EROSION CONTROL ALONG FLORIDA ROADWAYS

Contract BC-354 WO#7

Final Report

Submitted to

Mr. David Zeigler
Project Manager

Florida Department of Transportation
Environmental Management Office

By

Dr. Grady L. Miller
Dr. Robert J. Black
Dr. Gerald Kidder

University of Florida Institute of Food and Agricultural Sciences
Environmental Horticulture Department
Soil and Water Science Department

20 September 2002

Prepared in cooperation with the State of Florida Department of Transportation.

This report represents research supported by a grant from Florida Department of Transportation. Information contained in this report has not been subjected to scientific peer review, nor has it yet been incorporated into IFAS recommendations unless otherwise stated.

Table of Contents

Executive Summary

Under a grant awarded by the Environmental Management Office of the Florida Department of Transportation (FDOT), University of Florida faculty from the Environmental Horticulture and the Soil and Water Science Department conducted field and greenhouse studies to evaluate and recommend specifications for compost as a mulch for erosion control and as a soil amendment for nutritive benefits. The grant period began 4 October 1999 and proceeded through to the 20 September 2002 termination date.

The primary objectives of the project were:

- Provide fundamental information on utilization of composted yard waste to control erosion and facilitate turf establishment on steep roadside slopes.
- Determine the effectiveness of biosolids compost as a fertilizer for improving stands of poor roadside grass.
- Assist FDOT in establishing standards and specifications for using composts
- Provide FDOT with educational and promotional material on using composts

In these studies, composted yard waste mulch was effective at controlling erosion, but did not necessarily facilitate the growth and establishment of turfgrass or other vegetation. It provided slope stability for periods of at least 18 months and probably longer with or without vegetative growth. Some of the results in this study were influenced by lack of sufficient rainfall which severely limited establishment of vegetation. Sodding and erosion mat treatments were also very effective in erosion control under the conditions of these studies. Compost mulch plots had greater total vegetation and turfgrass cover equal to or better than bare soil plots. Given the level of maintenance and watering, nearly all of the ground cover plants died. Ground cover may be effective at erosion control, but will require more extensive maintenance during the establishment period. Composted biosolids materials provided greater vegetative cover when used as a topdressing than did a soluble fertilizer or no fertilizer at all the first year. The influence was not as great the second year when applied to a soil with approximately 4% organic matter. Observations suggest that adequacy of water has a greater impact on turf establishment than nutrient addition and that infrequent mowing contributed to high weed populations which may have reduced overall turf cover.

Print and visual aid materials on how to use compost were developed for FDOT professionals and contractors. These materials, including the interactive CD, can also be used to help promote composted waste utilization and increase the utilization of recycled materials.

Composted Materials on Florida Roadsides

Grady L. Miller, Michael S. Harrell, Gerald Kidder, and Robert J. Black

This fact sheet gives a brief overview of a two-year project conducted by researchers of the University of Florida's Institute of Food and Agricultural Sciences (UF-IFAS) as part of contract **WO#7** with the Florida Department of Transportation (FDOT).

Project Objectives

- Provide fundamental information on utilization of composted yard waste to control erosion and facilitate turf establishment on steep roadside slopes.
- Determine the effectiveness of biosolids compost as a fertilizer for improving stands of poor roadside grass.
- Assist FDOT in establishing standards and specifications for using composts
- Provide FDOT with educational and promotional material on using composts

Components of the Project

- Field studies of composted yard waste effects on erosion control
- Field studies on fertilizing roadside turf with biosolids compost
- Drafting specifications for compost use on FDOT projects

Erosion Control Study

The experiment involved the use of composted yard waste as a mulch on steep roadside slopes for slope stabilization and establishment of permanent turfgrass cover. The experiment was conducted at two locations in Florida during 2000 and 2001.

- The northern site was located near Crescent Beach, Florida at the intersection of SR 206 and I-95. Soils were disturbed material, with approximately 4% organic content, and greater than 95% medium sand. Slope of the mulch test plot area was approximately 26° (50%). At initiation of the study the turf stand covered approximately 45% of the area.
- The central site was located near Kissimmee, Florida at the intersection of US 27 and US 192. Soils were typical disturbed material found on road shoulders, with <1% organic matter and greater than 80% medium sand. Slope of the test plot area was approximately 12° (21%). At initiation of the study the turf stand was less than 20% of the area.

- Treatments consisted of mulch rates of 5 and 10 cm thick, seeded with 110 or 220 kg ha^{-1} 80:20 bahiagrass:bermudagrass seed mix by weight, ground cover (Asiatic jasmine), straw erosion control mats (central site), and bahiagrass sod (central site). Erosion at the northern site was too severe to allow proper installation of the control mat or sod treatments.

Fertilization Study

A second experiment utilized biosolids compost as a fertilizer on existing thin stands of bahiagrass and bermudagrass at the two locations. Treatments consisted of composted biosolids at 0, 20, 40, and 60 Mg ha^{-1}, and ammonium nitrate fertilizer at 98 kg ha^{-1} applied in late spring. A second application was made the following spring.

Major Findings of the Project

Erosion Control Study

- Composted yard waste mulch can effectively control erosion, but does not necessarily facilitate the growth and establishment of turfgrass or other vegetation.
- It can provide slope stability for periods of at least 18 months and probably longer with or without vegetative growth.
- At the central site, lack of sufficient rainfall severely limited establishment of vegetation in compost mulch treated plots. At this location, sod and erosion mat treatments had greater turfgrass and vegetative cover, but all treatments effectively controlled erosion for the duration of the study.
- At the north site, compost mulch plots had greater total vegetation and turfgrass cover equal to or better than bare soil plots. Given the level of maintenance and watering, nearly all of the ground cover plants died.

Fertilization Study

- Composted biosolids materials provided greater vegetative cover when used as a topdressing than did a soluble fertilizer or no fertilizer at all the first year. The influence was not as great the second year when applied to a soil with approximately 4% organic matter. Observations suggest that adequacy of water has a greater impact on turf establishment than nutrient addition and that infrequent mowing contributed to high weed populations which may have reduced overall turf cover.

Using Composted Materials in Florida Roadside Plantings

Grady L. Miller and Robert J. Black

Organic by-products can improve the establishment and maintenance of vegetative cover along Florida roadways. Plant debris such as tree and shrubbery trimmings and leaves and grass clippings are by-products of landscape and right-of-way maintenance. These natural organic materials are frequently processed into compost or simply ground up into coarse material to be used as mulch. These organic by-products have been shown to benefit roadside vegetation in Florida and other states.

Issues in roadside landscaping are substantially different from those in conventional landscapes or in agriculture where more intensive maintenance practices are usually the rule. For most roadside plantings, a fundamental maintenance practice – irrigation – is not available. Budgetary and/or environmental considerations limit or forbid applications of chemical fertilizers or herbicides. Roadside soils are often poor and will have been disturbed, compacted or otherwise compromised by highway construction activity.

