0516
WxL		0.0303
WxCxN		0.4691
WxCxL		0.8314
WxNxL		0.7156
WxCxNxL		0.6615

Table 4.6. Mean nitrate-N concentrations in MSW or leaf compost treated with different amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Amount of N added mg/kg	Nitrate-N detected (mg/kg dry wt)[z]					
	MSW compost			Leaf compost		
	$(NH_4)_2SO_4$		$Ca(NO_3)_2$	$(NH_4)_2SO_4$		$Ca(NO_3)_2$
0	255		285	165		185
1,150	495		1,000	225		1,725
2,300	480		2,500	215		1,995
Trend	L*, Q*		Q*	L*, Q*		L*, Q*
Source mean	410	*	1,260	200	*	1300
Compost mean		835			750	

[z]Means over 28-day sampling period. See ANOVA Table 4.5.

*Within composts, sources are different by F-test ($P \leq 0.05$). Compost means are not significantly different by F-test ($P \geq 0.05$).

L = significant linear regression, Q = significant quadratic regression, * = $P \leq 0.05$. NS = nonsignificant ($P > 0.05$).

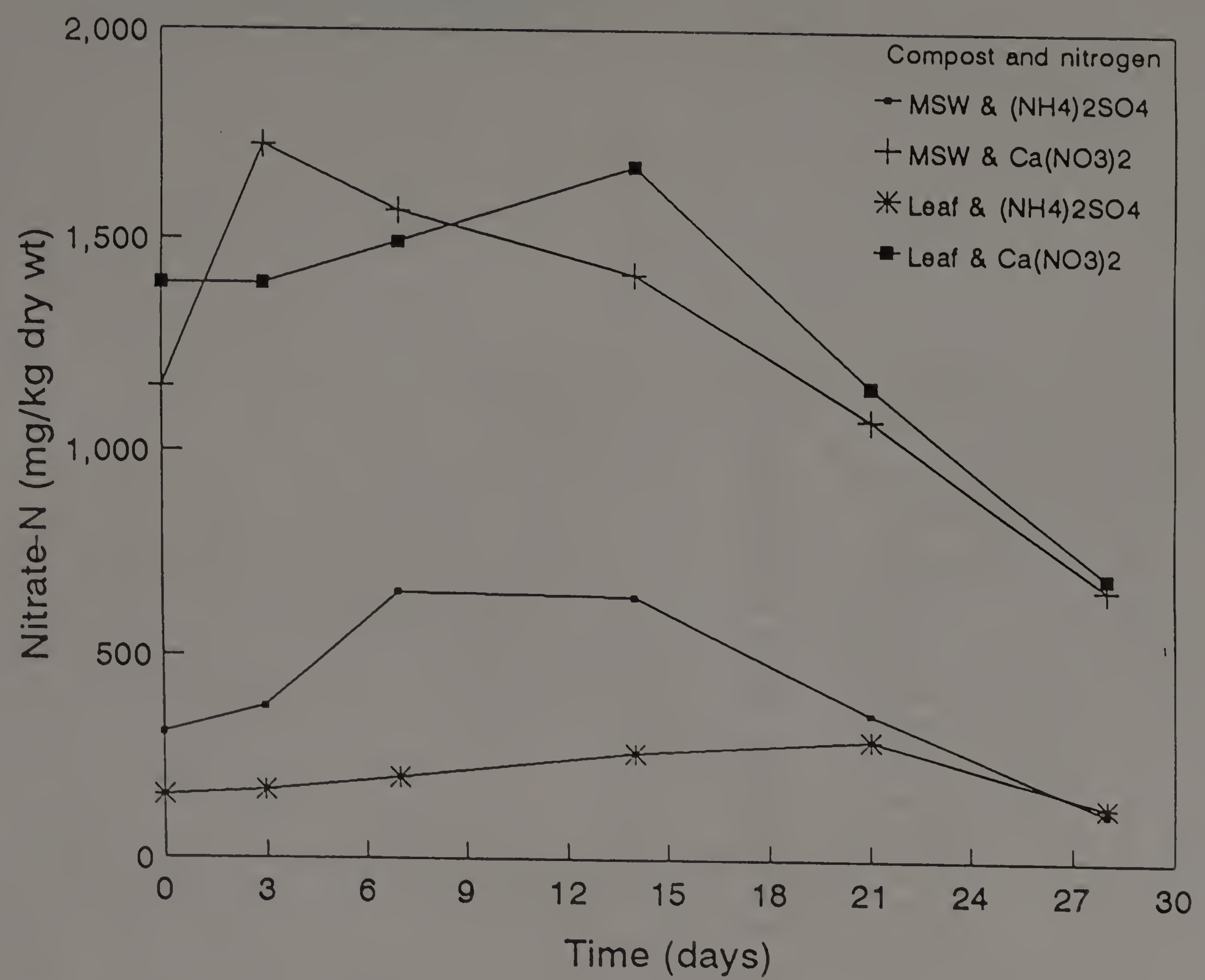

Figure 4.2. Variation in nitrate-N with time for MSW or leaf compost treated with $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Table 4.7. Variation in electrical conductivity with time in MSW or leaf compost with different amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Time (days)	EC (mmho/cm)[z]					
	$(NH_4)_2SO_4$			$Ca(NO_3)_2$		
	Amount of N added (mg N/kg dry wt)			Amount of N added (mg N/kg dry wt)		
	0	1,150	2,300	0	1,150	2,300
			MSW compost			
0	0.8	1.7	2.3	0.4	1.3	2.6
3	0.7	1.7	2.7	0.5	2.1	3.3
7	1.0	2.0	2.1	0.7	1.6	3.7
14	0.7	1.9	2.4	0.4	1.9	3.6
21	0.5	1.5	1.5	0.4	1.3	2.5
28	0.3	0.8	0.8	0.3	0.5	1.1
			Leaf compost			
0	0.2	1.5	2.2	0.2	1.7	2.4
3	0.2	1.8	3.0	0.3	1.6	2.6
7	0.3	1.8	1.7	0.3	2.5	2.1
14	0.2	1.9	2.8	0.3	2.6	2.6
21	0.2	1.3	1.4	0.2	1.4	1.9
28	0.2	0.7	0.6	0.1	1.0	1.2

[z]Electrical conductivity measured in 5:1 (water:medium, v:w) extracts.

See ANOVA Table 4.8.

Table 4.8. Analysis of variance table for variation in conductivity with time in MSW or leaf compost with 3 amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Source	Symbol	Significance
Weeks	W	0.0001
Compost	C	0.0096
N source	N	0.0234
Amount of N	L	0.0001
CxN		0.8860
CxL		0.0060
NxL		0.1068
CxNxL		0.0540
WxC		0.7437
WxN		0.8513
WxL		0.0001
WxCxN		0.5468
WxCxL		0.7221
WxNxL		0.8824
WxCxNxL		0.0312

Table 4.9. Mean electrical conductivity in MSW or leaf compost treated with different amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Amount of N added mg/kg	Electrical conductivity detected (mmho/cm)[z]			
	MSW compost		Leaf compost	
	$(NH_4)_2SO_4$	$Ca(NO_3)_2$	$(NH_4)_2SO_4$	$Ca(NO_3)_2$
0	0.7	0.5	0.2	0.2
1,150	1.6	1.5	1.5	1.8
2,300	2.0	2.8	2.0	2.1
Trend	L*, Q*	L*, Q*	L*, Q*	L*, Q*
Source mean	1.4	1.6	1.2	1.4
Compost mean	1.5		1.3*	

[z]Means over 28-day sampling period. See ANOVA Table 4.8.

*Within composts, sources are not significantly different by F-test ($P>0.05$), and compost means are significantly different by F-test ($P\leq0.05$).

L = significant linear regression, Q = significant quadratic regression, * = $P\leq0.05$. NS = nonsignificant ($P>0.05$).

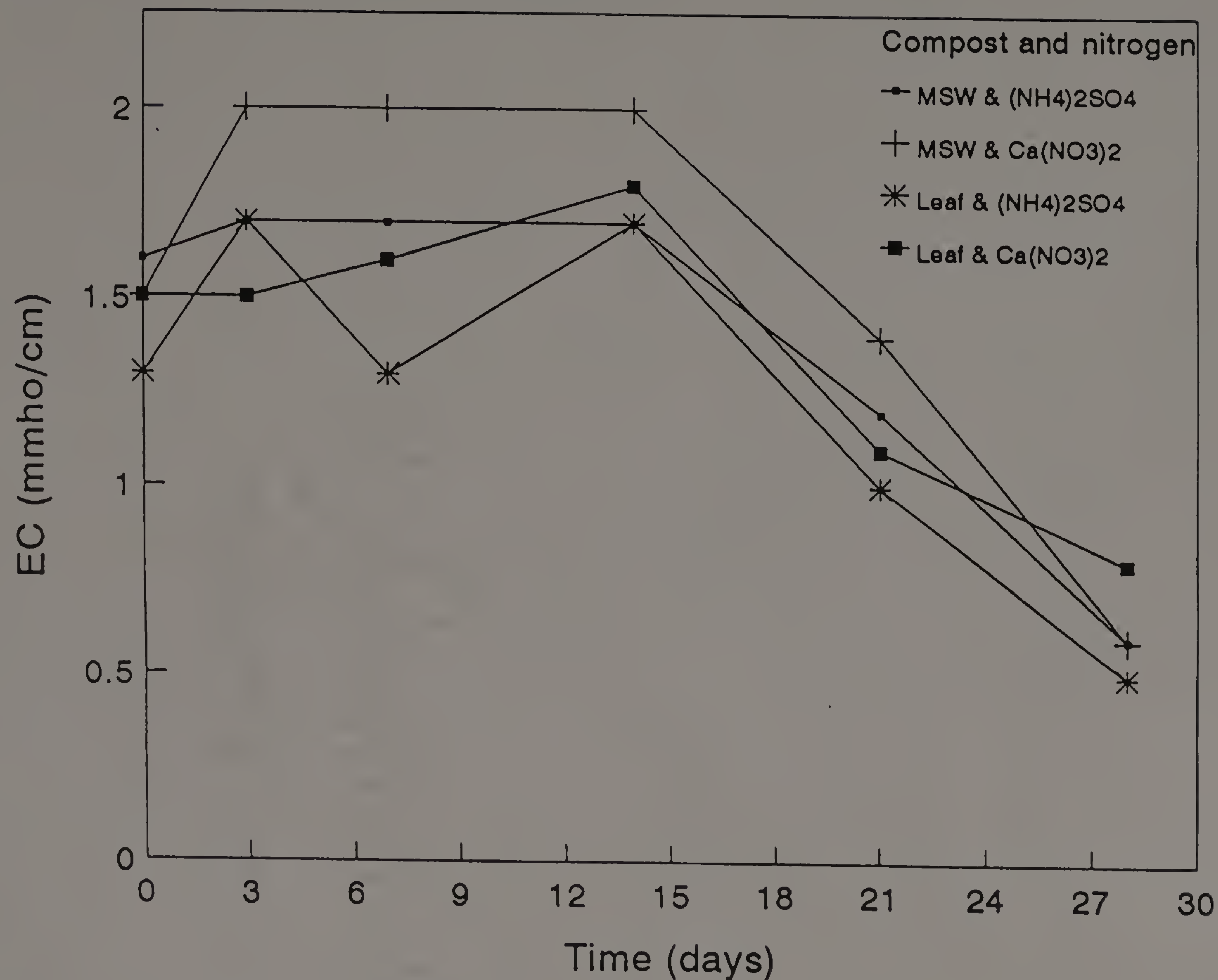

Figure 4.3. Variation in electrical conductivity with time for MSW or leaf compost with $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Table 4.10. Variation in stand with time in MSW or leaf composts with different amounts of $(NH_3)_2SO_4$ or $Ca(NO_3)_2$.

Time (days)	Stand establishment (visual index)[z]					
	$(NH_4)_2SO_4$			$Ca(NO_3)_2$		
	Amount of N added (mg N/kg dry wt)			Amount of N added (mg N/kg dry wt)		
	0	1,150	2,300	0	1,150	2,300
	MSW compost					
0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
7	7.0	5.6	4.3	7.1	2.8	1.0
14	10.9	10.6	9.5	10.9	7.1	3.5
21	12.8	13.0	13.0	12.0	10.0	5.9
28	12.8	13.0	13.0	12.0	13.0	8.5
	Leaf compost					
0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
7	5.3	4.0	2.6	5.6	1.6	0.6
14	6.6	7.8	6.8	8.4	4.6	2.3
21	8.3	9.8	9.8	7.8	7.5	4.9
28	8.3	10.8	11.8	8.3	9.5	6.3

[z]Visual index 0 to 13; 0 = no stand established, 13 = all rows in flat established.

See ANOVA Table 4.11.

Table 4.11. Analysis of variance table for variation in growth with time in MSW or leaf compost with 3 amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Source	Symbol	Significance
Weeks	W	0.0001
Compost	C	0.0015
N source	N	0.0096
Amount of N	L	0.0002
CxN		0.5210
CxL		0.1012
NxL		0.0006
CxNxL		0.8907
WxC		0.0002
WxN		0.0001
WxL		0.0001
WxCxN		0.6668
WxCxL		0.5642
WxNxL		0.0001
WxCxNxL		0.9023

Table 4.12. Mean stand in MSW or leaf compost treated with different amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Amount of N added mg/kg	Stand (visual index)[z]			
	MSW compost		Leaf compost	
	$(NH_4)_2SO_4$	$Ca(NO_3)_2$	$(NH_4)_2SO_4$	$Ca(NO_3)_2$
0	7.2	7.0	4.7	5.0
1,150	7.0	5.5	5.4	3.9
2,300	6.6	3.1	5.2	2.3
Trend	L*, Q*	L*	L*	L*
Source mean	7.0	5.2	5.1	3.7
Compost mean	6.1		4.4*	

[z]visual index 0 to 13; 0 = no stand established, 13 = all rows in flat established. See ANOVA Table 4.11.

*Within composts, sources are not significantly different by F-test ($P \geq 0.05$). Compost means are significantly different by F-test ($P \leq 0.05$).

L = significant linear regression, Q = significant quadratic regression, * = $P \leq 0.05$. NS = nonsignificant ($P > 0.05$).

Table 4.13. Germination of grass at 7 or 14 days after seeding in compost supplemented with different amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Amount of N added (mg N/kg dry wt)	Nitrogen treatment		
	$(NH_4)_2SO_4$	$Ca(NO_3)_2$	Mean
		7 days	
0	6.1	6.4	6.3
1,150	4.8	2.2	3.5
2,300	3.4	0.8	2.1
Trend	Q*	Q*	Q*
Mean	4.8a	3.1b	**
		14 days	
0	8.8	9.6	9.2
1,150	9.2	5.9	7.5
2,300	8.1	2.9	5.5
Trend	NS	Q*	Q*
Mean	8.8a	6.1b	**

** Interaction of nitrogen treatment x level of nitrogen at 7 days or 14 days is significant. Nitrogen treatment means followed by different letters are significantly different by F-test ($P \leq 0.05$).

Q = significant quadratic regression, * = $P \leq 0.05$.
NS = nonsignificant trend, $P > 0.05$.

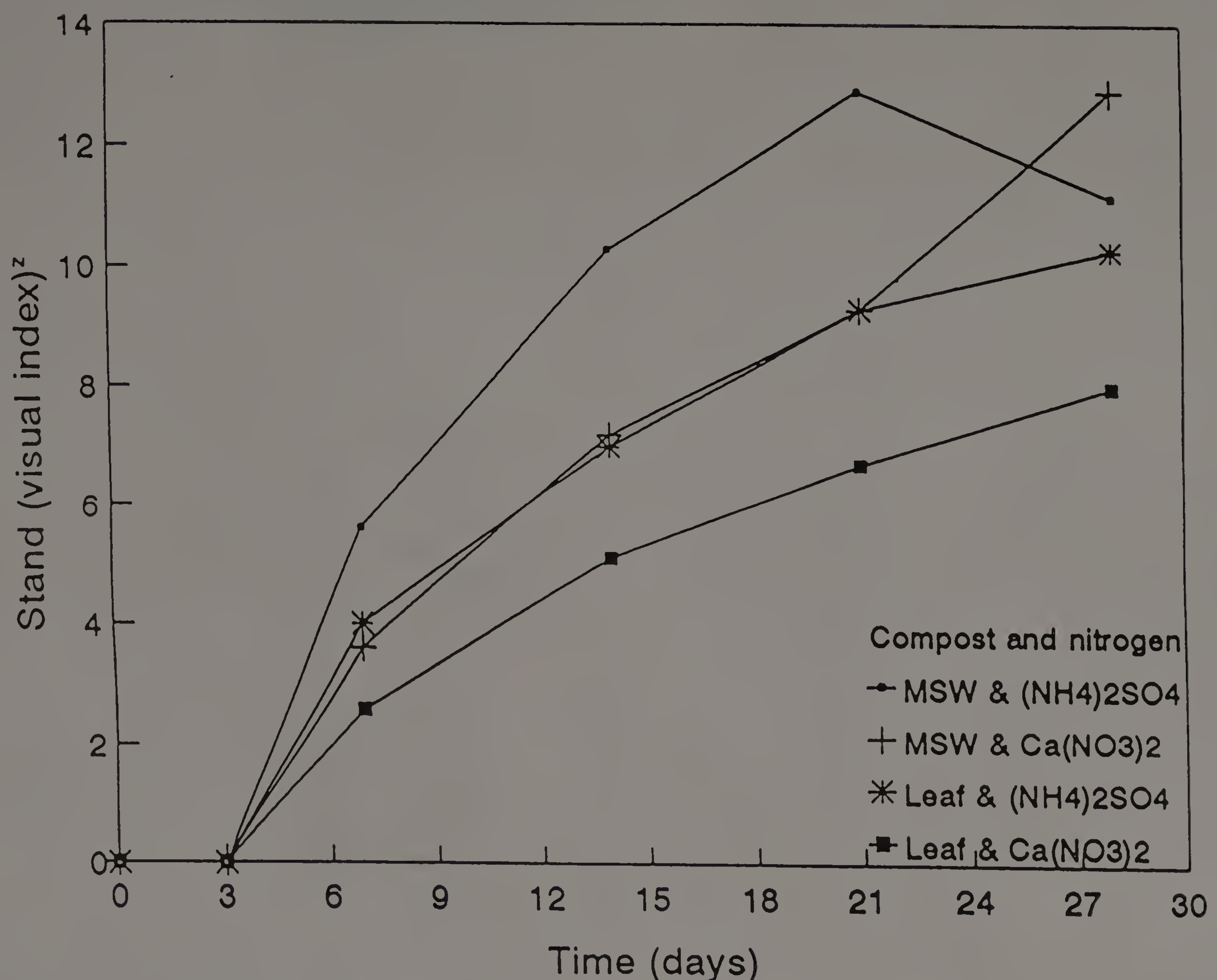

Figure 4.4. Variation in stand of grass with time for MSW or leaf compost treated with $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

[z]visual index 0 to 13; 0 = no stand establishment, 13= all 13 rows fully established.