Compost

The high cost of extensive sodding means that most grasses used in highway landscapes must be planted from seed. Once germinated, the grass must be able to establish itself in the face of erratic precipitation, little or no fertilization, competition from weeds, and the potentially erosive run-off of rainwater from pavement surfaces. Incorporation of compost into roadside soils can aid the establishment of vegetative cover by improving the physical and chemical properties of these soils.

Compost addition can also reduce erosion on roadside slopes. The best long-term solution for erosion control is establishment of a permanent vegetative cover. Compost as a soil amendment improves erosion control by enhancing planted or volunteer vegetation growth. The beneficial effects on soil properties expedite establishment and promote a dense stand of vegetation.

Compost can also be utilized as a mulch. In this situation it can increase water infiltration and reduce sediment movement. Compost mulch in roadside applications provides an alternative to straw, hydroseeding, netting, fibrous mats, asphalt emulsion and synthetic binders.

The benefits and practical consequences of using compost as a soil amendment in roadside plantings of utility turf are presented below.

Benefits	Practical Consequences
Increases water retention in sandy soils	More water available for grass seed germination and seedling establishment
Enables soil to hold more plant nutrients (increased cation exchange capacity) for longer periods of time	Increases growth rate of grass seedlings which results in faster coverage of seeded area
Provides small amounts of plant nutrients to the soil/plant system	More nutrients available for seedling growth
Reduces soil bulk density and increases total pore space	Provides greater aeration for enhanced root growth and microbial activity. Increases water infiltration and movement into soils which reduces runoff and erosion
Helps moderate soil temperatures	Prevents rapid fluctuations in soil temperature hence, a better environment for root growth
In some cases, reduces soil borne diseases	Healthy stands of grass seedlings
Suppresses the population of certain nematodes	A more extensive grass root system
Positive effect on soil microbial populations	Provides for slow release of plant nutrients

Mulch

Mulch is any material applied to the soil surface for protection or improvement of the area covered. Mulches are used in conventional landscapes to beautify plant beds, to modify the soil environment and to enhance plant growth. They are often used in roadside landscapes to prevent steep slopes from eroding until vegetation can become established.

Mulch, when correctly applied, has the following beneficial effects upon a roadside planting:

- Prevents loss of water from the soil by evaporation
- Suppresses weeds when the mulch material itself is weed-free and applied thick enough to prevent weed germination or to smother existing small weeds
- Acts as an insulator that keeps the soil cool under intense heat and warm under intense cold
- Prevents crusting of soil surface, thus improving the absorption and movement of water into the soil while at the same time reducing erosion
- Prevents soil splash, which helps to control erosion and keeps soil-borne disease from splashing up onto a plant
- Some mulches may add a small amount of nutrients to the soil
- Adds to the beauty of the landscape by providing a cover of uniform color and interesting texture to the surface

Mulching is an extremely important practice for establishing ground covers and woody plants in the landscape. Mulch helps to preserve moisture in the root ball of the new plant until it establishes, while discouraging weeds that can compete with new plantings. Newly-set plants should be mulched after they are planted and thoroughly watered. If mulch is applied before planting, care must be taken that the root ball of plants get good soil contact when planting. Mulch entire area with a layer of compost. When mulching woody material, pull compost 2.5 to 5 cm (1 to 2 inches) away from the stems/trunks of plants. The high moisture environment created by mulch increases the chances of stem or trunk rot which can result in plant death.

The amount of compost mulch to apply will depend on the texture and density of the product. Normally mulch should be applied at a depth of 5 to 10 cm (2 to 4 inches).

Specifications for composted materials for use on Florida roadsides are discussed in University of Florida, Cooperative Extension Service fact sheet SL-139 available on the web at http://edis.ifas.ufl.edu/SS192.

Florida Department of Transportation Specifications for Composted Materials[1]

Gerald Kidder, Grady L. Miller, and David J. Horhota[2]

This fact sheet presents the Florida Department of Transportation (FDOT) specifications for composted materials that are applied to medians and roadsides in Florida. Detailed reference is found on page 953 of the book *Florida Department of Transportation Standard Specifications for Road and Bridge Construction, 2000*. The 1012-page book is available fro $20 from the FDOT Specifications Office in Tallahassee. It can also be ordered from the web site shown in the Web Links section of this fact sheet.

General Requirements

All composts used in FDOT projects must meet requirements of the Florida Department of Environmental Protection (FDEP) for unrestricted distribution, i.e., the material must be classified as one of the following:

- Type Y (yard waste compost)
- Type YM (yard waste and manure compost)
- Type A (municipal solid waste compost containing <2% foreign matter)
- Type AA biosolids (composted biosolids).

The regulations for these materials can be found in FDEP Rule 62.709.550 for solid waste composts and in Rule 62.640.850 for domestic waste water residuals (biosolids). The rules are available on the web in pdf format at the addresses shown in the Web Links section of this fact sheet.

Compost as a Soil Amendment

In addition to the general requirements listed above, if the electrical conductivity (a.k.a. EC or soluble salt) value of the compost exceeds 4.0 dS/m (mmhos/cm) based on the saturated paste extract method, compost used as a soil amendment must be leached with water prior to application.

Compost for Use as Mulch

In addition to the general requirements noted above, compost that will be used as a mulch must meet the following:

- It shall contain no foreign matter such as glass, plastic, or metal shards.
- Over half of the solids should be from particles at least one half-inch in size but no greater than six inches (i.e., the material should be slightly coarse to coarse in nature).
- Preference shall be given to compost or mulch made from uncontaminated woody waste materials.

Web Links

To order the book, *Florida Department of Transportation Standard Specifications for Road and Bridge Construction, 2000*: http://www11.myflorida.com/MapsAndPublications

Florida Department of Transportation home page:
http://www11.myflorida.com/publicinformationoffice

Florida Department of Environmental Protection home page:
http://www.dep.state.fl.us

FDEP Solid Waste Rule (8 pages in pdf format):
http://www.dep.state.fl.us/legal/legaldocuments/rules/waste/62-709.pdf

FDEP Domestic Wastewater Residuals Rule (17 pages in pdf format):
http://www.dep.state.fl.us/legal/legaldocuments/rules/wastewater/62-640.pdf

---

[1] This document is SL-139, one of a series of fact sheets of the Soil and Water Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. First published: March 1998. Last revised August 2002. Please visit the EDIS Web site at http://edis.ifas.ufl.edu.

[2] Gerald Kidder, professor, Soil and Water Science Department; Grady L. Miller, associate professor, Environmental Horticulture Department, Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611-0290; David J. Horhota, Ph.D., P.E., State Geotechnical Materials Engineer, State Materials Office, Florida Department of Transportation, Gainesville.