Table 4.14. Dry weights of grass harvested after 28 days of growth in MSW or leaf compost with $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Amount of N added mg/kg	Dry wt (g/flat)			
	MSW compost		Leaf compost	
	$(NH_4)_2SO_4$	$Ca(NO_3)_2$	$(NH_4)_2SO_4$	$Ca(NO_3)_2$
0	14	11	6	7
1,150	21	17	16	9
2,300	25	8	17	5
Trend	L*, Q*	NS	L*, Q*	NS
Source mean	20	13	13	7
Compost mean	16		10*	

Nitrogen treatment means ($(NH_4)_2SO_4$, 17 g/flat and $Ca(NO_3)_2$, 10 g/flat) are significantly different by F-test ($P \leq 0.05$).

*Compost means are significantly different by F-test ($P \leq 0.05$). Within composts, sources are not significantly different by F-test ($P \geq 0.05$).

L = significant linear regression, Q = significant quadratic regression, * = $P \leq 0.05$. NS = nonsignificant ($P > 0.05$).

Table 4.15. Analysis of variance table for variation in dry weight in MSW or leaf compost with 3 amounts of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$.

Source	Symbol	Significance
Compost	C	0.0033
N source	N	0.0021
Amount of N	L	0.0006
CxN		0.4704
CxL		0.7370
NxL		0.0001
CxNxL		0.3612

CHAPTER V

THE EFFECTS OF DELAYING SEEDING AFTER COMPOST APPLICATION ON GRASS SOD PRODUCTION

Abstract

In some composts, seed germination and plant growth in some composts have been inhibited by high concentrations of ammonium or soluble salts. Ammonium and salt concentrations in media decrease with time after application to land or placement in containers for growth of plants. This study was conducted to determine if ammonium or soluble salt problems could be avoided by delaying seeding after compost application. Turfgrass (Lolium perenne L. 'Pennfine') was seeded into municipal solid waste (MSW) compost depleted of ammonium during storage and into this compost with 1,150 or 2,300 mg NH_4-N/kg (dry weight) added. Seeding occurred on the day of compost application and after 1, 3, 7, and 14 days from application. Flats of composts were watered daily after seeding but were not watered before seeding. Ammonium-N and nitrate-N concentrations, electrical conductivity, and pH in compost were measured on each day of seeding. Ammonium-N, electrical conductivity, and pH in compost declined, and nitrate-N concentration increased with time. Delaying seeding for 14 days after compost application increased germination and clipping weights. By delaying seeding, ammonium and salt problems were minimized, apparently by dissipation of inhibitory factors by ammonium volatilization.

Introduction

Depending on the composition and maturity of compost, ammonium and salt concentrations in compost can reach levels that can inhibit seed germination and plant growth (Inbar et al., 1990; He at al., 1992). Phytotoxic concentrations of ammonium have been reported in immature composts of biosolids and municipal solid wastes (see Chapter II). In previous studies, ammonium was identified as the principal inhibitory factor in immature composts (see Chapter VI). High concentrations of ammonium in compost decline to levels that do not impede growth after 7 to 10 days after compost application (see Chapter VI). However, the initial phytotoxicity of high ammonium concentrations can be so severe that seeds may be damaged, and plants may not recover, thereby necessitating reseeding or replanting.

One potential means of ensuring lower ammonium concentrations in compost is be to apply composts several days before planting to allow diminishing of ammonium in the medium by ammonia volatilization, by nitrification, or by both processes. Delaying of planting allows ammonium to dissipate to levels unlikely to inhibit germination or growth.

This study evaluated the effects of delaying seeding in compost that was amended to simulate immature composts that were inhibitory to grass seed germination and seedling growth. In earlier studies, fresh municipal solid waste (MSW) including biosolids compost was inhibitory to seed germination (Barker, 1993a, 1993b; Barker and O'Brien, 1993, 1994). The ammonium concentration in fresh mixed MSW was about 2,300 mg NH_4-N/kg dry weight. Compost remaining in a pile without turning for 2 months had about 1,150 mg NH_4-N/kg. Compost that was bagged for at least a month was depleted to 40 to 100 mg NH_4-N/kg. The inhibitory effect declined with diminishing NH_4. The compost used in this experiment was bagged and depleted of ammonium during storage. Ammonium sulfate was added to the depleted compost to establish 2,300 and 1,150 mg NH_4-N/kg in the medium. Germination and growth of perennial ryegrass was evaluated as functions of ammonium concentration in the medium and delay in seeding after application of compost.

Materials and Methods

Compost of mixed municipal solid waste (Delaware Solid Waste Authority, Dover, Delaware) was received in June 1993 and stored outdoors in plastic-mesh bags. The average ammonium-N and electrical conductivity of the bagged compost after depletion of ammonium was about 30 mg NH_4-N/kg (dry weight) and 3.38 mmho/cm (5:1 water:medium). Ammonium sulfate was added to the bagged mixed MSW to obtain levels of 1,150 or 2,300 mg NH_4-N/kg dry weight.

'Pennfine' perennial ryegrass was seeded into flats (25 cm wide x 50 cm long x 5 cm deep) filled with 4.0 kg of moist compost (about 40 % moisture). All flats were setup on 1 August 1994 in the greenhouse and seeded at different time intervals after setup in four randomized complete blocks. Seeding occurred on the 1st, 2nd, 4th, 8th, and the 15th of August 1994. Seeds were placed uniformly in 13 evenly spaced rows in the flats. Flats were watered for the first time at seeding and then daily afterwards.

Germination of grass seeds was assessed 14 days after seeding. Germination was indexed by uniformity and density of stand (0 to 13; 0 = no germination, 13 = 13 rows fully germinated). Twenty eight days after seeding, grass was clipped, and dry weights were recorded.

Ammonium-N, nitrate-N, pH, and electrical conductivity in compost were measured on the day that composts were treated and applied to flats (1 August 1994), then after 1, 3, 7, and 14 days. Therefore, ammonium-N, nitrate-N, conductivity, and pH in the composts at each time of seeding were known. Ammonium-N was determined volumetrically on 1M KCl extracts of compost (Bremner, 1965). Nitrate was determined electrometrically in 5:1 water:soil (vol:wt) extract (Barker, 1974). Conductivity was measured in the same extracts used for nitrate determinations (Richards, 1954).

Results

Compost Nitrogen

With ammonium-N additions of 1,150 or 2,300 mg N/kg to the media, ammonium concentrations remained constant for the first 3 days and then declined (Figure 5.1). By the seventh day after application, ammonium-N concentrations fell to about 60 % of the initial values.

Ammonium-N concentrations in composts with no nitrogen supplement were low and declined slightly over the 14-day period.

Nitrate in the composts was measured at the same times as the ammonium (Table 5.1). Nitrate concentrations rose with time after application of treatments in the composts. Increases in nitrate-N were not stoichiometric with the decline in ammonium-N (Figure 5.1 & Table 5.1). The amount of nitrate in the media did not vary with the amount of ammonium that was added (Table 5.1).

Compost Salinity

Significant differences occurred in electrical conductivities among the levels of nitrogen treatment and among the times after application (Table 5.2). Initially and until the seventh day after treatment, conductivity in composts supplemented with 2,300 mg NH_4-N/kg was higher than in composts supplemented with 1,150 mg NH_4-N/kg or with no supplement. By the fourteenth day, the values were about equal among the treatments. Most of the declines in conductivity occurred between the seventh and fourteenth days.

Compost pH

Acidity of composts increased slightly with time after treatment and application of the composts in the flats (Table 5.3). The highest pH was on the day of treatment, and the lowest pH was measured in compost 14 days later. No effects on acidity occurred due to the amounts of ammonium applied.

Germination and growth of grass

Grass germination was assessed 14 days after seeding in all cases. The best germination occurred in flats that were seeded 14 days after compost was treated (Table 5.4). The worst germination occurred in compost that was seeded immediately after composts were applied to the flats. The greatest improvement in germination with time after treatment occurred with composts in which the ammonium was added. Germination was excellent in unamended compost at all seeding dates, and no improvement in germination occurred with delay in seeding (Table 5.4).

Mean dry weights of grass clippings were measured after 28 days from seeding. Lowest dry weights were recorded in the compost seeded immediately after application, and the highest dry weights were in composts that were seeded 14 days after treatment (Table 5.4). Clipping weights of grass grown in composts treated with 2,300 mg NH_4-N/kg were higher than clipping weights of grass grown in the other two treatments. Grass grown in composts supplemented with 1,150 mg NH_4-N/kg had higher clipping weights than grass grown in compost with no nitrogen added.

Discussion

Substantial declines, about 20%, in ammonium concentrations in the media occurred by the seventh day after application of composts to the flats. About 40 % of the applied ammonium was lost in 14 days. In the ammonium-amended flats, the germination index rose from a mean of 7.5 (58 %) with seeding on the day of the composts application to a mean of 10.5 (81 %) with seeding at 14 days after application. The concurrent rise in germination with the fall in ammonium indicates a relation between improved germination and loss of ammonium (see Chapter IV).

Ammonium concentrations in composts treated with $(NH_4)_2SO_4$ remained high at 14 days after application (1,351 or 728 mg N/kg dry wt), yet germination improved. Stratification of ammonium likely occurred in the 5-cm-deep compost in the flats. Perhaps, volatilization depleted ammonium at the shallow depth (about 1 cm) in which the seeds were placed, thereby giving a zone in which the inhibitory effects of ammonium were removed. Depletion of ammonium allowed for germination to proceed, and later, the established seedlings benefitted from the abundance of nitrogen that remained in the lower strata.

Nitrate concentrations increased with time after application of ammonium fertilizer to the compost before seeding. The increase is attributed to nitrification of ammonium from the fertilizer or from the organic matter. The increase in nitrate-N was less than half the loss of ammonium-N. Therefore, the conversion of ammonium to nitrate is considered to be a small factor in the loss of ammonium from the medium. Nitrate losses by leaching would be nil, since the flats were not watered from the time of application of compost to seeding. Also during this period, denitrification would be small due to the absence of wetting and drying cycles in the sitting compost. Because of the lack of stoichiometry between nitrate accumulation and ammonium losses and the absence of factors contributing to nitrate removal from the media, ammonium losses are attributed to ammonia volatilization.

Electrical conductivities in the media suggest that salinity initially was sufficient to inhibit germination and growth of perennial ryegrass. Richards (1954) reported that an electrical conductivity of 12 mmho/cm (saturation extract) indicates sufficient salinity to injure perennial ryegrass. Standardization of 5:1 (water:medium) extracts with saturation extracts indicates that initial conductivities in the high-ammonium media were at or above 12 mmho/cm. With a lapse of time before seeding, conductivities fell below this apparently inhibitory level. Gaseous losses of ammonia are considered to be the ameliorating factor. Absence of conditions for leaching or denitrification suggest that nitrate losses were insignificant factors in lowering salinity.

Aging of immature composts after application of the compost to land or to containers allows for dissipation of inhibitory factors. The results of this experiment suggest that a 7-day to 14-day period of aging is needed to allow for volatilization of ammonia.

Concluding remarks

Since high concentrations of ammonium inhibit seed germination and growth and contribute to the soluble salt concentration, ammonia volatilization can reduce difficulties associated with ammonium and soluble salts. Delaying seeding in compost with high concentrations of ammonium minimized problems, apparently by dissipation of inhibitory factors by ammonium volatilization.

The next step in my research was to assess composts under field conditions. Experiments were run in the field, growing ryegrass and wildflower mixtures. Composts were applied as a mulch or incorporated into the top 2 inches of soil. Seedling establishment and plant growth were measured in response to the compost applications and changes with time.

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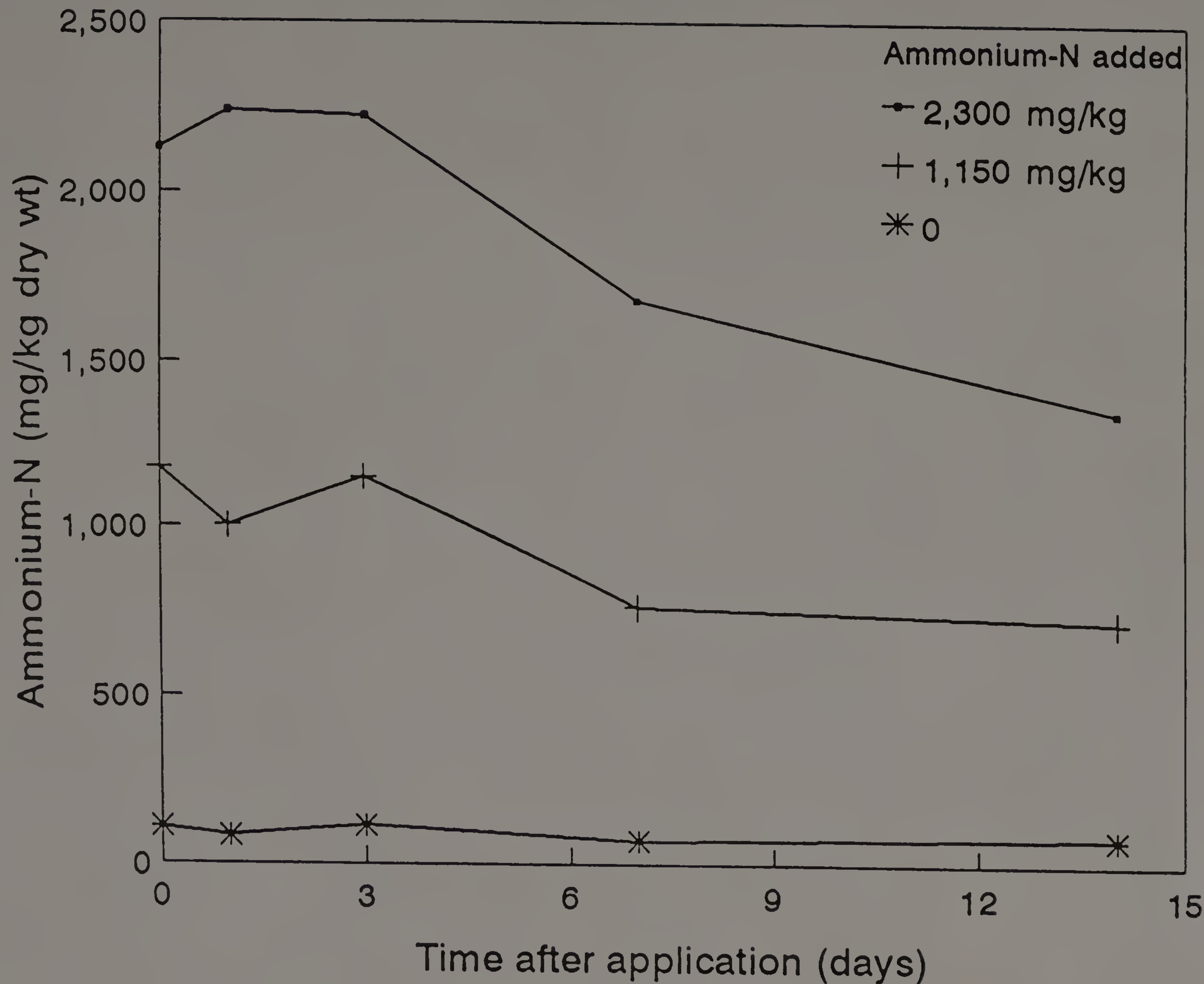

Figure 5.1. Variation in ammonium-N in compost as a function of time after treatment of compost with $(NH_4)_2SO_4$.

Table 5.1. Nitrate-N concentrations in compost as a function of time after treatment of compost with $(NH_4)_2SO_4$.

Time after application (days)	Ammonium-N added to compost (mg/kg dry wt)			Mean
	0	1,150	2,300	
		mg NO_3-N/kg		
0	580	400	395	460
1	665	440	625	575
3	660	355	555	525
7	620	940	925	825
14	565	750	590	635
Trend	NS	L*	L*, Q*	L*, Q*
Mean	620	580	620	NS

With time, L = significant linear regression, Q = significant quadratic regression; *, $P \leq 0.05$. NS, no significant change with amount of N added or time.

Table 5.2. Electrical conductivity in compost as a function of time after treatment of compost with $(NH_4)_2SO_4$.

Time after application (days)	Ammonium-N added to compost (mg/kg dry wt)			Mean
	0	1,150	2,300	
		mmho/cm[z]		
0	3.4	3.2	4.2	3.4
1	3.7	3.7	5.1	4.2
3	3.6	2.8	4.5	3.6
7	3.8	4.1	5.1	4.3
14	2.6	3.1	2.7	2.8
Trend	L*, Q*	NS	L*, Q*	L*, Q*
Mean	3.4	3.4	4.3	L*, Q*

[z]EC in 5:1 water:medium extract.

L = significant linear regression, Q = significant quadratic regression, *, $P \leq 0.05$. NS, no significant change with time.

Table 5.3. Acidity in compost as a function of time after treatment of compost with $(NH_4)_2SO_4$.

Time after application (days)	Ammonium-N added to compost (mg/kg dry wt)			Mean
	0	1,150	2,300	
		pH		
0	7.25	7.31	7.28	7.28
1	7.18	7.01	7.25	7.15
3	7.04	7.08	7.18	7.10
7	7.16	7.04	7.15	7.12
14	6.85	6.75	6.78	6.79
Trend	L*	L*	L*	L*
Mean	7.10	7.04	7.13	NS

With time, L, significant linear regression, *, $P \leq 0.05$. NS, no significant change with amount of N.

Table 5.4. Germination and growth of grass as a function of time after treatment of compost with $(NH_4)_2SO_4$.

Time after application (days)[z]	Ammonium-N added to compost (mg/kg dry wt)			Mean
	0	1,150	2,300	
	Germination, visual index[y]			
0	10	7	8	8
1	10	11	8	10
3	10	11	10	10
7	10	10	9	10
14	11	10	11	11
Trend	NS	L*, Q*	L*	L*
Mean	10	10	9	NS
	Growth, g dry wt/flat (1,250 cm^2)			
0	7.0	8.8	11.5	9.1
1	7.9	11.9	15.4	11.7
3	8.7	11.0	13.4	11.0
7	9.0	11.6	13.1	11.2
14	9.3	12.4	16.2	12.6
Trend	L*, Q*	L*	L*	L*
Mean	8.4	11.1	13.9	L*

With time, L* = significant linear regression, Q = significant quadratic regression; *, $P \leq 0.05$. NS, no significant change in germination with amount of N or time.

[z]days delay in seeding.

[y]visual index of germination 0 to 13 (0 = no emergence; 13 = all rows fully emerged) assessed at 14 days after seeding.

CHAPTER VI

EVALUATION OF FIELD-APPLIED FRESH COMPOSTS FOR PRODUCTION OF SOD CROPS

Abstract

Application of compost to cropland potentially can use large quantities of compost and serve as an alternative to waste disposal into landfills. This study was conducted to evaluate the suitability of field-applied composts of mixed municipal solid wastes, biosolids, leaves, and agricultural wastes for production of wildflower and grass sods. The composts were applied one-inch-thick on the soil surface. In half the plots, the composts were left on the surface as a mulch and in the other half, composts were worked into the top 2 inches of soil. The effects of the composts on wildflower, grass, and weed germination and growth and on wildflower diversity and flowering were investigated for 2 growing seasons. Wildflower and grass quality did not differ whether the composts were applied as a mulch or incorporated into the soil. In the first year, limited growth in apparently immature biosolids-woodchips and mixed MSW composts was attributed to high concentrations of ammonium or soluble salts. The detrimental effects of biosolids-woodchips compost which had high initial ammonium-N concentrations remained into the second season. In the first season, N from composts or fertilizers stimulated weed growth and resulted in poor crop quality. In the second season, crops had a competitive edge over the weeds, and N from the compost improved crop quality. Wildflower diversity and total amount of bloom improved as the N status of the media increased. Weed control and mature compost with readily available N and low soluble salt concentrations are required for high crop quality in the first season.

Introduction

High costs, lack of landfill space, and environmental concerns have caused municipalities to seek alternatives for waste disposal.

Composting of municipal solid waste is potentially a cost-effective alternative that benefits solid waste recycling (Chaney, 1992). Composting alone does not solve the disposal problem, for end uses of the compost must be found. Much of the compost that is made today may end up in a landfill.

Application of compost to cropland is a potential use of large quantities of compost (Hyatt, 1995). Amending soils with municipal solid waste composts for production of densely grown crops, such as sods or wildflower meadows, is one agricultural use. Use of compost for sod production can replenish topsoil that is lost during sod harvest and can improve soil chemical and physical properties by increasing plant nutrient supply, organic matter content, water holding capacity, cation exchange capacity, and pH and by decreasing bulk density (McConnell et al., 1993; Rosen et al., 1993). Nitrogen concentrations in composts are higher than in most agricultural soils (McConnell et al. 1993). The N of compost is combined organically, is released slowly, and is resistant to leaching into ground water (Chaney, 1990). These properties help to alleviate concerns about environmental contamination. Large amounts of compost can be applied to land to enrich the soil with N or can be applied as a mulch, which may give dual functions of supplying nutrients and suppressing weeds.

Further concerns about problems with contamination from municipal solid wastes have been minimized through sorting and recycling before composting (Rosen et al., 1993). Other problems that need to be addressed are immaturity and varying composition of compost. Immature composts may be high in ammonium concentrations and soluble salts in the final product (Inbar et al., 1990; He et al., 1992). Ammonium or soluble salts can impede plant establishment and subsequent growth (Cisar et al., 1992). High soluble salts in composts have had phytotoxic effects on plant growth in greenhouse experiments (Chanysak et al., 1983). However, soluble-salt problems in the field are believed to be minimized by dilution with compost incorporation into the plow layer. Leaching of soluble salts by precipitation and irrigation water also decreases the soluble salts in land-applied composts (McConnell et al., 1993). However, conflicting results have been reported showing that soluble salts can accumulate in agricultural soils amended with compost, particularly with repeated applications (Bevacqua and Mellano, 1993).

The objective of this study was to evaluate the suitability of field-applied solid waste composts of different compostable materials for production of wildflower and grass sods. Composts were applied as a mulch to the soil surface or worked into the top 2 inches of soil. Several physical and chemical characteristics of composts including ammonium-N and conductivity were measured to evaluate effects of compost maturity and soluble salts on the growth of wildflowers and grass.

Materials and Methods

Composts were delivered on about 1 June 1993 and were held in piles without turning for 2 weeks until they were applied to the land. Composts were derived from cocomposted mixed municipal solid wastes (MSW) including biosolids (Delaware Solid Waste Authority, Dover, Del.), biosolids and woodchips (Springfield, Mass., Wastewater Treatment Plant), agricultural wastes including cocomposted cranberry fruit pomace and chicken manure (MassNatural, Westminster, Mass.), and autumn leaves (Springfield, Mass., Wastewater Treatment Plant).

Composts differed considerably in bulk density, percent dry matter, conductivity, pH, and N composition (Table 6.1). The initial total N concentrations in biosolids-woodchips at 2.86 % (dry wt) was higher than that in all other composts, being more than twice the concentration in mixed MSW or agricultural compost. The leaf compost had the lowest total N (0.64 %) concentration of the four composts. Ammonium-N concentration differed widely with source of compost. The ammonium-N concentration in the biosolids-woodchips was 2,690 mg/kg (dry wt), higher than that in any of the other composts. The initial conductivities of the composts, measured in a saturation extract (Richards, 1954), differed with source of compost. The conductivities of mixed MSW, biosolids-woodchips, and agricultural composts were sufficient to affect plant growth if the plants were grown in pure compost (Richards, 1954). Leaf compost conductivity was 0.51 mmho/cm, the lowest conductivity of the four composts. The biosolids-woodchips compost had lower bulk density, lower pH, and higher percent dry matter than the other composts.

Composts were applied on field plots of Winooski silt loam (Table 2). Plots were 3.66-m squares (13.4 m^2 or 144 ft^2). Nitrogen application varied due to differences in compost composition (Tables 6.1 and 6.2). The N-rich mixed MSW, biosolids-woodchips, and agricultural composts carried more N than the leaf compost or that applied to the fertilized plots.

The wildflower mixture (Northeastern mix, Vermont Wildflower Farm, Charlotte, Vt.) included 25 species, 13 of which did not appear or were too sparse to be noted in this study (Table 6.3). The rate of seeding was 4.8 g/m^2 (1 lb. per 1000 sq ft.). Seeds were mixed with sawdust to ensure uniform coverage.

Perennial ryegrass seeds (Lolium perenne L. 'Pennfine') were raked into the surface at 29 g/m^2 (6 lb per 1000 square ft.). Grass seeds were spread uniformly without dilution. Irrigation was supplied at least weekly by overhead sprinklers for establishment of wildflowers and grass.

Composts were applied to give a one-inch-thick layer on the surface of the plots. In half of the plots, the composts were left on the surface as a mulch. In the other half, composts were raked into the top 2 inches of soil. Types of composts were arranged in 4 randomized complete blocks split for method of application (incorporation vs. surface application). A plot fertilized with 0.024 kg N/m^2 (5 lb N/1000 ft^2) from a 15 % N, 8 % P_2O_5, 12 % K_2O fertilizer and a plot with no application treatment were included in each block.

Growth responses of grass and wildflowers were assessed by:

1. Establishment of stands
2. Quality (visual assessment of stand)
3. Purity of stand (weediness, wildflower species)
4. Biomass
5. Species diversity
6. Flowering index
7. Nitrogen composition

Establishment of grass was assessed at 3 weeks after seeding by indexing uniformity and density of stand (cover index: 0 to 100; 0 = poorest stand, no coverage; 100 = best stand, dense and full coverage of plot). Using the same scale, stands were assessed at 6 weeks after seeding for uniformity and density of stands of grass and wildflowers. Also at 6 weeks, shoot biomass was harvested. Weeds and the crop plants were separated, and dry weights of each group were recorded. Total N in plant tissues was measured (Bradstreet, 1965). After 8 weeks of growth, species diversity of wildflowers was assessed by counting all species in 0.25 m^2 (0.5-m quadrate) of each plot.

In the first year, the surface inch of each plot was sampled at 0, 2, 4, and 9 weeks after seeding. Nitrogen composition of samples was determined by the Kjeldahl procedures (Bradstreet, 1965; Bremner, 1965). Conductivity was measured on 1:2 (w:v) soil:water extracts of soil or compost samples (Richards, 1954).

On 6 June 94, about 1 year after seeding, second-season species diversity was assessed by counting of species in a 0.5-m quadrate. Biomasses of wildflowers, grass, and weeds were determined on 5 July 94. Grass, wildflowers, and weeds were indexed visually for uniformity and density of stand in July (0 to 100; 0 = poorest coverage, no coverage; 100 = best coverage, full coverage of entire plot). Flowering was indexed visually (0 to 5; 0 = absence of a given species; 5 = showy, profuse bloom covering entire plot) in June and July to evaluate the impact of compost on second-year flowering.

Results

Performance of Grass in Different Field-Applied Composts

First-year Growth. Grass was seeded on 15 June 1993. Three weeks after seeding, germination of grass and weeds was lower in the compost-treated plots than in the conventionally fertilized or unfertilized plots (Table 6.4). No significant difference for grass germination occurred among the different sources of composts. Weed coverage exceeded that of the grass in all plots. More weeds emerged in the leaf compost than in any other compost. Weed emergence was higher in the unfertilized plots than in the other media. Method of application of compost (incorporation or mulch) had no effect on grass or weed emergence.

At 6 weeks, stands of grass in fertilized or unfertilized plots were at least twice those in the compost-treated plots (Table 6.5). Stands of grass in the biosolids-woodchips compost were similar to the stand in the mixed MSW, but sparser than those in the agricultural or leaf composts. Stands of grass did not vary with method of application. No differences in stands of weeds at 6 weeks occurred among compost sources or between method of application.

Growth also was measured at 6 weeks after seeding (Table 6.5). Mean harvest weights for grass grown in agricultural compost or in fertilized or unfertilized plots were higher than those for grass grown in mixed MSW, biosolids-woodchips, or leaf composts. Weed weights were higher in compost-treated plots and in the fertilized plots than in the unfertilized plots. Weed clipping weights varied with compost source. Weed growth was lower in agricultural and in leaf composts than in biosolids-woodchips compost, in which weed weights were similar to those from the mixed MSW compost. Clipping weights of grass or weeds did not vary with method of compost application.

Second-Year Growth. On 3 June 1994, about 1 year after seeding, mean harvest weights of grass were higher in compost-treated plots and in fertilized plots than in the unfertilized plots (Table 6.6). Plots treated with mixed MSW, biosolids-woodchips, or agricultural composts had higher grass dry weights than those with any other treatment. Growth of weeds at this time was too small to measure under the dense canopy of grass. The best grass stands were in the unfertilized plots, although these plots appeared N deficient. Stands in the fertilized plots were significantly greater than those in plots receiving mixed MSW or biosolids-woodchips compost. Grass stands did not differ statistically among sources of compost, although plots with the biosolids-woodchips compost had many bare spots, remaining from poor stands in the first year. Incorporation or surface application of compost had no effect on grass harvest weights or grass stands.

Performance of Wildflowers in Different Field-applied Composts

First-Year Growth and Flowering. Wildflowers were seeded on 15 June 1993. Three weeks after seeding, germination was too small to measure. At 6 weeks, no significant difference in wildflower or weed dry weights occurred among treatments (Table 6.5). However, weed harvest weights were 2 to 4 times that of wildflower weights. Stands of wildflowers after 6 weeks of growth were less in compost-treated and in fertilized plots than in unfertilized plots. Weed populations were densest in the mixed MSW and fertilized plots and were sparsest in the biosolids-woodchips compost and in the unfertilized plots. Weed stands were much greater than wildflower stands in all media except the unfertilized plots. Wildflower or weed stands or harvest weights were not affected by method of application of compost.

Species diversity and density of plants were measured at 6 weeks after seeding (Table 6.7). The unfertilized plots had greater density of plants than the other media. Black-eyed Susans grew better in unfertilized or fertilized plots than in compost-treated plots. Coreopsis grew better in unfertilized plots than in any other media.

The biosolids-woodchips compost hindered growth of most species. Flowering in the first season was minimal in all media and was related to shoot growth of wildflowers and inversely related to weed growth. Only the unfertilized plot produced a showy floral display. This display included baby's breath, coreopsis, cosmos, and poppy species. All other compost-treated and fertilized plots were dominated by weeds, which inhibited and obscured wildflower growth and flowering. Method of application of compost did not affect species diversity and density of wildflowers.

Second-Year Growth and Flowering. On 6 June 1994 of the second season, biomasses of wildflowers were measured. Mean wildflower harvest weights in the leaf compost were similar to those in the agricultural compost and unfertilized plots, but greater than the harvest weights in the mixed MSW, biosolids-woodchips composts, or fertilized plots (Table 6.6). Wildflower stands in leaf compost, agricultural compost, or in unfertilized plots were similar and were greater than stands in the other media. Biosolids-woodchips compost had the poorest stand of wildflowers. Weed growth exceeded wildflower growth in the biosolids-woodchips plots, whereas wildflower growth exceeded that of the weeds in all other media. Average weed dry weight was nil in the leaf compost or the unfertilized plots. This trend of wildflowers dominating weeds in the stand was the reverse of that observed in the first season. Method of application (mulch or incorporation) of compost had no effect on growth of wildflowers or weeds in the second season.

Species diversity and density of wildflowers were measured on 6 June 1994 (Table 6.7). The unfertilized plots had the greatest density of species relative to stands in the other media. Specifically, more black-eyed Susan, ox-eye daisy, and coreopsis grew in unfertilized plots than in the other media. Stands of coreopsis were poor in plots with fertilizer, mixed MSW compost, or biosolids-woodchips.

On 6 June and 5 July 1994, flowering was indexed visually (Table 6.8). In June, dame's rocket, ox-eye daisy, poppy, coreopsis, and wallflower were flowering. Total flowering was poorest in the plots with biosolids-woodchips compost and was best in the plots with leaf compost or no fertilizer. However, total flowering in the mixed MSW, agricultural composts, or in the fertilized soil was similar to that in the leaf compost or in unfertilized soil. Flowering of dame's rocket and ox-eye daisy with intermixed poppies gave a beautiful floral display. In July, black-eyed Susan, ox-eye daisy, poppy, coreopsis, catch-fly, and rocket larkspur dominated the display. Best flowering occurred in the plots treated with agricultural, mixed MSW, and leaf composts. Plots treated with biosolids-woodchips had the worst overall flowering of all the media. Overall flowering in plots with the agricultural compost was similar to flowering in the mixed MSW and leaf composts, but better than the overall flowering with the other media. Overall flowering was better with the leaf compost than in the unfertilized soil, but the display consisted mainly of black-eyed Susans. In the unfertilized plots, black-eyed Susans also dominated. In plots receiving agricultural, mixed MSW, or leaf composts, all 6 species were flowering. Flowering of poppy and rocket larkspur was not affected by treatment. Little flowering occurred in plots treated with biosolids-woodchips, with wild lettuce (Lactuca serriola L.) overwhelming the wildflowers in these plots.

Total Nitrogen in Grass and Wildflower Tissues

After 6 weeks of growth, total N in grass and wildflower tissues reflected the amount of N in the media (Table 6.9). The highest total N was in tissues grown with biosolids-woodchips. Grass grown in unfertilized soil had similar total N to grass grown with agricultural or leaf compost or in fertilized soil, but lower total N than grass grown with mixed MSW compost. Wildflowers grown in unfertilized media had lower total N than grass grown in the other media. Wildflowers grown in plots with mixed MSW compost, agricultural compost, or fertilized media had similar total N.

Ammonium, Total Nitrogen, and Electrical Conductivity in Composts

Samples of soil and compost taken during 9 weeks after application were analyzed for ammonium-N and total N. Ammonium-N in biosolids-woodchips compost initially averaged 2,349 mg/kg dry wt and rapidly decreased to 332 mg/kg in 4 weeks and to 82 mg/kg by 9 weeks (Figure 6.1). Fertilization of soil increased ammonium-N to 772 mg/kg which rapidly decreased to 33 mg/kg after 4 weeks. In the agricultural compost, ammonium-N decreased from 191 mg/kg to 32 mg/kg in the same time. The total N in the media did not change over the 9-week period, remaining at the initial level (Table 6.1). No significant differences in ammonium-N or total N in the media occurred between surface application or incorporation of composts.

Electrical conductivities were measured in the fresh composts after application using 2:1 (water:medium) extracts. Conductivities in mixed MSW, biosolids-woodchips, and agricultural composts indicated that soluble salts were initially high enough to affect plant growth. Conductivity was measured during 9 weeks. Conductivity in mixed MSW, biosolids-woodchips, and agricultural composts declined with time to levels that would not affect plant growth after 2 to 4 weeks (Figure 6.2). Surface application of compost had an average overall higher conductivity (1.8 mmho/cm) than compost that was worked into the top inch of soil (1.5 mmho/cm).

Discussion

Source of medium affected establishment of grass and wildflower sods. The compost-treated plots were more vulnerable to surface drying than bare ground; consequently, the stands of grass and weeds after 3 weeks were less in plots treated with compost than in plots with bare soil surfaces. This effect was also evident on grass stands and harvest weights at 3 and 6 weeks. Weed populations were at least 2 times the grass populations in the plots treated with compost after

3 weeks. Mixed MSW and biosolids-woodchips composts were more restrictive than the other composts in inhibiting grass growth. These media had sufficiently high levels of soluble salts to inhibit seedling growth. Biosolids-woodchips compost had high NH_4-N concentrations in addition to high soluble salt concentrations and produced the poorest stands and growth of grass. Mixed MSW had the highest soluble salt concentration and relatively low NH_4-N concentrations but also produced poor stands and low harvest weights of grass. The lower grass harvest weights in the mixed MSW and biosolids-woodchips composts may have been due in part to weed competition, for weeds responded well to the abundance of N supplied by these composts. At 6 weeks, the fertilized and unfertilized plots had better coverage with grass than with weeds; however, the fertilizer stimulated weed growth as well as grass growth.

In the first season, competition from weeds hindered growth of wildflowers. Weeds responded well to the abundance of N in the mixed MSW and agricultural composts and fertilized soil. The lower stands of weeds in biosolids-woodchips compost than in the above media is deemed to be a result of the high concentrations of NH_4-N, which hindered all plant growth. The lower stands of weeds in leaf compost and in the unfertilized media were attributed to N deficiency in these media.