Application Rates and Techniques for Using Composted Materials in Florida DOT Projects[1]

Gerald Kidder and Grady L. Miller[2]

Application rates of composted materials will differ depending on whether they are being used as soil amendments, mulches, or topdressing fertilizer. This fact sheet is designed to help a user determine the amounts of materials to apply for each use in Florida Department of Transportation (FDOT) Projects.

The following are some of the common ways that rates of application are expressed:

- weight per unit area (e.g., metric tons per hectare or U.S. tons per acre)
- dry matter per unit area (e.g., oven dry weight per unit area)
- volume per unit area (e.g., cubic meters per hectare or cubic yards per acre)
- thickness of layer (e.g., centimeters or inches)

Composts can contain a large percentage of water, so it is necessary to distinguish if the weight is being expressed on an as-received basis or an oven-dry basis. The oven-dry basis provides a constant reference point and is usually used for expressing the nutrient content of composts.

Soil Amendment

Roadside soil is amended with compost to improve the soil as a medium for plant growth. This is especially important when establishing utility turf on road shoulders and other areas of exposed soil. Soil that is good for building roadbeds is usually not good for growing plants.

Compost used as a soil amendment is usually mixed in the top 15 to 20 cm (6 to 8 in) of soil. Rototilling generally gives the most complete mixing, but disking is also used for incorporation of compost. The recommended rate of application of compost in FDOT projects is 100 metric tons of dry matter per hectare. Several expressions of this rate, given different known quantities of the compost, are presented in Table 1.

Mulch

Mulch is a layer of material placed on the soil surface. Mulch protects soil from the direct impact of rain and wind. Mulch can be very useful in protecting steep slopes from erosion while vegetation such as shrubs and groundcovers are becoming established. It also shades the soil and helps control weeds in plantings. Compost used as a mulch is applied at much higher rates than when it is used as a soil amendments. Coarse mulch such as ground-up urban plant debris (yard waste) should be applied in a layer 5 to 10 cm (2 to 4 inches) thick. Fine-textured organic materials are usually not appropriate for use as a mulch in FDOT projects.

Topdressing (fertilizer)

Compost that is rich in plant nutrients can be used as a fertilizer (a topdressing) and spread over the top of grasses growing on the roadside. Such nutrient-rich compost is an excellent substitute for chemical fertilizer. Additionally, its use helps the FDOT meet state guidelines for use of recycled materials.

However, fertilizing roadsides is not appropriate in the following circumstances:

- the grass is growing very well;
- there is very little grass to start with (i.e., poor stand).

In the first case, fertilizing will only increase the need for mowing and will not increase the soil protecting benefits of good soil cover. In the second case, there is little grass to take up the fertilizer, so the fertilizer is wasted. Poor stands are usually the result of other limiting factors such as droughty soil. Those will not be corrected by fertilizer.

How to use Table 1. Table 1 provides the amount of as-received compost to be applied to achieve the FDOT recommended amendment rate of 100 metric tons dry matter per hectare (45 US tons per acre). In the table, find the moisture content and bulk density of your material. Read across to the column which has the units you wish to use in applying the compost. Rates will be about three times greater when mulching. Topdressing (fertilizing) rates will depend on the nitrogen (N) content of the compost but will likely be approximately 5% of the amendment rate.

Table 1. Amount of as-received compost to apply to achieve the FDOT recommended amendment rate of 100 metric tons dry matter per hectare.

Moisture content	**Bulk density**		**Weight per unit area**		**Volume per unit area**		**Thickness of layer**	
(% by wt)	**g/cm^3**	**lb/cu yd**	**metric tons per hectare**	**U.S. tons per acre**	**cu meters per 10 sq meters**	**cu yards per 100 sq feet**	**centimeters**	**inches**
30	0.42	700	143	64	0.34	0.42	3.4	1.4
	0.48	800	143	64	0.30	0.37	3.0	1.2
	0.54	900	143	64	0.27	0.33	2.7	1.1
	0.59	1000	143	64	0.24	0.29	2.4	0.9
35	0.42	700	154	69	0.37	0.45	3.7	1.5
	0.48	800	154	69	0.32	0.39	3.2	1.3
	0.54	900	154	69	0.29	0.35	2.9	1.1
	0.59	1000	154	69	0.26	0.32	2.6	1.0
40	0.42	700	167	74	0.40	0.49	4.0	1.6
	0.48	800	167	74	0.35	0.43	3.5	1.4
	0.54	900	167	74	0.31	0.38	3.1	1.2
	0.59	1000	167	74	0.28	0.34	2.8	1.1
45	0.42	700	182	81	0.44	0.53	4.4	1.7
	0.48	800	182	81	0.38	0.47	3.8	1.5
	0.54	900	182	81	0.34	0.41	3.4	1.3
	0.59	1000	182	81	0.31	0.37	3.1	1.2
50	0.42	700	200	89	0.48	0.59	4.8	1.9
	0.48	800	200	89	0.42	0.51	4.2	1.7
	0.54	900	200	89	0.37	0.46	3.7	1.5
	0.59	1000	200	89	0.34	0.41	3.4	1.3
55	0.42	700	222	99	0.54	0.65	5.4	2.1
	0.48	800	222	99	0.47	0.57	4.7	1.8
	0.54	900	222	99	0.42	0.51	4.2	1.6
	0.59	1000	222	99	0.37	0.46	3.7	1.5

Footnotes

1. This document is SL-140, one of a series fact sheets of the Soil and Water Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. First published: May 1998. Reviewed: July 2002. Please visit the EDIS Web site at http://edis.ifas.ufl.edu.

2. Gerald Kidder, professor, Soil and Water Science Department and Grady L. Miller, associate professor, Environmental Horticulture Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611-0290.

Some Florida Producers of Composts and Organic Mulches

Robert J. Black, Gerald Kidder, and Grady L. Miller

There are many facilities in Florida that produce composts and other recycled organic waste products that could be used in FDOT projects. The purpose of this fact sheet is to inform interested parties (e.g., engineers, contractors, purchase agents) of a publication that should be quite useful in locating the large volumes of product that are normally required for FDOT projects.

The FORA (Florida Organic Recyclers Association) division of Recycle Florida Today compiled and published a list of organic recycling facilities in June 2000. The publication is entitled, "**Organic Recycling Facilities in Florida**" and is the most comprehensive compilation of such information we have found. It provides location, contact information (phone, fax, email, mailing address), facility owner, when the facility was established, annual tonnage and volume, feedstocks accepted, products produced, services provided, and other information for the 75 facilities listed. The facilities are listed alphabetically and by county. Another section lists in abbreviated form the contact information, including names of the facility operators.

The publication is available in pdf format on the Florida Department of Environmental Protection web site (www.dep.state.fl.us). At this writing the specific address of the publication is:
www.dep.state.fl.us/waste/quick_topics/publications/documents/organicrecycling.pdf

Questions about the report or about facilities which may have come on line since publication of the list can be directed to:

Recycle Florida Today, Inc.
POB 38070
Tallahassee, FL 32315-8070
Phone: 877-867-4RFT
Email: info@recyclefloridatoday.org
Web: www.recyclefloridatoday.org

UTILIZATION OF COMPOSTED MATERIALS ALONG FLORIDA ROADWAYS

By

MICHAEL S. HARRELL

A THESIS PRESENTED TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF
FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF SCIENCE

UNIVERSITY OF FLORIDA

2002

ACKNOWLEDGMENTS

Of the many people who have assisted with this project, Dr. Grady Miller has contributed the most to its completion. Whether it be a phone call or an unannounced office visit, he always had time to assist with my problems. I would also like to thank Dr. Robert Black and Dr. Gerald Kidder, the other members of my graduate committee. Their advice and assistance on many aspects of the project have proved to be invaluable. I would also like to thank Jan Weinbrecht, Jason Haugh, and Greg Means for their assistance with everything from help running the irrigation in the greenhouse to the back-breaking manual labor sometimes associated with this project. I am also indebted to Travis Teuton, Jeff Edenfield, Nick Pressler, and Adam Thomas, my fellow graduate students.

TABLE OF CONTENTS

CHAPTERS

LIST OF TABLES

LIST OF FIGURES

Abstract of Thesis Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Master of Science

UTILIZATION OF COMPOSTED MATERIALS ALONG FLORIDA ROADWAYS

By

Michael S. Harrell

August 2002

Chairman: Grady L. Miller
Major Department: Environmental Horticulture

Departments of Transportation around the country are faced with the difficult task of establishing and maintaining roadside turfgrass. Weak stands of roadside turf are not only unappealing to the eye, but can result in slope stability problems. Synthetic erosion mats and turfgrass sod have been used successfully in roadside applications but are costly and labor intensive to install. Poor growing conditions and periods of limited rainfall often prevent development of dense stands of turfgrass along roadsides. This two-part study was conducted to determine whether composted materials could be utilized to reduce erosion and improve roadside vegetation.

The first experiment involved the use of composted yard waste as a mulch on steep roadside slopes for stabilization and establishment of permanent turfgrass cover at two locations in Florida during 2000-2001. The mulch was applied at depths of 5 and 10 cm and compared to bahiagrass sod, an erosion control mat, and Asiatic jasmine ground cover. The second study utilized biosolids composted with yardwaste as a fertilizer on existing thin stands of bahiagrass and bermudagrass at two locations. Results from the erosion control experiment indicate that both 5 and 10 cm depths of compost can effectively control erosion but did not necessarily facilitate establishment of vegetation or turfgrass. In the fertilization experiment, compost treatments had greater vegetative cover than the control and soluble fertilizer treatments at both locations during the first year post-treatment. Existing soil organic matter varied by location. During the second year, compost treatments at the site with <1% pre-treatment organic matter continued to exhibit greater vegetative cover than the soluble fertilizer and control plots. The effects of the compost application had less of an impact at the site that had approximately 4% pre-existing organic matter. During the second year, limited mowing of the test plots favored weed populations and resulted in decreased quality values.

CHAPTER 1
INTRODUCTION

Municipalities throughout the world are facing the ever-increasing problem of disposing of refuse. While quantities of refuse are increasing, requirements of the disposal facilities are becoming more stringent. Composting has been employed as a solution to this problem, but finding productive uses for the product has been an issue. Applying composts to agricultural lands has proven to be a beneficial use of the material, but is not without its drawbacks. For some composts the quality of composted materials and the application rates used must be taken into consideration to avoid heavy metal accumulation in the soil. Uncertainty of testing procedures for compost maturity can also be a problem when dealing with land applications to agricultural or horticultural crops due to the risk of plant injury and the resulting decrease in marketability for the grower.

A solution to this dilemma is to find an application for composted materials where they can be applied in large quantities to areas with poor soil conditions and where risks associated with their use would be minimized. Throughout the United States miles of roadsides exist that are highly susceptible to erosion because they have poor vegetative cover. Applying compost to these areas could be a useful means of improving plant growth while decreasing the amount of waste going into landfills.

The focus of this research is to investigate effects composted biosolids will have on roadside turf conditions and to determine if composted yard waste can promote plant establishment and provide a means of slope stabilization. The approach taken was to apply two rates of compost at two roadside locations in Florida. The sites varied in slope and soil organic matter content. By evaluating compost rates compared to conventional erosion control measures of turfgrass sod and erosion control mats, a better discussion could be made when determining soil stability options. A second study evaluated the benefits to roadside turf from biosolids compost applied as a fertilizer. It was hypothesized that organic nitrogen from the compost would increase turf density over a longer period of time than soluble nitrogen.

CHAPTER 2
LITERATURE REVIEW

Composting is a popular means of turning waste into a useful soil amendment. Composts have several beneficial effects on soil properties such as plant available nitrogen (N), pH, and organic matter content (Bugbee and Elliot, 1999; Roe et al., 1997; He et al., 1992). Since yard trash can no longer be put in class A landfills in many states, large quantities of material have been diverted to composting facilities. The composting facility of Palm Beach County, FL, produced approximately 200,000 tons of yard waste (wood chips, grass clippings, and leaves from homeowners and landscaping firms) in 2000 (Oshins and Block, 2000). Composting provides a means of reducing the amount of material entering landfills while producing a useful end product. Research has indicated the usefulness of various composts as soil amendments (Duggan, 1973; McSorley and Gallaher, 1996; Kostewitcz, 1993). Composts have been utilized as a potting media for horticultural plants (Conover and Poole, 1990; McConnell and Shiralipour and McConnell, 1991) and can be used successfully as a growth substrate for wetland plants (McConnell et al., 1990). Compost has also been used successfully for turfgrass sod production (Cisar and Snyder,1992).

Compost Characterization and its Influence on Soil Chemical Properties

Typically, the carbon to nitrogen (C/N) ratio decreases during the composting process until it becomes stable in the range of 14:1 to 20:1(Brady and Weil, 1999). For composted biosolids, this ratio can vary substantially depending on the percentage of woody materials added during the composting process. Dissanayake and Hoy (1999) determined a C/N ratio of 7:1 for composted biosolids (no additional materials) used in a soil amendment study, while Bugbee (1999) and Shiralipour and Chrowstowski (1996) determined a ratio of 26:1 and 10:1 for co-composted hardwood chips and biosolids, respectively. Analysis of the chemical composition of several composts has shown that composted biosolids have a substantially greater N content than composts from other feedstocks (Dissanayake and Hoy, 1999). The increased N levels result in the lower C/N ratio desirable for crop production.

Compost applications as an amendment have been shown to reduce the C/N ratio of soils. Tester and Parr (1983) found that a sewage sludge-woodchip compost reduced the C/N ratio substantially when applied to an Evesboro loamy sand. Effects on soil C/N ratios can remain for several seasons. Epstein et al. (1976) found decreased C/N ratios for sludge compost amended plots over control plots when applied at rates of 160 and 240 Mg ha^{-1} two years after application. This suggests that inorganic nitrogen is still being released due to mineralization.