Growth of grass and wildflowers in the second season improved. Grass and perennial and biennial wildflowers established in stands in the first year had a competitive advantage over annual weeds. Weeds were too small or too sparse to measure in the grass plots in the spring of the second year. In the second year, stands of grass were the best in the unfertilized plots, but harvest weights of grass in those plots were the lowest compared to the those of other media. No fertilizer was applied after the initial application in the first season. The grass clipping weight was limited by the low fertility in the unfertilized plot. In comparison, the fertilized plots had greater harvest weights, but a less dense stand of grass. The highest grass harvest weights were in the mixed MSW, biosolids-woodchips, and agricultural composts, all of which are relatively N-rich media. The high grass harvest weights in these media were in response to the abundance of N remaining available in these composts, since N in composts was generally in an organic form. In contrast, most of the N from chemical fertilization likely was leached or taken up by plants in the first season.

Bare spots occurred with both crops in plots treated with biosolids-woodchips compost. This damage was attributed to the initial high ammonium concentration in this compost and to its restrictive effects on germination, stand establishment, and first-year growth. Weeds were a problem in the bare spots in the plots treated with biosolids-woodchips compost, especially in the wildflowers. In the first season, flowering was inhibited in most compost-treated plots and in the fertilized plots by weed competition that limited wildflower growth, diversity, and floral display. The unfertilized plot was the only one to produce a floral display in the first season. Baby's breath, coreopsis, cosmos, and poppy were the dominating flowering species. All other plots were dominated by weeds, which seemed to benefit more from increased N nutrition than the wildflowers.

Flowering in the second season greatly improved over that in the first year with distinct differences in the floral display. Early in the second season, unfertilized plots had the greatest diversity of species and highest density of wildflowers. Black-eyed Susan, ox-eye daisy, and coreopsis were more frequent in the unfertilized plots than in the other media. The compost-treated plots showed improvement in diversity and total number from the first year. The most dramatic change in wildflower growth from the first year took place in the leaf compost where stands and harvest weights greatly increased. In the first year, leaf compost had low N and low state of decompostition (many leaf fragments were readily recognizable). The additional year of decomposition made conditions more conducive for grass and wildflower growth in leaf compost.

In June of the second year, flowering was affected by the media and related to the ability of the species to become established and grow in the media. Overall flowering was poor in the biosolids-woodchips compost. Flowering in the leaf compost was diverse and dense. A mixture of dame's rocket and ox-eye daisy dominated the flowering, and poppy, coreopsis, and wallflower added color to create a spectacular floral display. In the unfertilized plots, the flowering was dominated by ox-eye daisies with some poppy, dame's rocket, and coreopsis. Ox-eye daisy flowered better in unfertilized plots or in leaf compost than in all other media. Ox-eye daisy appears to flower better in N-poor media than the other flowering species.

In July of the second year, the differences in flowering responses of species in different media again was related to the ability of the species to become established and grow in the media. However, at this time more flowering diversity occurred in the N-rich media, except that with the biosolids-woodchips compost, which at time of application was an immature compost high in ammonium. Even though biosolids-woodchips compost was N-rich, overall flowering was lower and less diverse than in the other media. This response was to be expected since very few wildflowers grew in the first season in the biosolids-woodchips compost. Growth and diversity was best in the unfertilized plots, but flowering did not reflect the diversity of wildflowers present. Black-eyed Susans dominated the flowering in the unfertilized plots creating a monoculture of floral display. Flowering in the leaf compost, also a N-poor medium, was also dominated by black-eyed Susan. Black-eyed Susan grew better than other species in these low N media and outcompeted other wildflower species producing a less desirable monoculture display. Agricultural and mixed MSW media produced the best diverse and colorful floral displays of the media in July. This display lasted until mid-September.

<u>Conclusions</u>

Quality of grass or wildflower growth differed little with whether the compost was applied as a 1-inch mulch or shallowly incorporated. Neither of these practices impeded weed growth in the first year. High salts and high ammonium in some media and weed competition in all media were major factors limiting quality of growth in the first year. Weeds out-competed annual wildflowers in all plots except the unfertilized ones and caused a virtual loss of floral display in the first season. Frequent mowing of the grass gave a setback to annual broadleaf weeds, but crabgrass was always a serious problem. In the second year, grass and wildflowers had a competitive advantage over weeds, except in plots with biosolids-woodchips compost. The biosolids-woodchips compost was immature. High ammonium concentrations in the initial product limited establishment of stands and plant growth. The resulting poor quality of growth gave bare spots which never filled in with crop and which became occupied with annual weeds in the second season.

The N status of the media was an important factor in quality of stands. An abundant supply of N without some weed-control practices resulted in a poor quality of crop in the first year with vegetation of most plots being dominated by annual weeds. Although flowering occurred in unfertilized plots and grass density was good, total growth was limited by nutrient deficiencies, especially in the second year. In the second year, crops had a competitive edge over weeds, and high N status in the media improved crop quality. Grass had a better color and higher clipping weights in the fertilized and compost-treated plots than in the unfertilized plots. Quality of wildflower bloom with respect to total amount of bloom and diversity of species improved as the N status of the media increased and as the season progressed.

For best success in establishing high quality grass sods or wildflower meadows in fields, growers should obtain a mature compost with readily available N and apply it to soil either as a surface or soil-incorporated application. Weed control is required for high crop quality in the first season (Barker and O'Brien, 1994). Researchable practices for weed control are application of thick layers of compost as mulches (perhaps 2-inch layers rather than 1-inch layers), application of the mulch in conjunction with an underlying barrier (sheets of permeable or impermeable materials) to weed emergence, or application of selective herbicides (premergent types below the mulch or postemergent types on the its surface) in combination with the mulches (Barker and O'Brien, 1995).

Concluding remarks

Composts varied in their capacity to support growth of plants under field conditions. A mature compost with readily available N and low soluble salt concentrations was required for high crop quality. Wildflower diversity and total amount of bloom improved as the N status of the media increased. Weed growth was stimulated by fertilizer or N from composts, resulting in poor crop quality in the first season. In the second season, grass and wildflowers had a competitive advantage over the annual weeds, and crop quality improved as the N status of the media increased.

Results from the field experiments indicated that weed control was necessary to get high crop quality in the first season. Based on these results, the next step in my research was to control weeds while maintaining the nutritional benefits provided by the composts. Experiments were run using frames lined with plastic to grow grass and wildflowers. In these experiments, mature or immature composts were used, and ammonium and nitrate contents in the media were monitored as a function of time. Germination, stand establishment, biomass production, diversity, and flowering responses of grass or wildflowers were assessed for each medium.

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Table 6.1. Characteristics of composts applied to land.

Compost	Bulk density (Mg/m$_3$ dry)	Dry matter (%)	EC (mmho/cm)	pH	Nitrogen: Total N (%)	Nitrogen: NH_4-N (mg/kg)
Mixed MSW	0.46a	56b	9.07a	6.4b	1.21b	119b
Biosolids-woodchips	0.31c	72a	7.73ab	5.3c	2.86a	2690a
Agricultural	0.41b	49c	4.95b	6.6a	1.26b	199b
Leaf	0.45a	60b	0.51c	6.4b	0.64c	34b

Within columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \le 0.05$).

Table 6.2. Amounts of compost, fertilizer, and nitrogen applied to land.

Material	Amount applied (kg/m^2)	Nitrogen applied (kg/m^2)
Mixed MSW	11.4	0.14
Biosolids-woodchips	10.2	0.29
Agricultural	9.9	0.13
Leaf	9.7	0.06
Fertilizer (15-8-12)	0.16	0.024

Table 6.3. List of wildflower species in Northeast mix*.

Common Names	Scientific Names
Annuals	
Plains coreopsis	*Coreopsis tinctoria* Nutt.
California poppy	*Eschscholzia california* Cham.
Cosmos	*Cosmos bipinnatus* Cav.
Orange cosmos	*Cosmos sulphureus* Cav.
Baby's breath	*Gypsophila elegans* Bieb.
Bachelor's Button	*Centurea cyanus* L.
Catchfly	*Silene armeria* L.
Rocket larkspur	*Delphinium ajacis* L.
Biennials	
Dame's rocket	*Hesperis matronalis* L.
Black-eyed Susan	*Rudbeckia hirta hirta* L.
Wallflower	*Cheiranthus allionii* Hort.
Perennial	
Ox-eye daisy	*Chrysanthemum leucanthemum* L.

* 25 species in mixture, but 12 did not appear or were too low to note in this experiment.

List of other species in Northeast Wildflower Mixture

Annuals
Baby blue eyes (*Nemophila menziesii* Nutt.)
Farewell-to-Spring (*Clarkia elegans* Dougl.)
Sunflower (*Helianthus annuus* L.)
Rose Mallow (*Lavatera trimestris* L.)
Scarlet flax (*Linum grandiflorum rubrum* Desf.)

Biennial
Sweet William (*Dianthus barbatus* L.)

Perennials
Blue flax (*Linum perenne lewisii* L.)
Perennial lupine (*Lupinus perennis* L.)
Purple coneflower (*Echinacea purpurea* L.)
Red mexican hat (*Ratibida columnaris* Nutt.)
Gloriosa Daisy (*Rudbeckia hirta pulcherrima* L.)
Lance-leaf coreopsis (*Coreopsis lanceolata* L.)

Table 6.4. Rating of stand establishment of grass and weeds 3 weeks after seeding.

Medium	Stand[z]	
	Grass	Weeds
Mixed MSW	4b	11d
Biosolids-woodchips	1b	11d
Agricultural	8b	11d
Leaf	8b	28c
Fertilized soil	34a	41b
Unfertilized soil	43a	54a

Within columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).

[z]Relative cover of ground expressed as percent by visual indexing.

Table 6.5. Harvest weights and stands of grass, wildflowers, and weeds after 6 weeks of growth.

	Evaluation of crop			
	Stand[z]		Harvest weights (g/m^2)	
Medium	Crop	Weeds	Crop	Weeds
		Grass		
Mixed MSW	11bc	36a	42b	183ab
Biosolids-woodchips	5c	36a	14b	219a
Agricultural	19b	30a	81a	134b
Leaf	20b	34a	36b	126b
Fertilized soil	51a	41a	94a	151b
Unfertilized soil	52a	39a	73a	63c
		Wildflowers		
Mixed MSW	15b	73a	48a	216a
Biosolids-woodchips	1b	33c	52a	240a
Agricultural	14b	70ab	48a	212ab
Leaf	6b	49bc	40a	176a
Fertilized soil	12b	78a	48a	276a
Unfertilized soil	55a	40c	40a	100a

Within columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).

[z]Stand = index of uniformity and density of stand (0 to 100; 0 = no cover, 100 = best stand, dense and full coverage of plot).

Table 6.6. Harvest weights and stands of grass, wildflowers, and weeds on 3 June 1994 of second season.

	Evaluation of crop			
	Harvest weights (g/m^2)		Stand[z]	
Medium	Crop	Weeds	Crop	Weeds
		Grass		
Mixed MSW	756a	0	63c	0
Biosolids-woodchips	778a	0	49c	0
Agricultural	756a	0	68bc	0
Leaf	360b	0	68bc	0
Fertilized soil	404b	0	79b	0
Unfertilized soil	132c	0	96a	0
		Wildflowers		
Mixed MSW	500b	48b	46b	27b
Biosolids-woodchips	424b	552a	17c	72a
Agricultural	700ab	72b	69ab	11b
Leaf	932a	0b	95a	0b
Fertilized soil	504b	32b	64b	17b
Unfertilized soil	740ab	0b	93a	7b[y]

Within columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).

[z]Stand = index of uniformity and density of stand (0 to 100; 0 = no coverage, 100 = best coverage, denxe and full coverage of plot).

[y]Weeds in stand too small to harvest.

Table 6.7. Species diversity and density of wildflowers on 3 August 1993 and 6 June 1994.

Medium	Density wildflower species (number/m^2) and date of counting					
	Wildflower Species 3 August 1993					
	Black-eyed Susans	Baby's Breath	Bachelor Button	Coreopsis	Poppy	Total
Mixed MSW	8bc	4a	4a	20b	8b	52b
Biosolids-woodchips	0c	0a	4a	4b	0b	8b
Agricultural	4c	12a	4a	20b	8b	52b
Leaf	4c	8a	8a	16b	8b	44b
Fertilized soil	24ab	12a	4a	2b	12b	68b
Unfertilized soil	40a	28a	4a	88a	84a	256a
	Wildflower Species 6 June 1994					
	Black-eyed Susans	Dame's Rocket	Ox-eye Daisy	Coreopsis	Poppy	Total
Mixed MSW	8b	12a	16b	0.33cd	12a	60bc
Biosolids-woodchips	8b	4a	0b	0.67cd	4a	16c
Agricultural	8b	12a	12b	2.0bc	4a	52bc
Leaf	40b	16a	16b	3.0b	4a	100b
Fertilized soil	20b	8a	16b	0.0d	16a	56bc
Unfertilized soil	124a	4a	48a	5.0a	0a	196a

Within columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).

Table 6.8. Flowering index on 6 June 1994 and 5 July 1994 of the second season.

Medium	Visual flowering index[z] and date of indexing					
	June Flowering Index					
	Dame's Rocket	Ox-eye Daisy	Poppy	Coreop sis	Wall flower	Total
Mixed MSW	2.5a	2.3b	0.7a	0.8a	0.8a	7.2ab
Biosolids-woodchips	0.5a	0.3c	0.3a	0.7a	0.2a	2.0a
Agricultural	2.3a	2.2b	1.5a	1.2a	0.7a	7.8ab
Leaf	2.5a	3.3ab	0.7a	2.0a	1.3a	9.8a
Fertilized soil	1.7a	2.8b	0.0a	1.5a	0.2a	6.2ab
Unfertilized soil	1.0a	5.0a	2.0a	1.7a	0.0a	9.7a

Medium	July Flowering Index						
	Black-eyed Susan	Ox-eye Daisy	Poppy	Coreopsis	Catch fly	Rocket Larkspur	Total
Mixed MSW	2.3bc	0.5a	1.7a	0.5abc	0.7a	0.3a	6.0a
Biosolids-woodchips	1.2c	0.0b	0.5b	0.0c	0.0a	0.0a	1.7d
Agricultural	3.0b	0.5a	1.7a	1.2a	0.7a	0.7a	7.7a
Leaf	4.7a	0.0b	0.3b	0.8ab	0.3a	0.2a	6.3a
Fertilized soil	2.7b	0.3ab	0.7b	0.0c	0.3a	0.2a	4.2c
Unfertilized soil	5.0a	0.0b	0.0b	0.2bc	0.0a	0.0a	5.2b

Within columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).

[z]Flowering index = visually indexed for uniformity and density (0 to 5; 0 = no bloom, 5 = profuse bloom).

Table 6.9. Total nitrogen in grass and wildflower tissue harvested after 6 weeks of growth in first season (1993).

Medium	Total Nitrogen (% dry wt)	
	Grass	Wildflowers
Mixed MSW	3.13b	3.02bc
Biosolids-woodchips	3.77a	4.16a
Agricultural	2.96bc	3.08bc
Leaf	2.77bc	2.48cd
Fertilized soil	2.75bc	3.58b
Unfertilized soil	2.39c	2.04d

Within columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \le 0.05$).

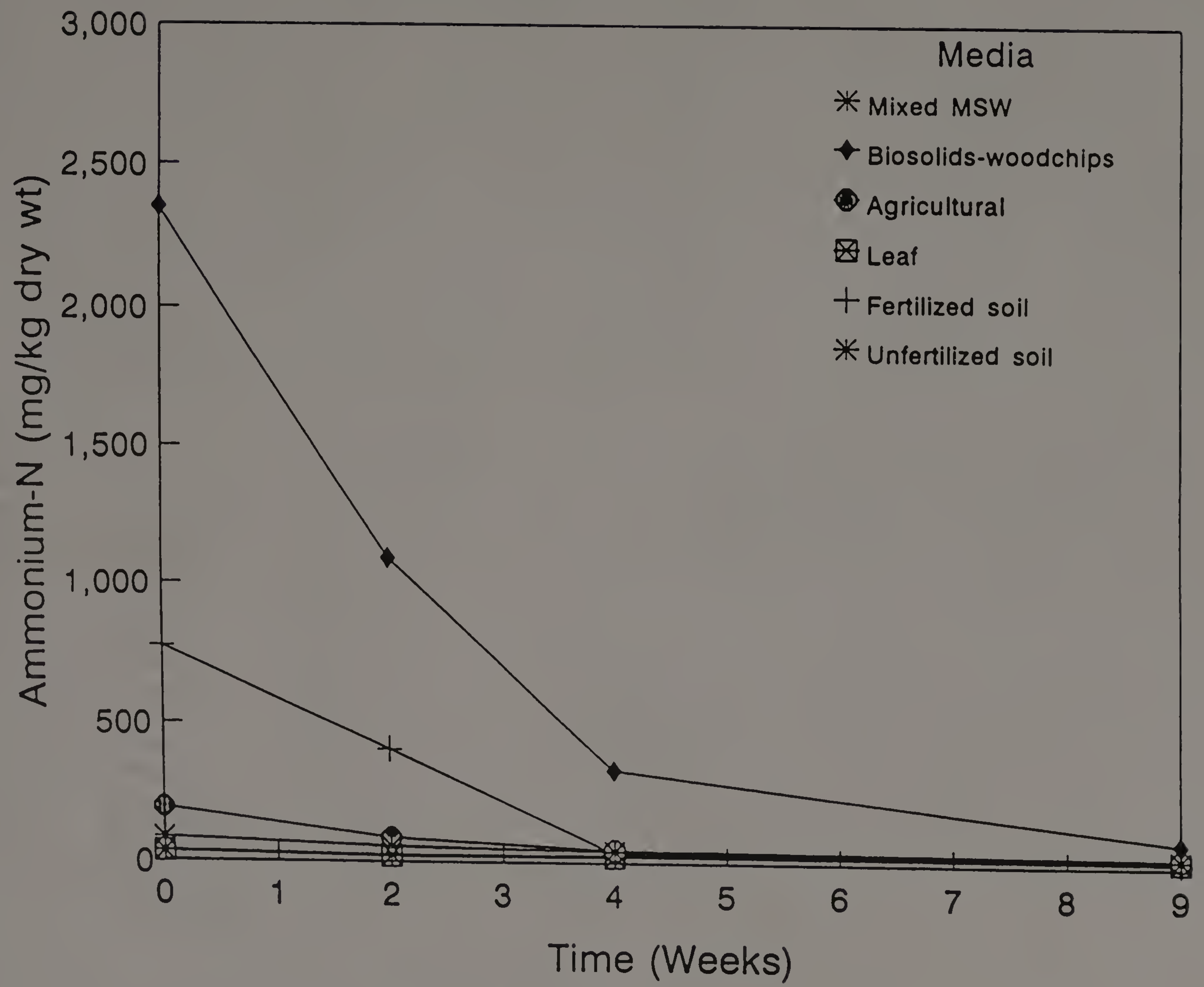

Figure 6.1. Ammonium-N in field-applied compost as a function of time after application of compost to land.