Composts typically contain high levels of C. Giusquiani et al. (1995) found C levels of about 27% for urban waste compost, while Sims (1990) found concentrations ranging from 58 to 73% for co-composted sewage sludge. High levels of C, without corresponding N, increases the C/N levels in soil. High C/N ratios can result in immobilization of N by microbes, thus, reducing the availability to plants.

Compost contains macro and micronutrients necessary for plant growth in varying amounts depending on the feedstock source used (Sims and Kline, 1991). Compost applied as an amendment can increase soil concentrations of nutrients. Jackson (1997) found that compost application increased extractable zinc (Zn), copper (Cu), manganese (Mn), and iron (Fe) in the soil immediately following, 3, and 6 months after application. Epstein et al. (1976) found increased levels of calcium (Ca) and magnesium (Mg) after treatment application in plots amended with sludge compost.

Increasing soil concentrations of nutrients can affect plant uptake. Roe et al. (1997) found that compost applied to a sandy field soil increased concentrations of P, K, Ca, and Mg in pepper (*Capsicum annuum* L.) leaf. However, in the same study, compost applications were found to decrease levels of Cu in pepper leaf. Jokela et al. (1990) found elevated levels of N and P in slash pine (*Pinus elliottii* Engelm.) grown in soils amended with municipal garbage composted with sewage sludge

The feedstock used to produce the compost can have a significant effect on the final pH, thus affecting the rate of pH change in the soil. Roe et al. (1997) determined pH values ranging from 5.9 to 7.7 for several composts. Compost amendments can increase the pH of the soil. Tester and Parr (1983) found an increase in soil pH of about 2.5 units with the addition of sewage sludge-woodchip compost. This is a result of alkaline pH and abundance of $CaCO_3$ in compost (Shiralipour and Chrowstowski, 1996).

Compost amendments do not always increase the pH of the soil and effects can vary with compost source and rates. Jackson (1997) found that the addition of composted municipal solid waste with biosolids decreased the pH of the soil over the control initially, while composted yardwaste had the opposite effect. However, after 6 months compost addition of any source did not significantly affect soil pH. Avnimelech et al. (1994) found the addition of some composts to be as effective as or superior to gypsum applications for reclaiming alkaline soils.

Compost applications have been shown to reduce salinity of soils (Avnimelech et al., 1994) by replacing the sodium with calcium. However, compost applications can increase the salinity of soils. Epstein et al. (1976) found that salinity of the soil increased with increasing sludge compost application rates. However, due to leaching over time, salinity levels tend to decrease to normal levels in the soil.

Effects on Soil Physical Properties

Many composts contain mixed feedstocks often from plant materials. This addition of organic matter can have an effect on soil properties including, aggregate stability, decreased bulk density, and increased pore space and water retention (Brady and Weil, 1999; Jackson, 1997; Shiralipour and Chrowstowski et al., 1996; Khaleel et al., 1981). Giusquiani et al. (1995) found that the addition of urban waste compost increased soil porosity and decreased bulk density when applied to a calcareous soil.

One of the primary causes of poor turfgrass cover on roadsides is the droughty nature of the road shoulder. Good drainage is required to protect the roadbed. During periods of high rainfall roadside turf can thrive, but drought conditions can take a toll on turfgrass quality and density. Water holding capacity of soils may be increased with the addition of compost. Epstein et al. (1976) found higher soil moisture content and retention in test plots treated with dry sludge compost than the control throughout most of the measuring period. Shiralipour and Chrowstowski et al. (1996) applied co-composted biosolids and yard waste at a rate of 134 Mg ha $^{-1}$. Water holding capacity (weight basis) increased 15 percent in sandy loam, 14 percent in loam, and 5 percent in clay loam. This was attributed to the increase in soil organic matter provided by the compost. Giusquiani et al. (1995) found that compost addition linearly increased water retention of the soil and increased plant available water correspondingly. This shows that compost additions may have a positive effect in areas susceptible to drought stress. However, plant available water may not be increased. The addition of compost can decrease bulk density, which can negate the effects of the increased available water on a volume basis (Khaleel et al., 1981).

Compost applications have been shown to improve soil structure. Pagliai and Antisari (1993) found that the addition of organic materials can improve micro- and macroporosity, reduce the formation of surface-soil crusts, and can reduce compaction.

Effects on Plant Growth

Compost as a soil amendment can have substantial effects on seed germination, plant growth, and yield. Ozores-Hampton et al. (1999) found that a high salt concentration in co-composted yard trimmings and biosolids delayed tomato germination by 14 and 21 days. There were no differences from the control 30 days after seeding which was attributed to leaching of soluble salts.

Since the nutrient content of composts varies with feedstock composition, application rates should be adjusted when used as a N source. Pure composted biosolids can contain about 2.5 to 3.5 percent N (Garling and Boehm, 2001). However, some compost sources require an additional source of N to avoid immobilized N from a poor C/N ratio. Sims and Kline (1991) found that dry matter production of wheat (*Triticum aestivum* L.)decreased with increasing co-composted sewage sludge applications likely due to immobilization of N as a result of the high C/N ratio of the compost. Effects on soybean (*Glycine max* L.) growth where N is not a limiting factor were either equal to or greater than the control. Additional sources of N can be obtained from either an inorganic source, organic source, or can be blended with a feedstock having a high N content (Stevens and Kostewicz, 1992; Kostewitcz, 1993; Stevens and Kostewicz, 1994).

Garling and Boehm (2001) found that compost applied to a mixed sward of creeping bentgrass [*Agrostis stolonifera* var. *palustris* (Huds.) Farw.] and annual bluegrass (*Poa annua* L.) improved color, increased growth, and increased foliar N. Composted biosolids and biosolids co-composted with yard waste increased foliar N by 50% and 30%, respectively over a 3-yr period when compared to the control. However, results were not always positive and can vary depending on rates, compost maturity, and available N. Cisar and Snyder (1992) found that St. Augustine (*Stenotaphrum secundatum (*Walt.) Kuntze.) and bahiagrass (*Paspalum notatum* Flugge.) grown in a solid waste compost had discolored leaves and poor growth after 6 weeks. However, at 5 months, sod produced in fertilized compost over plastic had higher quality, offered better tear resistance, and exhibited enhanced rooting when compared to non-fertilized sod grown in soil.

Maturity of compost amendments can have a substantial effect on plant responses. Chanyasak et al. (1983) found that yields of komatsuna (*Brassica rapa* var *Pervidis*) were reduced substantially by immature compost treatments regardless of rate. It was also determined that well-matured composts gave greater yields than the control at 10 dry tons ha^{-1} but gave diminished yields at 20 dry Mg ha^{-1}. Compost has been shown to have positive effects on plant yield regardless of application method. McSorley and Gallaher (1996) found increased yield of maize (*Zea mays* L.) with applications of yard waste compost applied as a mulch or incorporated into the soil.

Some composts can contain high levels of heavy metals which can limit their use in agricultural applications. Research has shown that elevated levels of some heavy metals can produce increased levels in plant tissues (Sims and Kline, 1991). However, a maximum concentration in plant tissues (plateau effect) can exist for several elements, regardless of available concentrations in the soil (Barbarick et al.,1995).

Microbial Activity

Dissanayake and Hoy (1999) found that soil amendment with composted biosolids reduced root-rot symptom severity caused by *Pythium arrhenomanes* in sugarcane (interspecific-hybrids of *Saccharum*) in a steam-treated soil infested with the causal pathogen. The highest microbial activity was recorded for composted biosolids when compared to several other feedstock sources (Dissanayake and Hoy, 1999). High levels of microbial activity can result in a general suppression of soilborne pathogens (Brady and Weil, 1999). These results suggest that soil amendments with organic materials may provide an effective biological disease control option for soilborne plant diseases. In addition, microbial populations in the soil are responsible for the breakdown of plant tissues, converting organically held nutrients into plant available forms (Brady and Weil, 1999). By adding composted biosolids with high microbial activity, an increase in plant available nutrients can be expected.

Influence of Turfgrass on Erosion

Compost has been utilized on roadsides in several states around the nation as an alternative to traditional practices of turfgrass sod and synthetic erosion mats for controlling erosion and nonpoint source pollutants (Ettlin and Stewart, 1993; Haynes, 1997; Mitchell, 1997; Block, 2000). The best long-term biotic solution for erosion control is establishment of a permanent vegetative cover. Previous research suggests that composts have many beneficial effects on soil properties and plant growth which can expedite establishment and promote a dense stand of vegetation.

Erosion along slopes is a combination of many factors that determine the amount of sediment movement from an area. Among these factors are rainfall and run-off (Wischmeier and Smith, 1978). Turf establishment on slopes plays an important role in controlling these factors. The fine root system of turfgrasses holds soil in place (Robinson et al., 1996). Roots near the surface improve surface porosity and increase water infiltration which can prevent soil from becoming saturated and unstable (Carroll, 1992). Plant stems lying on the soil surface decrease water velocity, which reduces the sediment carrying capacity (Robinson et al., 1996). Without this matrix of stems and roots, soil can easily be moved by the flow of water.

A key characteristic of mowed turfgrass that contributes to erosion control is its dense ground cover and high shoot density (Beard and Green, 1994). Raindrop impact erodes any unprotected surface and initiates transport of detached particles (Mutchler et al., 1994). Dense turf canopies can absorb the energy of raindrops, reducing their ability to detach particles upon impact with the soil.

CHAPTER 3
EFFECTS OF COMPOSTED YARD WASTE MULCH ON SLOPE STABILITY AND ROADSIDE VEGETATION

Introduction

Exposed soil along roadways is commonly found after road construction. Steep exposed slopes represent potential erosion problems if left untreated. Conventional methods of erosion control such as synthetic erosion control blankets and turfgrass sod can be labor intensive and costly to install. Turf establishment on slopes plays an important role in their stability. Raindrop impact erodes any unprotected surface and initiates transport of detached particles (Mutchler et al., 1994). The matrix of stems and roots characteristic of turfgrass is ideal for holding soil in place and reducing the ability of rainfall to detach and move particles (Robinson et al., 1996). Dense turf canopies can absorb the energy of raindrops, reducing their ability to detach particles upon impact with the soil. Roots near the surface improve surface porosity and increase water infiltration, preventing soil from becoming saturated and unstable (Carroll, 1992).

While turfgrass is the best means for long-term erosion control, establishment on steep slopes can be difficult. Temporary erosion control measures have been used successfully to protect seed, soil, and fertilizers from the impact of rainfall (Collier et al., 1997). Carrol (1992) found that man-made erosion control materials such as shaved wood, jute, or fiber based mats reduced sediment losses from 94 to 99 percent of that lost from bare soil. However, these materials are intended for temporary erosion reduction until a permanent vegetative stand can be established.

One possible solution to controlling erosion and establishing permanent vegetation is to utilize composted yard waste as a mulch on steep slopes. Compost applied as a mulch can protect exposed soil from erosion (Ettlin and Stewart, 1993). Composts have shown beneficial effects on soil physical and chemical properties (He et al., 1992; Giusquiani et al., 1995) and can be a useful soil amendment for plant growth if combined with a nitrogen source (Kostewitcz, 1993; Stevens and Kostewicz, 1992 and 1994).

Legislation in the last decade has banned the landfilling of yard waste in many states (Steutville, 1995). Florida produces yard waste throughout the year unlike the northern states which produce it mainly in the summer and fall. The composting facility of Palm Beach County, FL produced approximately 200,000 tons of yard waste compost in 2000 (Oshins and Block, 2000).   Finding useful applications for the large quantities of composted materials produced can be a challenge.

The objective of this study was to determine the effectiveness of composted yard waste at specific rates to control erosion and facilitate turfgrass establishment on steep roadside slopes. Turfgrass sod, erosion mats, and asiatic jasmine (*Trachelopermum asiaticum*) ground cover plants were also utilized to compare their effectiveness to the compost treatments.

Materials and Methods

Field Study

A field study was conducted from 1 May 2000 through 1 November 2001 to evaluate the effectiveness of composted yard waste for controlling erosion on roadside slopes. Test sites were located near Kissimmee, FL (central site) at the intersection of

US27 and US192 (81°W 40’39” 28°N 20’54”) and near Crescent Beach, FL (north site) at the intersection of SR206 and I95 (81°W 21’21” 29°N 44’10”). Before treatment initiation, the sites were evaluated for vegetative cover, slope, and soil physical characteristics. Soils were typical disturbed material found on road shoulders. Soils at the central site contained <1 percent organic content while the soil at the north site contained approximately 4 percent organic content as determined by weight loss on ignition (450°C for 24 hr). Both soils were predominantly sand with greater than 80 percent of the particles falling into the medium sand category (150-250 μm) for the central site and greater than 95 percent for the north site. Studies were conducted on slopes with existing thin stands of bahiagrass [*Paspalum notatum* Flugge] and bermudagrass [*Cynodon dactylon* L.]. Initial turfgrass stands were <20% cover for the central site and <45% cover for the north site

Treatments at the central site were: 5 cm compost mulch planted with asiatic jasmine ground cover on 30-cm centers, 5 cm compost mulch with the standard Florida Department of Transportation (FDOT) seeding rate of 110 kg ha^{-1} 80:20 bahiagrass:bermudagrass seed mix by weight, 5 cm compost mulch with double the FDOT standard seeding rate, 10 cm compost mulch with standard FDOT seeding rate, and 10 cm compost mulch with double the standard FDOT seeding rate, SC-150 straw erosion control mat with standard FDOT seeding rate, erosion control mat with double the standard FDOT seeding rate, and a bahiagrass sod treatment. Plots were 3.0 m by 10.0 m. Slope of the test plots was approximately 12° (21%).