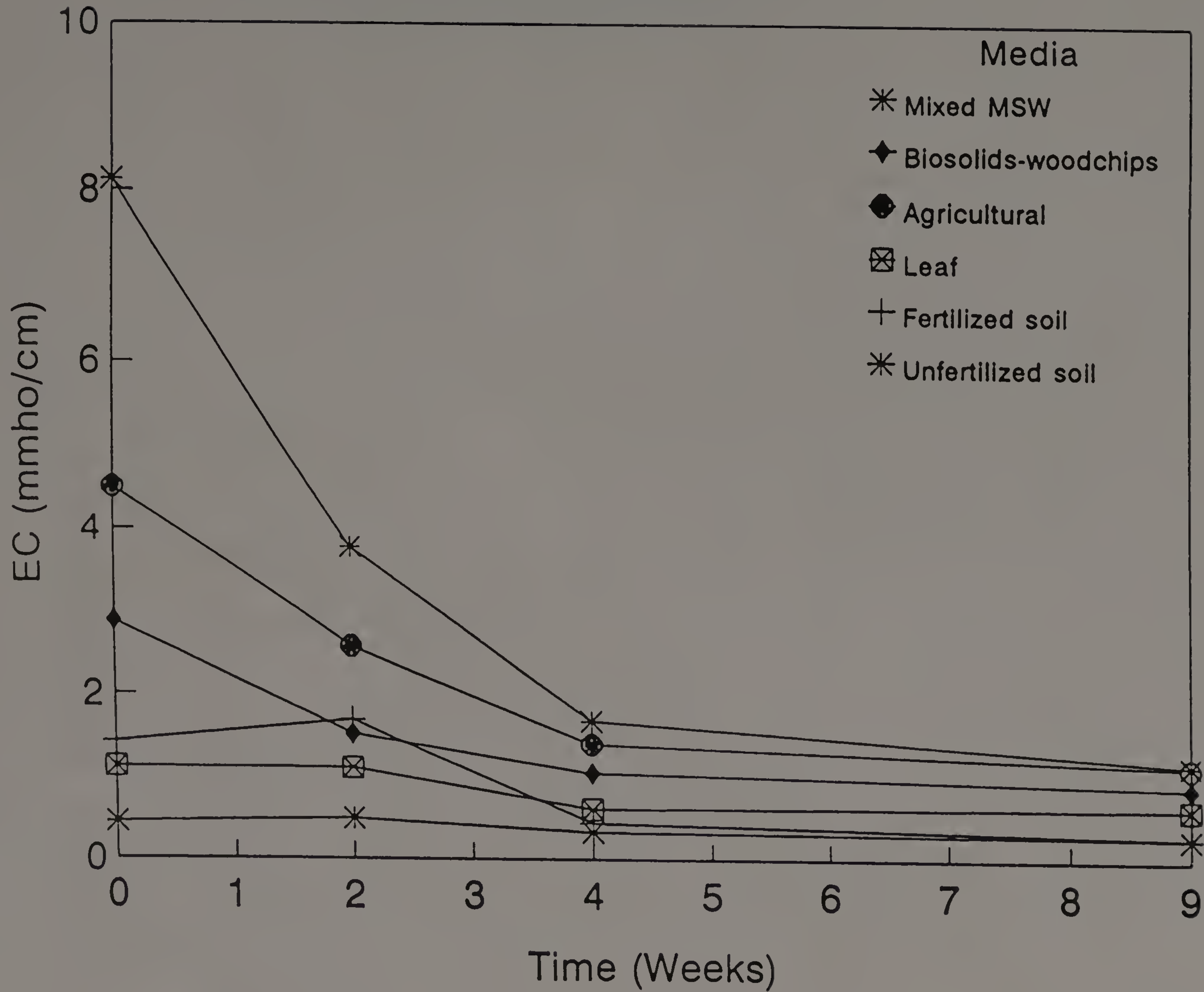

Figure 6.2. Conductivity of field-applied composts as a function of time after application of compost to land. Electrical conductivity was measured in 1:2 (w:v) soil:water extracts.

CHAPTER VII

EVALUATION OF FRESH AND YEAR-OLD COMPOSTS OF SOLID WASTES FOR PRODUCTION OF WILDFLOWER AND GRASS SODS ON PLASTIC

Abstract

Source of compostable materials and length of composting or aging affect quality of composts and their suitability as media for crop growth. In this experiment, year-old and fresh composts of mixed municipal solid wastes (MSW), agricultural wastes (chicken manure and cranberry pomace), and autumn leaves were evaluated for their capacities to support production of perennial ryegrass and mixed wildflower sods. Composts were laid in 5-cm-thick layers on plastic in outdoor plots. Germination, stand establishment, biomass production, and flowering responses of grass or wildflowers were assessed for each medium. Seed germination and stand establishment were sensitive to factors present in fresh, apparently immature composts of mixed MSW or autumn leaves. Subsequent plant growth was limited in these compost largely due to poor establishment of stands. The limiting factors were identified as excessive ammonium in the fresh MSW compost and to inadequate total N in the leaf compost. Aging of the composts increased their value in sod production by lowering the concentrations of ammonium in the MSW compost and by increasing the concentration of N in the leaf compost. Agricultural compost was N-rich and low in ammonium, and aging of this compost had a lesser effect on plant growth than with the other composts. Flowering of annual wildflowers in the first season and early flowering biennial and perennial wildflowers in the second season was better in the mixed MSW or agricultural compost than in leaf compost. Bloom of late flowering species was unaffected or only slightly affected by the source of compost in the second season. The results of this experiment show that a fully mature compost is required for production of high quality sods.

Introduction

Sod production on plastic using composted solid wastes is a practical alternative to sod production on land. Production on plastic essentially eliminates topsoil loss and facilitates harvest by limiting root damage during harvest (Mitchell et al., 1994). Sod production on land can take 1 to 2 years whereas sod production on plastic can reduce production time to 6 to 8 weeks according to results in this experiment and 8 to 12 weeks according to Mitchell et al. (1994). Commercial interest in wildflower sod production is increasing, particularly for the purpose of landscape beautification. Wildflowers reduce maintenance time required for mowing of grass and enhance biodiversity and the ecological and aesthetic value of landscapes. In addition, established wildflower meadows provide erosion stability and habitat and food for wildlife (Ahearn et al., 1991).

If sod growers use compost, municipalities can reduce landfill disposal and benefit solid waste recycling efforts (Cisar and Synder, 1992; He et al., 1992). However, use of compost is not without problems. Immature and varying compositions of compost can lead to substantial concentrations of ammonium and soluble salts in the final product. High ammonium concentrations have been shown to be an indicator of immature compost (Inbar et al., 1990; He et al., 1992). Ammonium-nitrogen or soluble salts can impede germination and subsequent growth (Cisar and Snyder, 1992; Mitchell et al., 1994). However, the benefits realized in using composted municipal solid wastes and the ecological and economical benefits of wildflower sods have led to increased interest in using composted solid wastes for sod production on plastic.

The objective of this study was to evaluate the suitability of solid waste composts of different compostable materials and of two maturities for wildflower and grass production on plastic. The following matters were examined: Effects of compost maturity on seed germination and plant performance; effects of different kinds of composts on germination and subsequent growth; and effects of composts on flowering of specific plant species in wildflower mixtures.

Materials and Methods

Fresh composts were delivered in 1992 and 1993. Composts were from cocomposted mixed municipal solid waste (MSW) including biosolids (Delaware Solid Waste Authority, Dover, Delaware), cocomposted mixed agricultural wastes including cranberry press cake and chicken manure (MassNatural, Westminster, Mass.), and autumn leaves (Springfield, Mass., Wastewater Treatment Plant).

Each compost had two maturities, one maturity being compost a year-old or aged and the other maturity being fresh compost. The aged composts were received in July 1992 and were held in piles without turning and used in July 1993, when this experiment was started. The fresh composts were received in June 1993 and were used also in July 1993. Wildflower and grass seed were sown in two randomized complete blocks in separate experiments for wildflowers and grass.

These composts differed considerably in total N and ammonium-N contents (Table 7.1). The average total N concentration in mixed MSW compost was about 1 % (dry wt) and did not differ with maturity. The total N concentration of the agricultural compost averaged about 1.5 %, also not differing with maturity. The leaf compost had the lowest total N concentration of the three composts, being about 0.8 % in the aged compost and about 0.4 % in the fresh compost. Ammonium-N concentration differed widely with source and age of compost. The ammonium-N concentration in the fresh mixed MSW was 940 mg/kg compared to only 82 mg/kg in the aged mixed MSW compost. The ammonium-N concentrations in the other two composts were much lower than those in the mixed MSW compost and did not differ appreciably between maturities of compost.

The initial conductivities of the composts measured by saturation extraction (Richards, 1954) differed with source and age of compost (Table 7.1). The conductivity in fresh mixed MSW was 5.90 mmho/cm compared to only 1.57 mmho/cm in aged mixed MSW. The conductivity of the other two composts was much lower than that in the fresh mixed MSW and did not differ with age.

The wildflower mixture (Northeastern mix, Vermont Wildflower Farm, Charlotte, Vt.) included 25 species, 13 of which did not appear or were too small or sparse to be noted in this study (see Chapter VI; O'Brien and Barker, 1995a). The rate of seeding was 4.8 g/m^2. Seeds were mixed with sawdust and spread by hand onto a watered surface. The first layer of seeds was watered and seeded again to ensure uniform coverage. 'Pennfine' perennial ryegrass (Lolium perenne L.) was the grass species used. Grass seed was spread uniformly by hand without dilution at about 29 g/m^2.

Frames were constructed into 0.91 m x 1.82 m plots with 2-cm-thick x 9-cm-wide lumber. Black (0.0001-m) plastic slitted for drainage was placed underneath the frames. Each plot filled to 5-cm deep held about 0.083 m^3 of compost. The experiment was run on the campus of the University of Massachusetts at Amherst.

Growth responses of the wildflower and grass sods were assessed by:

1. Germination and establishment at 2 and 3 weeks
2. Quality at 4 or 6 weeks (visual assessment)
3. Purity of stand (weediness, wildflower species)
4. Biomass
5. Flowering index
6. Nitrogen composition

Germination (seedling emergence) was assessed at 2 and 3 weeks by indexing uniformity and density of stand (cover index: 0 to 100; 0 = no stand, no coverage, and 100 = best stand, dense and full coverage of surface). After 4 weeks for grass and 6 weeks for wildflowers, shoot growth was sufficient to mandate a harvest of biomass for determination of dry weight production. Establishment was assessed again on these dates by indexing uniformity and density of stand by the same procedures used at 2 and 3 weeks. Biomass was harvested by clipping of shoots, and dry weights were recorded. Total N in the plant tissues was measured on these samples by Kjeldahl procedures (Bradstreet, 1965). Ammonium-N concentrations (Bremner, 1965) and total N (Bradstreet, 1965) were determined in samples of composts taken from the plots at time intervals of 1 to 3 weeks. In the following season (1994), flowering of individual species was indexed visually (0 to 5; 0 = no bloom, 5 = showy, profuse bloom covering the entire plot) to compare the impact of compost on quality of stand in the second season.

Results

Performance of Grass Sods Grown in Different Maturities of Composts

Grass was seeded on 2 July 1993. Two weeks after seeding, grass germination (seedling emergence) was significantly higher in aged composts than in fresh composts (Table 7.2). Small differences in germination occurred among the different sources of composts. Highest germination occurred in the aged leaf compost. At 3 weeks after seeding, seedling establishment improved in all media (Table 7.2). Grass germination in aged mixed MSW or aged leaf composts was significantly higher than grass germination in fresh media. Grass establishment at 3 weeks was not affected by maturity of agricultural compost. Best improvements in stand over those at 2 weeks were in the fresh mixed MSW and agricultural composts.

Stands were assessed again at 4 weeks (Table 7.3), at which time the plants had grown sufficiently that mowing was considered necessary. Stand establishment remained better in aged composts than in fresh composts. Within aged composts, stands of grass were not affected by source of compost. Within fresh composts, the best stand was established in the agricultural compost, and the worst stand occurred in the leaf compost. Maturity of compost did not have an effect on stand in the agricultural compost, but with the other two composts best stands were established with the aged composts. The best mean stand occurred in the agricultural composts, and the mixed MSW and leaf composts on average were about equal in stands.

Mean dry weights of grass clippings were higher in the aged compost than in the fresh compost (Table 7.3). This trend was evident also with the individual composts, especially with the leaf compost. Mean clipping weights with agricultural compost were more than twice those with the other treatments. Visually the sod in the leaf-based composts appeared N deficient, whereas these symptoms were absent in the sods grown with the other media, which were relatively N rich (Table 7.1).

<u>Performance of Wildflowers Grown in Different Maturities of Composts</u>

Wildflowers were seeded on 2 July 1993. At 2 weeks after seeding, trends for differences in seedling emergence among sources or between maturities of composts were developing but were not yet significant (Table 7.2). At this time, wildflower seed germination (seedling emergence) was inhibited in fresh leaf composts relative to that of wildflowers grown in fresh agricultural and mixed MSW composts. In aged composts, wildflower germination was not significantly different among composts (Table 7.2). Virtually the same trends in stand establishment at 2 weeks were noted at 3 weeks after seeding, with the worst performance being in the fresh leaf compost and with significant differences occurring between maturities.

After 6 weeks of growth (Table 7.3), stands remained better in the aged composts than in the fresh composts. Best stands were established in the agricultural composts, and a significantly better stand was established in the mixed MSW compost than in the leaf compost. Aging of composts diminished the differences in stands among the individual composts. The stand in the fresh leaf compost was very poor, only about 7% coverage of the area.

The mass of wildflower shoots at 6 weeks followed the similar trends as that of the stands (Table 7.3). Shoot masses of plants grown in the aged composts were more than twice those in the fresh composts. Shoot masses in the agricultural composts were at least twice those produced in the other media regardless of maturity. Higher masses were produced with aged agricultural compost than with fresh agricultural compost. Larger masses occurred also with the aged leaf compost than with the fresh leaf compost. Maturity of compost had a small but nonsignificant effect on shoot weights in the mixed MSW compost.

Flowering Performance

In the first season, coreopsis, cosmos, and baby's breath were the dominating flowering species. Their flowering responses were related to plant growth (Table 7.2). Large plants such as cosmos and coreopsis dominated in N-rich mixed MSW and agricultural media, whereas baby's breath was dominant in the leaf compost. The cosmos flowered until a killing frost on 12 October 1993, but the other species stopped flowering before this date. Weights of cosmos shoots harvested on the date of the frost indicate their response to the N-rich media. The mean weights were 142 g/m^2 in mixed MSW compost, 247 g/m^2 in agricultural compost, and 87 g/m^2 in leaf compost. The mean weights of cosmos shoots were 215 g/m^2 in aged compost and 102 g/m^2 in fresh compost.

In June 1994, the second season, flowers were indexed visually (0 to 5; 0 = no bloom, 5 = showy, profuse bloom covering the entire plot) (Table 7.4). Dame's rocket, ox-eye daisy, and wallflower were flowering at this time. Dame's rocket flowered significantly better in the agricultural compost than in the mixed MSW and leaf composts. Also dame's rocket flowered significantly better in mixed MSW compost than in leaf compost. Ox-eye daisy flowered better in agricultural compost than in mixed MSW or leaf compost, and wallflowers flowered the same in all composts. In June, ox-eye daisy was the only species to be affected by compost maturity. Ox-eye daisy flowered significantly better in fresh composts (mean index = 4.17) than in aged composts (mean index = 2.83).

By July 1994, the above biennials ended flowering, and coreopsis, black-eyed Susan, bachelor's button, catchfly, baby's breath, and ox-eye daisy were flowering (Table 7.4). Black-eyed Susans and coreopsis dominated the flowering display. Black-eyed Susans flowered significantly better in leaf compost than in agricultural compost. Flowering of coreopsis, bachelor's button, catchfly, baby's breath, and ox-eye daisy was not significantly different among sources of composts. Coreopsis flowered significantly better in fresh composts (mean index = 4.17) than in aged composts (mean index = 2.83). Flowering of the other species was not affected by the maturity of the compost.

Total Nitrogen in Grass and Wildflower Tissues

After 6 weeks of plant growth in the composts, total N concentration in grass tissue was significantly higher for grass grown in agricultural compost than in mixed MSW or leaf compost (Table 7.5). Total N in wildflower tissues of plants grown in different sources of compost was not significantly different. Total N in grass or wildflower tissues was not affected by compost maturity.

Ammonium and Total Nitrogen in Composts

For samples taken from the plots at the time the experiment was established and at intervals over a 6-week period, ammonium-N in mixed MSW compost (1993) was initially 1,067 mg/kg dry weight and rapidly decreased with time to a constant level (Figure 7.1). In all other composts, the mean NH_4-N concentrations were less than 150 mg/kg dry weight and did not vary much with time. Total N in composts was measured for 6 weeks. The total nitrogen in composts did not change over the 6-week period, remaining at the same level reported in Table 7.1.

Discussion

This system of growing wildflower sods and grass sods in compost on plastic was very successful. Production time to get a marketable grass sod was 4 weeks and to get blooming wildflowers was 8 weeks. The advantages of using this system as a research tool are many. The self-contained plastic frames prevent growth of weeds through compost from the soil below and provide a barrier so that all rooting of sods occurs only in the compost media. These conditions are conducive for evaluating fertility (nutrient supply) in compost.

Maturity of composts affected establishment of grass and wildflowers. Grass and wildflower growth was better in aged compost than in fresh compost of any origin. In general, growth of grass and wildflowers was better in agricultural compost than in mixed MSW or leaf composts. The inhibitory effects of the mixed MSW and leaf composts may be due to their immaturity, for sod production in these composts improved with compost aging. Wildflower growth was better in aged agricultural compost than in fresh agricultural compost, but grass growth did not differ with maturity of agricultural compost. The low N concentration and low state of decomposition (many leaf fragments readily recognizable) in the fresh leaf compost were indicators of immature compost. The high initial ammonium concentration in the fresh mixed MSW compost is deemed responsible for inhibited germination and poor subsequent growth (Barker et al., 1967; Maynard and Barker, 1967). High initial ammonium concentrations are an indicator of immaturity (Inbar et al., 1990; He et al., 1992). Aging reduced the ammonium concentrations in mixed MSW and agricultural composts.

The total N in the wildflowers did not differ with maturity or sources of composts. The wildflowers sample was a composite of several species, some of which may have strong capabilities of accumulating N. Also, wildflower growth was poorer in leaf and mixed MSW composts than in agricultural compost, and N in tissues may have been concentrated due to this lack of growth. Determination of total N in wildflower tissues does not appear to be a good assay of the N status of wildflowers. On the other hand, grass showed differences in total N with different composts, and total N appeared to indicate the N status of grass and the capacity of compost to supply nitrogen. Grass grown in agricultural compost had significantly higher total N than grass grown in other media.

Flowering of annual wildflowers in the first season was related to the growth of the sods in response to the media. The relatively N-rich agricultural and mixed MSW composts supported good growth of cosmos, bachelor's button, and coreopsis, which bloomed profusely. The growth of these plants was poor in the leaf compost, but baby's breath and a few annual poppies bloomed and gave good color to the growth in the leaf compost.

In the second year, biennials and perennials were the first to bloom. In June of the second year, ox-eye daisy, dame's rocket, and wallflower dominated the bloom. Best appearing bloom of these species generally occurred in the agricultural and mixed MSW composts. These species bloomed until about July 1. The bloom in July was dominated by coreopsis and black-eyed Susan. The bloom of these species lasted until mid-August and did not differ much among the media, except that bloom of black-eyed Susan was superior in the leaf compost. Another general observation was that coreopsis flowered better in the fresh composts than in the aged composts during the second season.

The differences in flowering responses of species in the different media appear to be related to the ability of the species to become established and to grow in the media. More diversity of species occurred in the N-rich media. This response gave better bloom with the annuals in the first season and with the biennials and perennials in the second season, thereby giving a longer lived bloom and more colorful bloom in two years. Black-eyed Susan did not require a fertile medium and flowered well regardless of age or source of compost. The better bloom of the annual coreopsis in the less mature medium in the second season could have been due to slightly better nutrition in leaf medium than in the more mature leaf medium after overwintering and to a better chance for reseeding to occur in the sparsely populated fresh leaf medium. The summer bloom in the first season indicated a better response of annuals to the N-rich media than to the less fertile media.

At 4 weeks, grass needed mowing, and at 6 weeks, wildflowers were initiating bloom. The grass sods had a high tensile strength from their intermeshed masses of roots. Wildflower sods also had well established roots allowing for easy transplanting. These conditions suggest that sods were at marketable stage of growth. In previous work (Mitchell et al., 1994) on wildflower production on plastic, sods were marketable after 8 to 12 weeks. Mitchell et al. (1994) suggested that soluble salts caused delays in production time and believed that salts were leached after 7 to 10 days. Since Mitchell et al. worked with fresh mixed MSW compost, ammonium in the compost also could have been a factor hindering growth. Current research (O'Brien and Barker, 1995b) shows that ammonium also dissipates after 7 to 10 days correlating with the responses recorded by Mitchell et al. Soluble salts may have been a factor hindering growth in mixed MSW compost, for Richards (1954) suggests that conductivity above 2.0 mmho/cm (saturated extract) may hinder plant growth. The conductivity of saturation extract of fresh mixed MSW compost was 5.90 mmho/cm, indicating that salinity may have been an inhibiting factor in this compost.

In general, the best vegetative growth was with aged compost of any source. Aging of compost improved capacity of all composts to support sod growth apparently as a result of reductions in ammonium-N or soluble salts and increases in availability of total N in the media. Agricultural compost was superior to the other composts because of its combined qualities of low ammonium and low soluble salts and favorable total N content.

Concluding remarks

Length of composting or aging affects quality of composts and their capacity as a media for crop growth. High ammonium or inadequate total N were factors that hindered germination and growth and were associated with immaturity. Aging of the composts increased their value by lowering the concentrations of ammonium and increasing the concentration of N. Flowering of annuals and in the first season and early flowering biennial and perennial wildflowers in the second season was better in the N-rich media (MSW and agricultural) than in the compost with inadequate N (leaf). Results show that a fully mature compost was required for production of high quality sods. The next step in my research was to grow wildflowers in frames lined with plastic with composts, soil (fertilized and unfertilized), or sawdust as the source of nutrition. Wildflowers were seeded in the July and September in separate experiments, and germination of seeds and quality of sod were assessed for two seasons.

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Table 7.1 Nitrogen concentrations and conductivities of aged and fresh composts at initiation of experiment.

Compost	Nitrogen concentration, dry wt					
	Ammonium-N (mg/kg)		Total N (%)		Conductivity[z] (mmho/cm)	
	Aged	Fresh	Aged	Fresh	Aged	Fresh
Mixed MSW	82	940	0.96	1.00	1.57	5.90
Agricultural	120	170	1.52	1.47	1.85	2.40
Leaf	30	30	0.82	0.45	1.28	1.21

[z]Saturated extract

Table 7.2. Effects of source and maturity of compost on wildflower and grass seedling emergence.

Compost	Seedling emergence, cover index[z]					
	Grass			Wildflowers		
	Compost maturity			Compost maturity		
	Aged	Fresh	Mean	Aged	Fresh	Mean
			2 weeks			
Mixed MSW	63	28	46ab	62	38	50a
Agricultural	63	22	42b	50	53	52a
Leaf	75	34	54a	53	5	29a
Mean	67	28*		55	32	
			3 weeks			
Mixed MSW	77	62	70b	68	52	60a
Agricultural	80	75	78a	70	58	64a
Leaf	72	55	64b	70	7	38a
Mean	76	64		69	39*	

[z]Cover index: assessment of uniformity and density of stand; 0 to 100, 0 = no stand, no coverage, and 100 = best stand, dense and uniform coverage of surface.

*Means of years significantly different by F-test ($P \leq 0.05$). Means for sources are significantly different if followed by different letters within time of measurement. Interaction of source x maturity, nonsignificant at 2 weeks; LSD (0.05) = 6 for grass and 22 for wildflowers at 3 weeks.

Table 7.3. Stands and dry weights of grass and wildflower shoots at harvest in first season of growth on plastic.

Compost	Measurement					
	Stand, cover index[z] Compost maturity			Dry wt, g/m^2 Compost maturity		
	Aged	Fresh	Mean	Aged	Fresh	Mean
			Grass			
Mixed MSW	88	63	75b	61	37	49b
Agricultural	90	92	91a	123	100	111a
Leaf	80	43	61b	55	14	35c
Mean	86	66*		80	50*	
			Wildflowers			
Mixed MSW	80	60	70b	126	70	99b
Agricultural	100	83	91a	275	143	209a
Leaf	70	7	39c	127	15	71b
Mean	83	50*		176	76*	

[z]Cover index: visual assessment of uniformity and density of stand; 0 to 100, 0 = no stand, no coverage, and 100 = best stand, dense and uniform coverage of surface.

*Means of maturity of compost significantly different by F-test ($P \leq 0.05$). Means followed by different letters in columns for grass or wildflowers are significantly different by Duncan's multiple range test ($P \leq 0.05$). For interaction of source x maturity, LSD (0.05) = 24 for grass stand, 11 for wildflower stand, 39 for grass weights, and 100 for wildflower weights.

Table 7.4. Second season flowering index of wildflowers grown in compost on plastic.

Compost[z]	Flowering index[y]						
	June-flowering species						
	Dame's Rocket	Ox-eye daisy	Wallflower	Sum			
Mixed MSW	2.75b	3.25b	3.00a	9.00b			
Agricultural	5.00a	4.50a	2.75a	12.25a			
Leaf	1.75c	3.00b	2.00a	6.75c			
	July-flowering species						
	Coreopsis	Black-eyed Susan	Bachelor's button	Catch-fly	Baby's breath	Ox-eye daisy	Sum
Mixed MSW	3.50a	4.00ab	0.50a	0.75a	0.0a	0.25a	9.00ab
Agricultural	3.50a	3.00b	0.0a	0.50a	0.0a	0.25a	7.25b
Leaf	3.50a	5.00a	0.25a	1.75a	0.25a	0.0a	10.75a

[z]Maturity of compost had no significant effect on flowering in second season. Means followed by different letters within columns and times of flowering are significantly different by Duncan's multiple range test ($P \leq 0.05$).

[y]Visual index, 0 = no bloom, 5 = showy, profuse bloom covering the entire plot.

Table 7.5. Total nitrogen concentrations in grass and wildflowers shoots at time of harvest.

Compost	Total N, % dry wt					
	Grass			Wildflowers		
	Compost maturity			Compost maturity		
	Aged	Fresh	Mean	Aged	Fresh	Mean
Mixed MSW	2.66	2.32	2.49b	2.01	2.10	2.06
Agricultural	2.88	3.29	3.08a	2.36	2.42	2.39
Leaf	2.35	1.71	2.03b	1.63	2.94	2.28
Mean	2.63	2.44		2.00	2.49	

Means followed by different letters in columns are significantly different by Duncan's multiple range test ($P \leq 0.05$). Interaction of source x maturity was nonsignificant for grass and wildflowers. Maturity means for grass and wildflowers, nonsignificant.

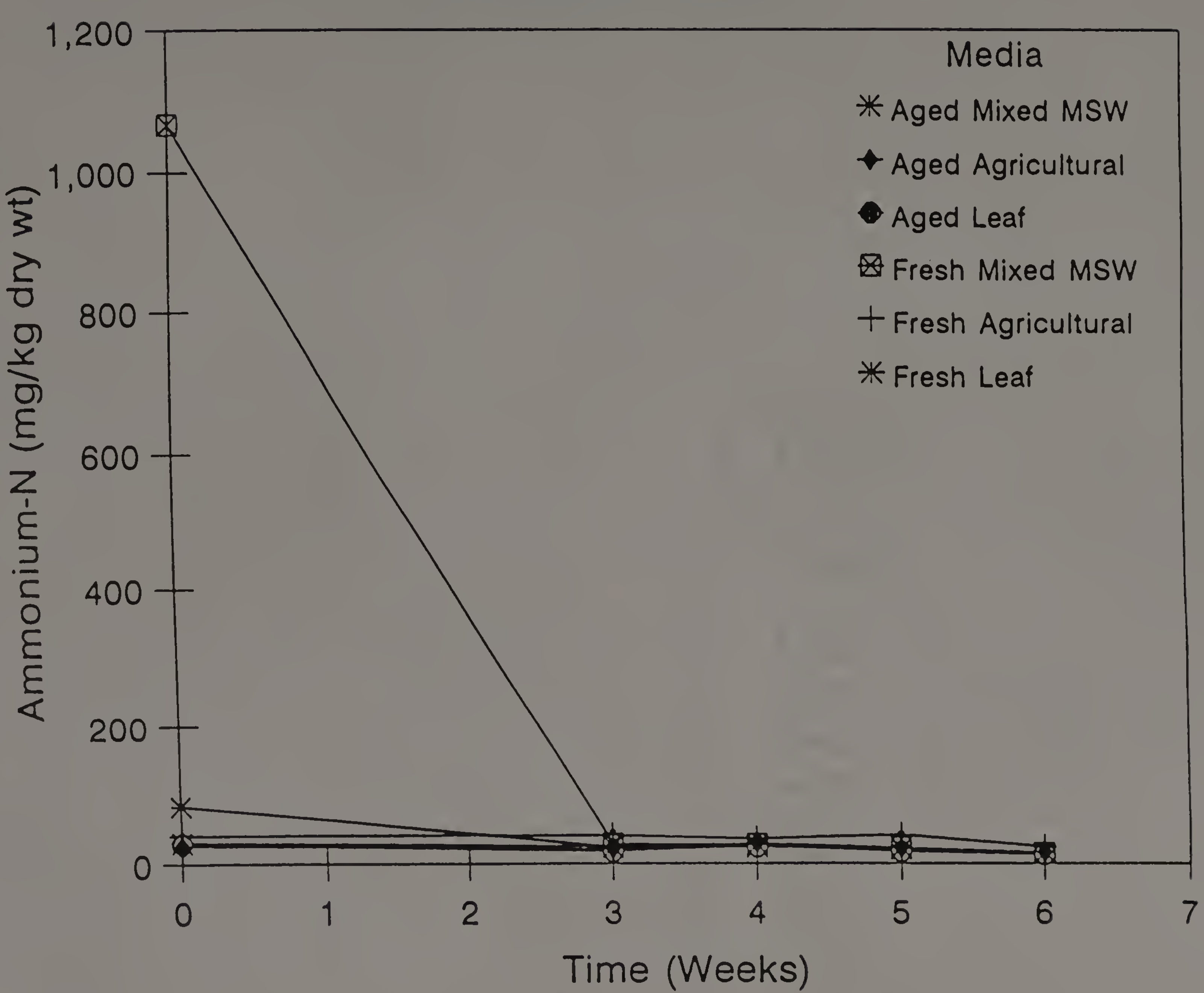

Figure 7.1. Ammonium concentrations in different composts as a function of time after application.

CHAPTER VIII

EVALUATION OF COMPOSTS FOR PRODUCTION OF WILDFLOWER SODS ON PLASTIC

Abstract

Failure of seeds to germinate and of seedlings to grow are common difficulties in many media used to grow wildflowers. Competition from soil-borne weeds additionally hinders establishment of stands and lowers quality of sods. This research evaluated production of wildflower sods in soil and in composts of mixed municipal solid waste, biosolids and woodchips, autumn leaves, and mixed agricultural wastes. Soil or composts were laid on plastic sheeting in outdoor plots, and a mixture of wildflower seeds was sown in July and in September in separate experiments. Germination of seeds and quality of sods were assessed by establishment and bloom of stands in two growing seasons. Germination and growth of wildflowers were limited in immature biosolids composts due to high initial ammonium concentrations in the compost. Best sods with respect to seed germination, stand establishment, and intensity and diversity of bloom in two seasons occurred in mature biosolids compost and in agricultural compost. These composts were low in ammonium but rich in total N. Nitrogen deficiency limited sod growth and quality in leaf composts. Poor N nutrition and weed competition restricted sod development in soil; fertilization of soil promoted unacceptably large weed growth. Summer seeding or fall seeding resulted in good sods, but many annual flowers that appeared in the summer seeding were absent in the fall-seeded planting. The use of plastic-lined plots gave a convenient system for evaluation of composts and other media in outdoor culture.

Introduction

Composting of MSW and agricultural wastes is potentially an important alternative in management of solid wastes. A targeted end use of compost is needed in response to economic concerns of elevated waste disposal costs and environmental problems with landfills and incineration. One potential use of compost is for production of sods on plastic (Mitchell et al., 1994; Cisar and Snyder, 1992). Observations in field experiments showed that weeds growing through surface-applied or shallowly incorporated compost from the soil below greatly interfere with the establishment and attractiveness of the wildflower sods (O'Brien and Barker, 1995a). Plastic can serve as a barrier to limit weed growth and to facilitate harvest of sods for marketing.

Lack of maturity and inclusion of unwanted materials in composts have caused great public concern; however, in compliance with state and federal regulations and better means of sorting wastes, problems with composition are decreasing (Rosen et al., 1993). Means of measuring maturity are still the focus of current research. High ammonium concentrations in compost are indicators of immaturity and have potential to limit germination and plant growth (O'Brien and Barker, 1995b; Inbar et al., 1990; He et al., 1992).

In this research, fresh composts were evaluated for production of wildflower sods on plastic to seek further information on uses of various composts of local origin. Ammonium concentrations in the compost were measured to evaluate maturity and the impact on growth. Two seeding dates, July and September, were used to assess flowering in the current and ensuing season.

Materials and Methods

Fresh composts were delivered in June 1993 and were held in piles without turning. Composts were from cocomposted mixed municipal solid waste (mixed MSW) including biosolids (Delaware Solid Waste Authority, Dover, Delaware), biosolids and woodchips (Springfield, Mass., Wastewater Treatment Plant; or Marlborough, Mass., supplied by AllGro, Lebanon, N.H.), agricultural wastes including cranberry fruit pomace and chicken manure (MassNatural, Westminster, Mass.), and autumn leaves (Springfield, Mass., Wastewater Treatment Plant). Two studies were conducted, one set up on 18 July 1993 and seeded on 23 July 1993 and the other set up on 5 September 1994 and seeded on 15 September 1993.

Composts used in these studies differed considerably in total N and ammonium-N contents (Table 8.1). The average total N concentration in mixed MSW was about 1 % (dry wt). This mixed MSW compost had a low initial ammonium-N concentration at the time of seeding. It is likely that ammonia was lost by from the compost between the time that the compost was applied and the time of seeding. The total N of agricultural compost averaged about 1.55 % N. Leaf compost had the lowest total N with about 0.5 % N. Springfield biosolids-woodchips compost had total N of 3.8 % in July and 2.13 % in September. Ammonium-N in Springfield biosolids-woodchips was 2,462 mg/kg dry wt in July compared to 1,685 mg/kg in September. The ammonium content in the other composts were much lower than those in the Springfield biosolids-woodchips and did not differ appreciably between the two setup dates. The Marlborough biosolids-woodchips compost was used only in the September planting. This compost had a total N concentration similar to that of the Springfield biosolids-woodchips compost but did not have a high concentration of ammonium, indicating a higher state of maturity in the Marlborough compost than in the Springfield compost.

At the time of receipt of the Springfield biosolids-woodchips compost, temperature of the pile was 65° C (150° F). The pile temperatures of the other composts ranged from ambient temperatures 21° C (70° F) to 50° C (120° F). The high ammonium and high temperatures in the Springfield biosolids-woodchips compost indicate that it was immature. The leaf compost was assessed as immature based on its low total N content and presence of unrotted fragments of autumn leaves.

Other media used in these studies included Winooski silt loam from the A horizon of the site where the plants were grown and also a mixture of pine and hardwood sawdust. The soil with or without fertilization had approximately 0.20 % total N. The sawdust had virtually no total N and no detectable ammonium. In soil, ammonium content was increased with fertilization (10N-10P_2O_5-10K_2O supplying 0.024 N kg/m^2; 5 lb N/1000 sq ft). Fertilized soil had 228 mg NH_4-N/kg dry wt, whereas the unfertilized soil averaged 15 mg NH_4-N/kg dry wt.

Wildflower mixture (Northeastern mix, Vermont Wildflower Farm, Charlotte, Vermont) included 25 species, 15 of which did not appear or were too small and sparse to be noted in this study (O'Brien and Barker, 1995a). The rate of seeding was 4.8 g/m^2 into wood-framed, plastic-lined plots holding 0.083 m^3 of compost in a 5-cm layer. The experimental design was a randomized complete block with four replicates and was sited at the University of Massachusetts research farm at South Deerfield.