Treatments at the north site were: bare soil control, bare soil with 110 kg ha^{-1} 80:20 bahiagrass:bermudagrass seed mix (standard FDOT seeding rate), bare soil with double seeding rate, 5 cm compost mulch planted with asiatic jasmine ground cover, 5 cm compost with standard seeding, 5 cm compost mulch with double seeding rate, 10 cm compost mulch with standard seeding, and 10 cm compost mulch with double seeding rate This site was on the embankment of the I95 overpass over SR206. Plots varied from 3.0 m by 10.0 m to 3.0 m by 14.0 m due to the tapering of the embankment from north to south. Slope of the test plots ranged from 26° to 27° (49% to 51%). Sod and erosion mat treatments were replaced with bare soil treatments because without complete reworking of the slope to smooth the surface, these treatments would not have been practical. Reconstruction of the slope was contrary to the aim of this experiment.

Composted yard waste treatments were applied with a blower truck. Stakes marked at 5 and 10 cm were inserted into the test plots prior to compost application to insure uniform compost application depths. Seeds were then surface applied and incorporated into compost treatments by hand raking. Test design was a randomized complete block with eight treatments and four replications.

Yard trimmings (tree and shrubbery trimmings, grass clippings, and leaves from homeowners and landscaping firms) compost provided by Enviro-Comp Services Inc. (Jacksonville, FL) was used in this experiment. Rooted asiatic jasmine ground cover plants were transplanted from 10 cm pots.

An unknown volume of irrigation water was applied at the onset of the experiment to sod and ground cover treatments to prevent dessication. Effluent water was delivered and applied by FDOT maintenance crews using a tanker truck and truck mounted nozzle. Test plots were not mowed and received only minor weeding as necessary to improve aesthetic quality. Due to insufficient rainfall, many of the ground cover plants died and were replanted October 2000.

At the time of compost delivery, 2 to 6 random grab samples were taken and combined. A composite sample was then analyzed in duplicate for specific physical and chemical properties and averaged. Bulk densities for compost samples were determined by filling a tared 500 mL beaker. The sample was then shaken to settle but not compact the material, then more sample was added until the desired volume was attained. The recorded mass was divided by the volume to calculate bulk density. Percent moisture was determined as weight loss upon drying at 105° C for 24 h divided by the mass of dry sample. Samples were homogenized using Ultra-Turrax T25 (Labrotechnik) and then analyzed for N content as received at the Suwannee Valley REC Livestock Waste Testing Laboratory (Live Oak, FL) using the semi-micro Kjeldahl method (Bremner and Mulvaney, 1982). The pH in water was determined with a glass electrode using a 1:2.5 sample:water ratio (McLean, 1982).

Percent cover and visual quality were estimated by at least two raters on a monthly basis. Percent cover was estimated for both total vegetation and turf. A visual scale of 1 to 9 was used with 9 being the highest quality and 5 being minimally acceptable. Factors that where considered with regard to quality were turf color, density, uniformity, and undesirable plant species.

A silt fence was constructed along the foot of the slope to contain any eroded soil from the test plots. After one year, the silt fence was removed, and eroded soil was collected and weighed. Sediment loss data are reported for the north site only, since no measurable erosion occurred at the central site due to lesser slope and treatment selection.

Another system of 1.5 m wide silt fence catchments was installed at the north site 8 m below the top of the slope on each plot 3 June 2001. This was done to reduce the likelihood of damage from mowers and other equipment operating near the foot of the slope and to reduce the effect of soil erosion from neighboring plots. These catchments were installed by burying the lower 15 cm of the material, folding down the slope, and then staking the sides 30 cm downhill from the buried section. This creates a pocket to catch any eroded soil and facilitate collection and measurement.

Rainfall data were obtained from the Florida Automated Weather Network. Data for the north site was taken from the agricultural experiment station located approximately 12 miles from the research site in Hastings, FL. Data for the central site was taken from the agricultural experiment station located approximately 15 miles from the research site in Lake Alfred, FL.

Data were analyzed by ANOVA procedure using SAS statistical software (SAS Institute, 1987). All reported differences were significant at $P \leq 0.05$. Means were separated with Duncan’s LSD. Single degree of freedom comparisons of treatments were made using orthogonal contrasts.

Greenhouse Study

A twelve week bahiagrass and bermudagrass establishment trial was conducted in a glasshouse at the Turfgrass Envirotron in Gainesville, FL to evaluate the effectiveness of seeding practices when using composted yard waste mulch and erosion control mats. This was done to determine if soil to seed contact would be sufficient for seed germination. Treatments consisted of seed applied to the surface of the erosion mat or compost mulch, seed incorporated into the top 4 cm of the compost mulch, and seed placed beneath the erosion control mat. Studies were conducted in 15-cm diameter (182 cm^2 planted surface area) pots with sand (60% medium sand) and 10% peat using the 80:20 bahiagrass:bermudagrass mix seeded at standard FDOT rate of 110 kg ha^{-1}. A completely randomized design was used with four treatments and four replications. Plants which emerged and grew to a height of >2 cm were recorded at 2 week intervals for each container. Several plants died near the end of the study and were not counted. Irrigation was applied at two 5 min intervals (8 mm total) per day from initiation through week 8 (Figure 3-7) at which time the irrigation was applied at one 2 h interval (96 mm total) daily for the last four weeks to simulate heavy summer rainfall.

Results and Discussion

Selected characteristics of composts used at the north and central sites are shown in Table 3-1. Compost samples were generally similar for percent moisture, pH, and total N. Bulk densities varied somewhat, likely due to the difficulty in sampling the coarse, heterogeneous material

Table 3-1. Bulk density, percent moisture, pH, and total N (as received basis) of yard waste compost applied at north and central sites.

Location	Bulk density	Percent moisture	pH	Total N
	g cm^{-3}	%		g kg^{-1}
North site	0.25	27.3	5.7	5
Central site	0.30	28.3	5.8	5

Total Vegetation--Central Site

Due to significant date, treatment, and date x treatment interactions (Table 3-2), treatment changes were analyzed over time for total vegetation and presented in Figure 3-1. There was no difference in total vegetation between standard and double seeding rate

Table 3-2. Mean squares for the primary dependant variables and interactions at the central site.