Growth responses of the wildflower and grass sods were assessed by:

1. Germination and establishment
2. Quality (visual assessment)
3. Purity of stand (weediness, wildflower species)
4. Biomass
5. Species diversity
6. Flowering index
7. Nitrogen composition

<u>Comparison of Fresh Composts and Soil for Production of Wildflower Sods on Plastic with a Midseason Sowing Date</u>

Composts were arranged in 4 randomized complete blocks in the wood-framed, plastic-lined plots described above. The media used in this experiment were mixed MSW compost, Springfield biosolids-woodchips compost, agricultural compost, leaf compost, and fertilized and unfertilized soil. Wildflower seeds were sown midseason (23 July 1993).

In the first season, samples of the media were taken at time intervals during 10 weeks for ammonium (Bremner, 1965) and total N analyses (Bradstreet, 1965). Conductivity of the composts was measured also on these samples (2:1 water:soil, vol:wt, extract) (Richards, 1954). Germination and growth were measured at 2 weeks and 5 weeks after seeding by indexing for uniformity and density of stand on a scale of 0 to 100 (0 = no stand, no coverage; and 100 = best stand, dense and full coverage of surface). After 9 weeks, species diversity and total plant numbers were assessed, and biomass production was harvested from 0.25 m^2 of each plot. The wildflowers and weeds were separated, and dry weights were recorded. Total N was determined in the wildflower tissues (Bradstreet, 1965). In the second season, wildflower stand, species diversity, biomass production, and flowering index were determined early in May, and flowering indexing was repeated in July. Flowering indexing was a visual assessment of uniformity and density of specific flowering species (0 to 5; 0 = no flowering, 5 = best flowering with showy profuse bloom of entire plot).

Comparison of Fresh Composts and Sawdust for Production of Wildflower Sods on Plastic with a Late Sowing Date

Wood-framed, plastic-lined plots were used as above for application of composts of mixed MSW, biosolids-woodchips (2 sources, the same one as above from Springfield and a newly obtained one from Marlborough, Mass.), agricultural wastes, and autumn leaves. In addition, one treatment included a mixture of pine and hardwood sawdust with fertilization ($20N-20P_2O_5-20K_2O$ to supply 1 g N/plot). Sawdust is a by-product of the lumber industry in this region and was evaluated as a potential substitute for compost in sod production. Wildflower seeds were sown late in the season (15 September 1993).

Initial ammonium-N and total N in the composts were determined at the time of seeding. Early in June of 1994, wildflower stand, biomass production, species diversity, and flowering index were assessed. In July of the 1994 season, flowering index was repeated.

Results

Variation in Compost Ammonium-N and Electrical Conductivity with Time

Ammonium-N and total N in composts were measured over a 10-week sampling period (Figure 8.1). Ammonium-N concentrations at 10 weeks were nil and are not reported. Ammonium-N, starting at about 2,500 mg/kg, in Springfield biosolids-woodchips decreased significantly in the first 11 days and was at virtually the same ammonium concentration as in the other composts after 21 days. Total N in compost varied with source of compost, but did not change with time, remaining at the levels reported in Table 8.1.

Electrical conductivity of the media was measured at time intervals for 10 weeks after seeding (Table 8.2). Salinity significantly declined in biosolids-woodchips, agricultural, mixed MSW, and leaf composts within the first 11 days; however, no changes occurred afterward. The media with mixed MSW, biosolids, or agricultural compost had higher salinities than those in the leaf compost or soils.

Growth Performance of Wildflower Sods in Fresh Compost and Soil on Plastic with a Midseason Sowing Date

Wildflowers were seeded 23 July 1993. Germination was assessed as an index of uniformity and density of stand at 2 weeks after seeding. Wildflowers germinated significantly better in mixed MSW than in all other media (Table 8.3). After 5 weeks, wildflower stand (density of plants and visual assessment) was best in fertilized soil followed in order by those in agricultural compost, mixed MSW compost, and unfertilized soil. Development of stand was hindered in the Springfield biosolids-woodchips and leaf compost. After 9 weeks of growth, wildflower shoot weights were highest in the fertilized soil followed in order by those in the agricultural, Springfield biosolids-woodchips, and mixed MSW composts. Wildflower shoot weights in the leaf compost and unfertilized soil were limited, apparently by nutrient deficiencies. Weed growth was about 33 % of the total dry matter production in the plots of fertilized soil and about 36 % of the dry matter production in the unfertilized soil, but weed biomasses differed greatly within these media, making weed growth in the fertilized soil much more noticeable than in the unfertilized soil. Weed growth was negligible in the mixed MSW, Springfield biosolids-woodchips, and agricultural composts. Weed growth, although small in the leaf compost, noticeably diminished the quality of the sod, because of the greatly suppressed wildflower growth.

In the second season, wildflower growth followed trends set in the first season (Table 8.3). In May of the second season, wildflowers in agricultural compost had significantly better stand, greater density, and more shoot biomass than in other media. Wildflowers quality in mixed MSW fell just below that in the agricultural compost. Mean dry weights in the agricultural and mixed MSW exceeded those in the other media. Growth of wildflowers in Springfield biosolids-woodchips, unfertilized soil, or fertilized soil was limited. Wildflowers grown in leaf compost showed signs of improving relative to the first season as indicated by stand quality and density. Growth of weeds in May of the second year was too small to be measured.

Wildflowers harvested after 9 weeks of growth were analyzed for total N (Table 8.4). Shoots of wildflowers grown in Springfield biosolids-woodchips or leaf composts had the highest total N concentrations. The lowest concentrations occurred in the plants grown in unfertilized soil, but differences were nonsignificant between fertilized soil and unfertilized soil.

<u>Flowering Performance of Wildflowers Grown in Fresh Compost and Soil on Plastic with a Midseason Sowing Date</u>

Species diversity after 9 weeks of growth in the first season was assessed (Table 8.5). Black-eyed Susan, coreopsis, ox-eye daisy, cosmos, poppy, clarkia, and baby's breath were present. Wildflower species diversity and density were greater in agricultural or mixed MSW composts than in the other media (Tables 8.3 & 8.5). Coreopsis grew well in all media except in Springfield biosolids-woodchips in which all growth was limited.

In the second season, on 9 May 1994, dame's rocket and ox-eye daisy dominated the floral display, and a few bachelor's buttons were present (Table 8.6). Dame's rockets and daisies flowered best in mixed MSW or agricultural composts. Overall flowering quality indicated by the sum of the flowering indices was better in agricultural and mixed MSW composts than in the other media. Flowering of wildflowers was most limited in Springfield biosolid-woodchips or in fertilized or unfertilized soil.

In July, black-eyed Susan, coreopsis, bachelor's button, and catchfly were flowering. Overall flowering quality was better in leaf compost, unfertilized soil, or agricultural compost than in other media. In general, black-eyed Susans dominated the display and grew well in all media. Coreopsis flowered better in unfertilized soil than in other media. Bachelor's buttons flowered better in leaf, agricultural, or mixed MSW composts than in other media. Catchfly was sparse and occurred only in the leaf and Springfield biosolids-woodchips composts and in unfertilized soil. In August, bloom was not different from that in July.

Growth Performance of Wildflower Sods in Fresh Composts with a Late Sowing Date

Since seeding took place late in the 1993 season, cool weather limited germination, and germination in 1993 was not assessed. After overwintering, growth measured by stand, density, dry weights, and species diversity was assessed on 16 June 1994 when the bloom on some flowering plants was peaking (Table 8.7 & 8.8). Weed growth was negligible in all media. No growth of any plants occurred in the sawdust media. Stands and harvest weights of wildflowers were greater in Marlborough biosolids-woodchips compost and in mixed MSW compost than in the other media (Table 8.7). Growth of wildflowers in Springfield biosolids-woodchips compost was the poorest among the group of composts. Nearly equal growth occurred in the agricultural compost and in the leaf compost.

On 16 June 1994, diversity of species in Marlborough biosolids-woodchips or in mixed MSW composts was greater than that in the other media (Table 8.8). Black-eyed Susan, bachelor's button, ox-eye daisy, coreopsis, and dame's rocket dominated the population. Diversity and density were low in the Springfield biosolids-woodchips compost. Black-eyed Susan dominated in the leaf compost. The agricultural compost supported enough density and diversity to give an attractive stand.

<u>Flowering Performance of Wildflower Sods Grown in Fresh Composts with a Late Sowing Date</u>

Flowering was indexed on 16 June 1994 and on 19 July 1994 (Table 8.9). In June, bachelor's button, dame's rocket, and ox-eye daisy were flowering. Overall flower quality, indicated by sum of the flowering indexes, was better in Marlborough biosolids-woodchips or mixed MSW compost than in the other media. Flowering quality in agricultural compost followed closely behind these composts. Flowering was significantly less in Springfield biosolids-woodchips compost than in the other composts. Dame's rockets flowered best in mixed MSW, Marlborough biosolids-woodchips, and agricultural composts. Ox-eye daisies flowered best in Marlborough biosolids-woodchips and mixed MSW composts. Poor quality of flowering of ox-eye daisy in the agricultural compost limited the overall quality of flowering in this medium relative to that in the mixed MSW or Marlborough compost.

In July, blooming of the dame's rocket and ox-eye daisy ended, and new blooms appeared. Black-eyed Susan, coreopsis, bachelor's button, poppy, and catchfly were flowering. Black-eyed Susan and bachelor's button dominated the display. In July, overall flowering quality was the same in all composts, but flowering of individual species varied among composts. Black-eyed Susans flowered significantly better in Springfield biosolids-woodchips compost than in any other media, but were virtually the only flowering species in that compost. In August, no significant bloom change occurred from that in July.

Discussion

The system of growing sods in compost on plastic was very successful with some composts producing a weed-free, marketable wildflower sod in 8 weeks. Except for leaf compost, weed seeds were not present directly in the composts, and weeds appearing in the composts were from seeds blown or carried in from the surrounding area. Production of wildflowers in fertilized soil was hampered by growth of soil-borne weeds. With field application (O'Brien and Barker, 1995a) in which composts were applied directly on the soil surface or incorporated shallowly into the soil, soil-borne weeds grew through the compost and greatly limited wildflower growth and hindered evaluations of the composts as media to support sod production. The use of plastic serves as a barrier to weed growth and also provides a tool for studying compost fertility. In this study, media were isolated in the frames allowing for a controlled system in which the media were the only source of fertility and in which few interferences for sod production were present.

Production of Sods Seeded in Midseason

Germination and growth of wildflowers on plastic varied with media. Nitrogen in the media was a factor affecting germination and growth. Germination of wildflowers was limited by the extremely high ammonium concentrations in Springfield biosolids-woodchips compost (Barker et al., 1967; Maynard and Barker, 1967). After concentrations of ammonium in Springfield biosolids-woodchips compost declined with time, some remaining viable seeds germinated, and surviving seedlings benefited from the abundance of residual total N although stand remained poor. Low concentrations of N in leaf compost limited establishment of stand and ensuing growth. Agricultural compost and mixed MSW compost produced the best plant growth with respect to quality and density of stand and biomass. Each of these composts was relatively rich in N and low in ammonium at the time of seeding, and each was a mature compost compared to the Springfield biosolids-woodchips compost and leaf compost.

Early in the second year with all media, biennial and perennial wildflowers appeared to have a competitive advantage over annual weeds so that the problem with weeds was much diminished in established plantings. In May 1994, weeds were too small to be measured in all plots. However, later in the season, weeds began to interfere with the attractiveness of wildflowers in the fertilized and unfertilized soil.

Based on the assessments of growth in the first year of the study, the best overall quality of sod was produced in the agricultural compost, which gave a uniform stand of relatively large, healthy plants. Second best overall quality of growth occurred in the mixed MSW compost. In the first year, quality of sod in the mixed MSW compost was limited by production of smaller plants relative to those in the agricultural compost. The population of plants in the Springfield biosolids-woodchips composts was limited by poor germination, but the surviving plants grew well and were second only to those in the agricultural compost in total dry matter production. The sparse stand, however, diminished the quality of the sods relative to that in mixed MSW or agricultural compost, particularly in the second year. Wildflowers in the leaf compost were numerous but small and spindly, apparently in need of nutrition. Establishment of seedlings was limited in the soil relative to that in the composts. In the fertilized soil, this limitation was overcome by the response of the plants to the applied nutrients; however, weed growth in the fertilized soil gave an unacceptable quality of sod. Poor nutrition limited the growth of wildflowers in the unfertilized soil, and the high relative growth of spindly weeds also gave a poor quality of sod in the first year. The results with fertilized and unfertilized soil were similar to those of Ahearn et al. (1992), who found that application of fertilizer in the field was more advantageous to weeds than to the wildflowers.

Differences in plant growth among composts were less in the second year or with seeding late in the season. The similarities among composts in the second year appear to be due to increases in maturities and weathering of composts and removal of inhibiting factors, such as high ammonium concentrations and N deficiency. A problem with late seeding is that annual wildflower species do not become well established in either season.

Species diversity creates a colorful and attractive floral display. First year growth and diversity of wildflowers was better in the agricultural and mixed MSW composts than in other media except fertilized soil. The agricultural and mixed MSW composts did not have high ammonium-N concentrations. The N concentrations in the wildflower tissues grown in these composts suggest that sufficient amounts of N were available, although N concentrations in wildflower tissues are not good indicators of plant nutrition. Quality of wildflower stand was limited in the leaf compost by low diversity and low biomass. Many seeds germinated in the leaf compost, but seedlings failed to grow. Growth in unfertilized soil was similar to that in leaf compost but with even fewer wildflower plants. The lack of fertility, particularly available N, is deemed responsible for the limited growth in the leaf and soil media. Fertilization of leaf compost may be considered as a means of improving quality of sods, but fertilization of soil does not seem practical without a practice for weed control in the first season. Weeds similarly may be a problem in some leaf composts, which may bear seeds from yard wastes mixed in with the leaves.

Although N appears to be a limiting factor in production of wildflowers in some composts, plant tissue analysis did not give a good indication of the N status of the plants. Wildflowers grown in the leaf compost had a unexpectedly high total N concentration relative to that present in the medium and in the tissues of plants grown in the N-rich media. These results were similar to those in an earlier study (O'Brien and Barker, 1995b). These responses are due likely to the effects of concentrating a small amount of N in a small amount of tissue with the plants grown in the leaf compost and to dilution of the N with dry matter production in the plants grown in the N-rich media.

Growth of wildflowers in unfertilized or fertilized soil was limited in the second year relative to growth in the composts. No fertilizer was added to any medium in the second season. Poor nutrition in the second year was more pronounced in the soil than in any compost. Relative to the first year, growth of wildflowers in leaf compost was improved in stand and biomass production. This improvement in growth is attributed to the additional year for maturation of the compost and to better availability of N.

The media affected the flowering of species in the second season. In May 1994, dame's rocket and ox-eye daisy dominated the flowering display, and flowering was better in the agricultural and mixed MSW composts than in the other media. In July 1994, black-eyed Susans flowered well in all media. This species appears to be well adapted to growth in infertile media. Compared to other media, bachelor's buttons flowered better in leaf compost whereas coreopsis flowered better in soil. Since little growth occurred in soil and leaf media in the first year, space for reseeding was readily available. Reseeding is particularly important, for bachelor's buttons and coreopsis are annuals.

Production of Sods Seeded in Late Season

For the wildflowers sown in compost on 15 September 1993, germination occurred in 1993 and in 1994. No growth occurred in the sawdust in 1994. A few seedlings appeared in the sawdust in 1993; but all died overwinter, and no germination occurred in the sawdust in 1994. Nitrogen was so severely deficient in sawdust that no plants could grow. Growth of wildflowers in Springfield biosolid-woodchips compost was limited relative to growth in the other media. High initial ammonium concentrations apparently injured seeds and seedlings, and overwintering killed the weakened seeds and plants, leading to a poor stand and limited growth.

Wildflowers grew well in agricultural compost, in Marlborough biosolids-woodchips compost, and in mixed MSW compost. Species diversity was higher in Marlborough biosolid-woodchips and mixed MSW composts than in the other media. Wildflowers also grew well in leaf compost, but species diversity was not as good as that in the other media. These results, indicating an improvement in plant growth with aged leaf compost, are similar to those observed with the midseason seeding and in a previous study (O'Brien and Barker, 1995b).

Different media affected the flowering of specific flower species with the late seeding. In June 1994, flowering in Springfield biosolids-woodchips compost was less attractive than flowering in the other media. The poor stand and poor flowering of the early blooming species limited the quality of this sod. Wildflowers in the mixed MSW and Marlboro biosolids-woodchips compost had better overall flowering than that in the other media. In July 1994, flowering was dominated by black-eyed Susans and bachelor's buttons. Flowering of bachelor's button was weak in the Springfield biosolids-woodchips compost, but black-eyed Susans flowered better in this medium than in any other medium. Black-eyed Susans appear capable of growing in media of low fertility, such as poor soil, and to flourish in some otherwise growth-limiting composts, such as the biosolids compost with high ammonium.

Conclusions

Different kinds of composts have varying effects on wildflower sod growth. Agricultural compost consistently produced marketable wildflower stands with diverse species in approximately 8 weeks. Maturity of composts is important in establishment of stands. High concentrations of ammonium in immature N-rich composts hindered establishment of stands. High ammonium concentrations are associated with the N-containing compostable materials entering into the media, and immature N-rich composts often are high in ammonium. Maturation of composts in piles or application of composts on a site and waiting for the ammonium to dissipate in 1 or 2 weeks improves quality of high-ammonium composts as media for sod production. Fresh leaf compost limited growth because of its low state of decomposition as indicated by low N composition and visible leaf fragments. Wildflower growth in leaf compost improved in the second year.

Salinity did not appear to be a factor impeding growth in this experiment. However, electrical conductivity declined in the first 11 days in biosolids-woodchips, agricultural, and mixed MSW composts. Since the frames were self-contained, leaching of soluble salts was likely not a strong factor removing salt from the composts. Mitchell et al. (1994) work and Cisar and Snyder's (1992) suggested that leaching as a significant factor removing salts from the media even though the plastic was an impermeable barrier. It may be more likely that much of the change in electrical conductivity may be accounted for by the decline in ammonium by volatilization, particularly in the first 11 days.

The surface of the Marlborough biosolids-woodchips compost was attractive. In the second year, the woodchips appeared as if they were applied as a mulch to the plots, and the combined appearance of the compost and dense, diverse stand in this compost gave the best appearing sods of the group. The individual woodchips in this compost had the aesthetic benefit of being uniform sized with none being more than 1 cm in any dimension.

Establishment of wildflowers in composts was superior to that in soil. Weed competition with wildflowers was less in composts than in the soil. Fertilization of soil was required to produce substantial plants, but weed growth was stimulated with fertilization of soil so that the sod was unacceptable. Fertilization of N-rich composts appears to be unnecessary for at least 2 years.

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Table 8.1 Average initial ammonium-N and total N concentrations in media for midseason and late season establishment of wildflowers.

Medium	Nitrogen concentration, dry wt	
	Ammonium (mg/kg)	Total N (%)
	Midseason (July) Seeding	
Mixed MSW	48b	1.18c
Biosolids-woodchips (Springfield)	2,462a	3.82a
Agricultural	81b	1.55b
Leaf	35b	0.47d
Unfertilized soil	15b	0.18e
Fertilized soil	228b	0.22e
	Late (September) Seeding	
Mixed MSW	57b	1.01c
Biosolids-woodchips (Springfield)	1,685a	2.13a
Biosolids-woodchips (Marlborough)	63b	2.17a
Agricultural	70b	1.59b
Leaf	43b	0.48d
Sawdust	0	0

Within columns in seeding dates, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).

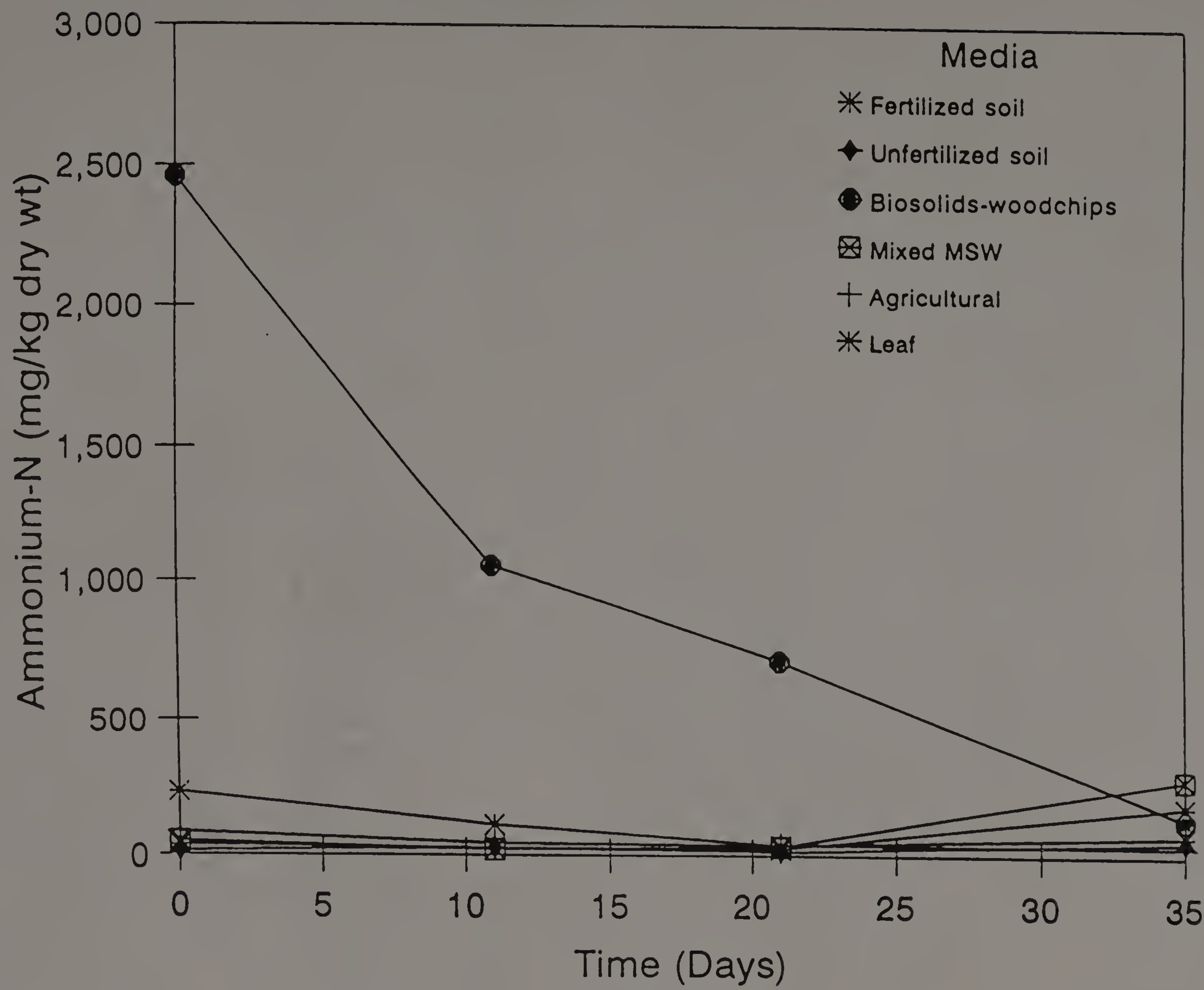

Figure 8.1. Ammonium concentration in soil and composts as a function of days after application and types of media.

Table 8.2. Measurements of salinity of composts as a function of time after seeding of composts.

Medium	Conductivity on days after application[z], mmho/cm						
	0	11	21	37	72	Trend	Mean
Mixed MSW	4.22	1.68	1.58	1.50	1.30	NS	2.06d
Biosolids-woodchips (Springfield)	3.86	1.16	1.35	0.70	1.09	NS	1.63c
Agricultural	2.48	1.42	1.42	1.44	0.99	NS	1.56c
Leaf	0.88	0.68	0.82	0.77	0.94	NS	0.81b
Unfertilized soil	0.32	0.29	0.28	0.78	0.37	NS	0.41a
Fertilized soil	0.61	0.53	0.95	0.51	0.37	NS	0.59a
Mean	2.06	0.96	1.07	0.95	0.84	NS	

[z]1:2 medium:water (w:v) extracts

Means for media followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).

LSD(0.05) for interaction of days x medium = 0.39.

NS, trend is nonsignificant by polynomial regression.

Table 8.3. Germination, plant populations, stand quality, and dry weights of wildflowers in two growing seasons with an original midseason date of seeding.

Medium	Wildflowers				Weeds
	Germination[z]	Stand[y]	Total plants[x]	Dry wt[x] (g/m^2)	Dry wt[x] (g/m^2)
	First Season, 1993				
Mixed MSW	29a	36b	126ab	21bc	0b
Biosolids-woodchips (Springfield)	1b	2c	15d	32bc	0b
Agricultural	8b	39b	166a	38b	1b
Leaf	6b	8c	107bc	9c	1b
Unfertilized soil	8b	17bc	54cd	8c	5b
Fertilized soil	8b	68a	40d	68a	34a
	Second Season, 1994				
Mixed MSW		59b	63b	80ab	
Biosolids-woodchips (Springfield)		4d	11c	52abc	
Agricultural		85a	97a	89a	
Leaf		34c	97a	52abc	
Unfertilized soil		10d	37bc	39bc	
Fertilized soil		2d	12c	33c	

[z]Germination measured 2 weeks after seeding on 23 July 1993. Visual indexing of uniformity and density of cover; 0 = no emergence, 100 = dense, full coverage of surface.

[y]Stand assessment made 5 weeks after seeding. Visual indexing of uniformity and density of cover;
0 = poorest cover, 100 = best cover.

[x]Total plant numbers (density per square meter) and dry weights were measured at 9 weeks after seeding in the first season and on 9 May 1994 in the second season. In the second season, weed growth was too small and noncompetitive to estimate at this time.

Table 8.4. Total nitrogen in wildflowers grown in fresh compost and soil on plastic.

Medium	% N, dry wt[z]
Mixed MSW	2.82ab
Biosolids-woodchips (Springfield)	3.64a
Agricultural	2.34b
Leaf	3.36a
Unfertilized soil	1.88b
Fertilized soil	2.20b

[z]Within column means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$). Analyses are of plant material collected 9 weeks after seeding in first season.

Table 8.5. Differences in species diversity in wildflower sods grown in fresh composts and soil on plastic (1st season; 9 weeks of growth with midseason seedling).

Media	Black-eyed Susan	Coreopsis	Daisy	Cosmos	Poppy	Clarkia	Baby's Breath	Catchfly	Bachelor's Buttons
Mixed MSW	37a	20a	20ab	3b	15a	5b	24b	2	8
Biosolid-woodchips (Springfield)	7b	3b	0c	2b	1b	0b	2c	0	2
Agricultural	44a	33a	26a	6a	6b	14a	42a	2	13
Leaf	49a	32a	10abc	1b	2b	4b	6c	2	3
Unfertilized Soil	18b	23a	2bc	1b	0b	0b	5c	2	5
Fertilized soil	5b	26a	3bc	2b	0b	1b	0c	3	1

Within columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).

Table 8.6. Rating differences by visual indexing in May and July of second season flowering wildflower species grown in media on plastic.

Medium	Flowering Indices[z]				
	May-Flowering Species				
	Bachelor's Button	Dame's Rocket		Ox-eye Daisy	Sum
Mixed MSW	0.00a	2.75a		4.25a	7.00a
Biosolids-woodchips (Springfield)	0.00a	0.25b		0.25c	0.50c
Agricultural	0.50a	2.50a		5.00a	8.00a
Leaf	0.75a	0.50b		2.50b	3.75b
Unfertilized soil	0.25a	0.75b		1.00c	2.00bc
Fertilized soil	0.00a	0.25b		0.00c	0.25c
	July Flowering Wildflower Species				
	Bachelor's Button	Black-eyed Susan	Coreopsis	Catchfly	Sum
Mixed MSW	1.75ab	1.75ab	1.25b	0.00b	4.75b
Biosolids-woodchips (Springfield)	0.00c	4.25a	0.25b	0.25b	4.50b
Agricultural	1.50ab	3.25a	1.25b	0.00b	6.00ab
Leaf	2.50a	2.50a	1.25b	0.75a	7.00a
Unfertilized soil	1.00bc	2.25a	3.50a	0.25b	7.00a
Fertilized soil	0.00c	3.75a	0.25b	0.00b	4.00b

Within columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).
[z]0 to 5 visual index; 0 = no bloom, 5 = showy, profuse bloom covering entire plot.

Table 8.7. Average dry weights, stand, and total plant numbers for late-seeded wildflowers seeded in fresh compost or sawdust.

Medium	Measurements[z]		
	Stand[y]	Total plants (per m^2)	Dry wt (g/m^2)
Mixed MSW	75a	62a	95a
Biosolids-woodchips (Springfield)	36c	34b	14c
Biosolids-woodchips (Marlborough)	73a	53ab	102a
Agricultural	63ab	67a	70b
Leaf	51b	46ab	59b
Sawdust	0d	0c	0c

Within columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).

[z]Wildflowers seeded in composts 15 September 1993; measurements conducted on 16 June 1994.

[y]Stand: Visual index of uniformity and density of cover (0 to 100; 0 = poorest cover, 100 = best cover).

Table 8.8. Species diversity of late-seeded wildflowers seeded in fresh compost and sawdust.

Medium	Wildflower species, density per square meter				
	Black-eyed Susan	Bachelor's Button	Ox-eye Daisy	Coreopsis	Dame's Rocket
Mixed MSW	34ab	5a	19a	12a	19ab
Biosolids-woodchips (Springfield)	6cd	2bc	2b	0c	4cd
Biosolids-woodchips (Marlborough)	43a	8a	18a	9ab	22a
Agricultural	18bc	7a	6b	4bc	16b
Leaf	26ab	5ab	4b	4bc	8c
Sawdust	0c	0c	0b	0c	0d

Within columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).

[z]Wildflowers seeded in compost on 15 September 1993; measurements conducted on 16 June 1994.

Table 8.9. Visual indexing of flowering of late-seeded wildflowers seeded in fresh compost and sawdust on plastic.

Medium	Visual indexing^z			
	June Flowering			
	Bachelor Buttons	Dame's Rocket	Ox-eye Daisy	Sum
Mixed MSW	2.50a	5.00a	3.50a	11.0ab
Biosolids-woodchips (Springfield)	0.25b	1.25b	0.50c	2.0d
Biosolids-woodchips (Marlborough)	4.00a	5.00a	4.00a	13.0a
Agricultural	4.00a	4.25a	0.25c	8.5b
Leaf	2.50a	1.75b	1.75b	6.0c
Sawdust	0.00b	0.00c	0.00c	0.0d

Medium	July Flowering					
	Bachelor Buttons	Black-eyed Susan	Coreopsis	Poppy	Catch fly	Sum
Mixed MSW	2.50a	1.25b	0.25a	0.75a	0.25a	5.0a
Biosolids-woodchips (Springfield)	0.75b	2.75a	0.00a	0.00a	0.00a	3.5a
Biosolids-woodchips (Marlborough)	1.75a	1.00bc	0.00a	1.00a	0.25a	4.0a
Agricultural	2.75a	1.50b	1.25a	0.00a	0.00a	5.5a
Leaf	2.25a	1.50b	0.50a	0.25a	0.50a	5.0a
Sawdust	0.00b	0.00c	0.00a	0.00a	0.00a	0.0b

Within columns, means followed by different letters are significantly different by Duncan's multiple range test ($P \leq 0.05$).

^{z}0 to 5 visual index; 0 = no bloom, 5 = showy, profuse bloom covering entire plot. Seeding on 15 September 1993. Ratings made on 16 June 1994 and 19 July 1994.

CHAPTER IX

CONCLUSION

A mature compost with good availability of nitrogen is required for mint production and for grass and wildflower sods. Composts made with biosolids or farm manure were rich in nitrogen relative to compost made with leaf or yard waste. Maturity is a principal factor in determining whether a compost is acceptable for crop production. Chemical analysis and growth trials are necessary to assess compost maturity. However, other means have been suggested for assessment of maturity. Mature composts generally have cooled to ambient temperatures in piles due to moderation of microbial decay of compostable materials and do not contain undecayed fragments other than woody materials. Immature composts may contain high concentrations of ammonium in N-rich composts, contribute to N deficiency in leaf and yard-waste composts, or possibly impart salinity in all kinds of compost.

Aging of compost is the best method of diminishing immaturity problems. Aging in piles conserves N, but aging in mesh bags, in greenhouse flats, or on land for several days gives rapid dissipation of ammonia. Volatilization is the principal process by which ammonia is lost rapidly from mesh-bags or spread composts, leaving behind organically combined N that mineralizes to support crop growth. Results showed that delaying seeding for about 14 days in composts with high ammonium concentrations increased germination and growth of ryegrass. Ammonium and salinity problems were minimized apparently by dissipation of inhibitory factors by ammonia volatilization.

Application of compost to land can use large quantities of compost and serve as a soil amendment. Results showed that wildflower and grass sod quality did not differ whether the composts were applied as a mulch or incorporated into the soil. In the first season, nitrogen from composts stimulated weed growth and resulted in poor crop quality. In the second season, crops had a competitive edge over the weeds, and nitrogen from composts improved crop quality. Wildflower diversity and total amount of bloom improved as the N status of the media increased. If composts are applied to land, weed control and mature composts with readily available N and low soluble salt concentrations are required for high crop quality in the first season.

Frames lined with plastic gave a convenient system for evaluation of composts and other media in outdoor culture. Weeds were not capable of growing through the plastic. Harvest of sods was facilitated from media over plastic. Some researchers have suggested the use of root permeable or biodegradable barriers that impede emergence of soilborne weeds are useful in establishment of grassed areas or meadows on site. When soil was used as a medium, weed competition and poor N limited growth. Fertilization stimulated weed growth and produced a poor quality of crops. Summer or fall seeding produced good quality of sod, but fall seeding did not produce as many annuals as the summer seeding.

Composts show much potential for agricultural uses in landscaping. Composts are nutrient-rich, and with proper applications to control weeds, high quality landscapes can be produced.

APPENDIX

TABLES

COMPOSITION OF COMPOST

Table A1. Compositions of various composts obtained in 1992 and 1993.

Element	Compost								
	MSW92	MSW93	ALL93	SPR93	AGR92	AGR93	YARD93	LEAF92	LEAF93
	Macronutrients, % dry wt								
Nitrogen	1.16	1.30	2.82	2.88	1.90	1.73	0.84	0.79	0.53
Phosphorus	0.59	0.63	2.16	1.63	0.98	0.94	0.15	0.16	0.10
Potassium	0.21	0.24	0.40	0.18	0.80	0.55	0.34	0.19	0.20
Calcium	2.03	2.02	3.06	1.49	3.54	3.31	0.76	1.09	0.77
Magnesium	0.40	0.41	0.30	0.54	0.59	0.44	0.38	0.43	0.36
	Trace elements, mg/kg								
Zinc	903	923	466	997	236	237	196	135	90
Copper	460	438	423	531	55	73	37	40	30
Manganese	693	734	3630	1525	345	426	280	407	281
Iron	15355	15816	16285	17423	9229	8099	9677	10860	7973
Boron	28	24	8	0	0	8	2	5	3
Molybdenum	11	12	18	10	6	5	4	4	3
Aluminum	15889	17560	18709	12339	8306	7818	6900	8047	5630
Lead	332	377	109	423	19	21	149	80	58
Cadmium	4	4	4	18	2	1	1	2	2
Nickel	128	134	97	124	19	12	15	15	12
Chromium	83	90	155	154	25	26	20	19	18

DEFINITIONS OF ABBREVIATIONS

Table A2. List of definitions for abbreviations used in Table A1.

Abbreviation	Definition
MSW92 and MSW93:	Mixed municipal solid waste compost including biosolids obtained in 1992 or 1993 from Delaware Solid Waste Authority, Dover, Delaware.
ALL93:	Biosolids and woodchips compost obtained in 1993 from Marlborough, Massachusetts.
SPR93:	Biosolids and woodchips compost obtained in 1993 from Springfield, Mass. Wastewater Treatment Plant.
AGR93 and AGR93:	Chicken manure and cranberry waste compost obtained in 1992 or 1993 from MassNatural, Westminster, Mass.
YARD93:	Yard waste compost obtained in 1993 from Earthgro, Lebanon, Conn.
LEAF92 and LEAF93:	Leaf compost obtained in 1992 or 1993 from Springfield, Mass. Wastewater Treatment Plant.

Table A3. Maximum pollution concentrations in sewage sludge and loading limits for land application by the United States Environmental Protection Agency*.

Pollutant	USEPA
	mg/kg, dry wt
Arsenic	41
Cadmium	39
Chromium	1200
Copper	1500
Lead	300
Mercury	17
Molybdenum	18
Nickel	420
Selenium	36
Zinc	2800

*USEPA, 1993 (The 503 regulations issued by EPA).

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