Source	df	Total Vegetation	Turfgrass Cover	Total Quality
Date	17	5366.55**	4009.87**	13.32**
Rep	3	8518.07**	14707.25**	109.65**
Treatment	7	9232.16**	15600.47**	98.67**
Date x Rep	51	185.04**	556.36**	1.16**
Date x Treatment	119	171.46**	425.73**	1.27**
Rep x Treatment	21	807.20**	1190.65**	9.44**
Error	357	52.52	270.71	0.57
CV, %		15.3	43.76	18.6

** significance at the 0.01 level of probability.

treatments (Table 3-3). High compost rates were generally not different from low compost rates with the exception of two months during the first year and three months during the second year when low rates had greater total vegetation. This can likely be attributed to the burying of existing vegetation with the higher compost rate covering a larger percentage of pre-existing cover. Increased rainfall during the second year facilitated increased vegetation for all treatments with a greater effect on the low compost treatments where plant growth through the compost was less hindered. Total vegetation for erosion mat treatments and compost treatments were generally not different for the first nine months of the study, but erosion mat treatments exhibited greater vegetative cover in the last nine months. This can likely be attributed to compensatory growth after the vegetation emerged through the mat in the spring. Sod treatments had greater total vegetation than compost and erosion mat treatments throughout the study. Compost rates of 5 cm were not different from ground cover treatments except for 4 months following replanting where ground cover treatments exhibited greater total vegetation. Total vegetation declined sharply in March 2001 for all treatments after an extended period of low rainfall beginning October 2000. By March 2001 all ground cover plants had died.

Turfgrass Cover--Central Site

Due to significant date, treatment, and date x treatment interactions (Table 3-2), changes over time for turfgrass cover are presented in Figure 3-2. Results for standard seeding rates and double seeding rates were not different throughout the study. High compost mulch rates were generally no different than low compost mulch rates with the exception of two months during the first year when low rates had greater turfgrass cover. As with the total vegetation cover, this could be attributed to the burying of existing turfgrass corresponding to rates. Turfgrass cover for erosion mat treatments and compost treatments was generally not different for the first nine months of the study, but erosion mat treatments exhibited greater turf cover for the last nine months. This can likely be attributed to compensatory growth after the turf emerged from the mat in the spring. Sod treatments had greater turfgrass cover than compost mulch and erosion mat treatments throughout the study.

Mulch rates of 5 cm were not different from ground cover treatments for all but one rating period because the ground cover died due to extended drought. These data indicate that seeding was ineffective regardless of rate because the ground cover treatment essentially became an unseeded 5 cm compost treatment.

Total Quality--Central Site

Standard and double seeding rates had no effect on total quality at any time during the study (Table 3-3). High compost mulch rates were not different from low compost rates for all but one rating period. Total quality for erosion mat treatments and compost mulch treatments were generally not different for the first nine months of the study, but erosion mat treatments exhibited higher quality for the last nine months due to greater turfgrass cover. Sod treatments had greater total quality than compost mulch and erosion mat treatments throughout the study. Mulch rates of 5 cm were not different from ground cover treatments for all but two rating periods immediately following replanting where ground cover treatments exhibited higher quality. Ground cover plants died three months after replanting.

Mean separations at the conclusion of the study did not show significant differences between high and low seeding rates for 5 cm compost, 10 cm compost, and erosion mat treatments (Table 3-4). Seed germination was likely affected by limited rainfall following treatment applications (Figure 3-3.)

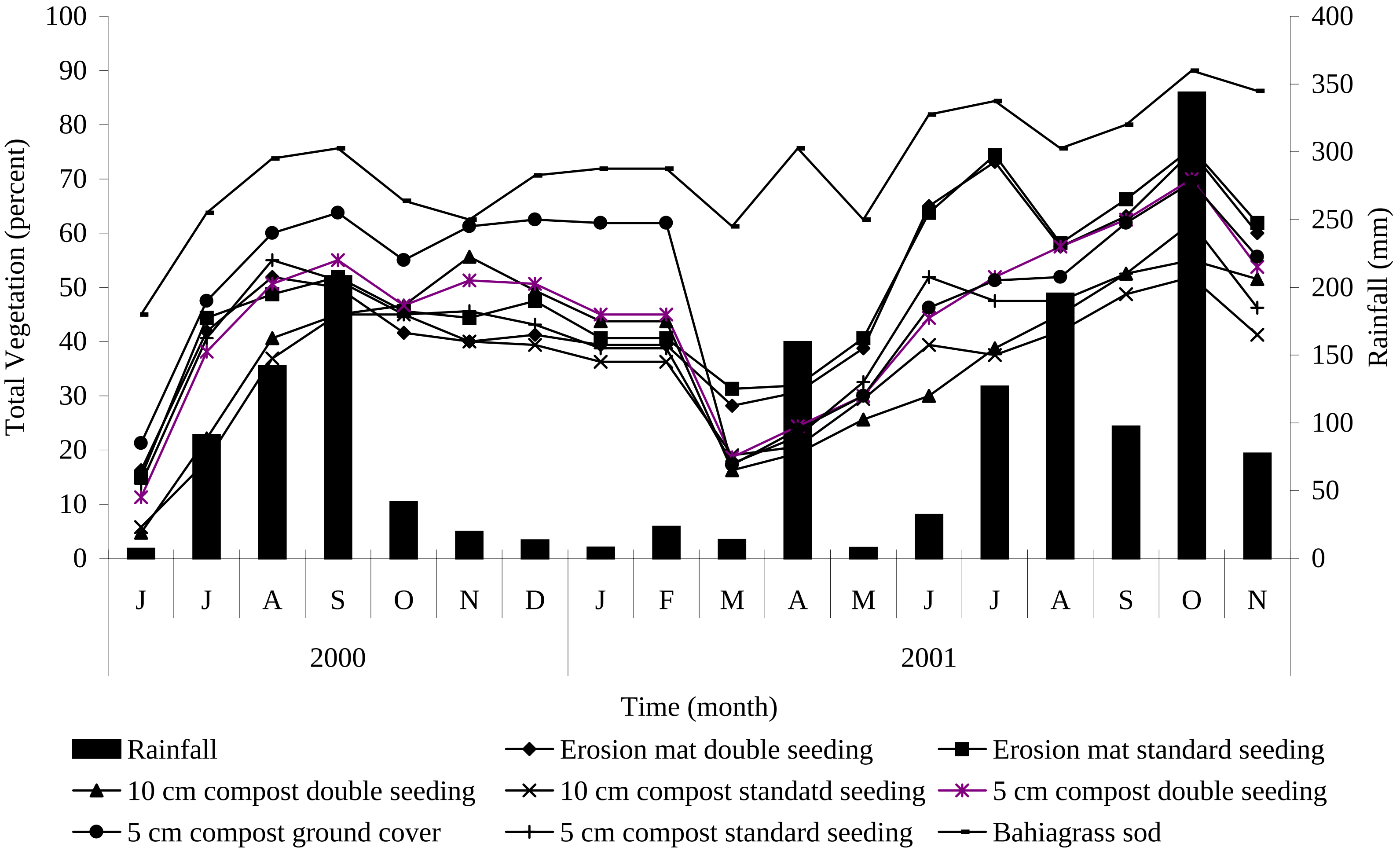

Figure 3-1. Percent total vegetation and rainfall over 18 months at the central site.

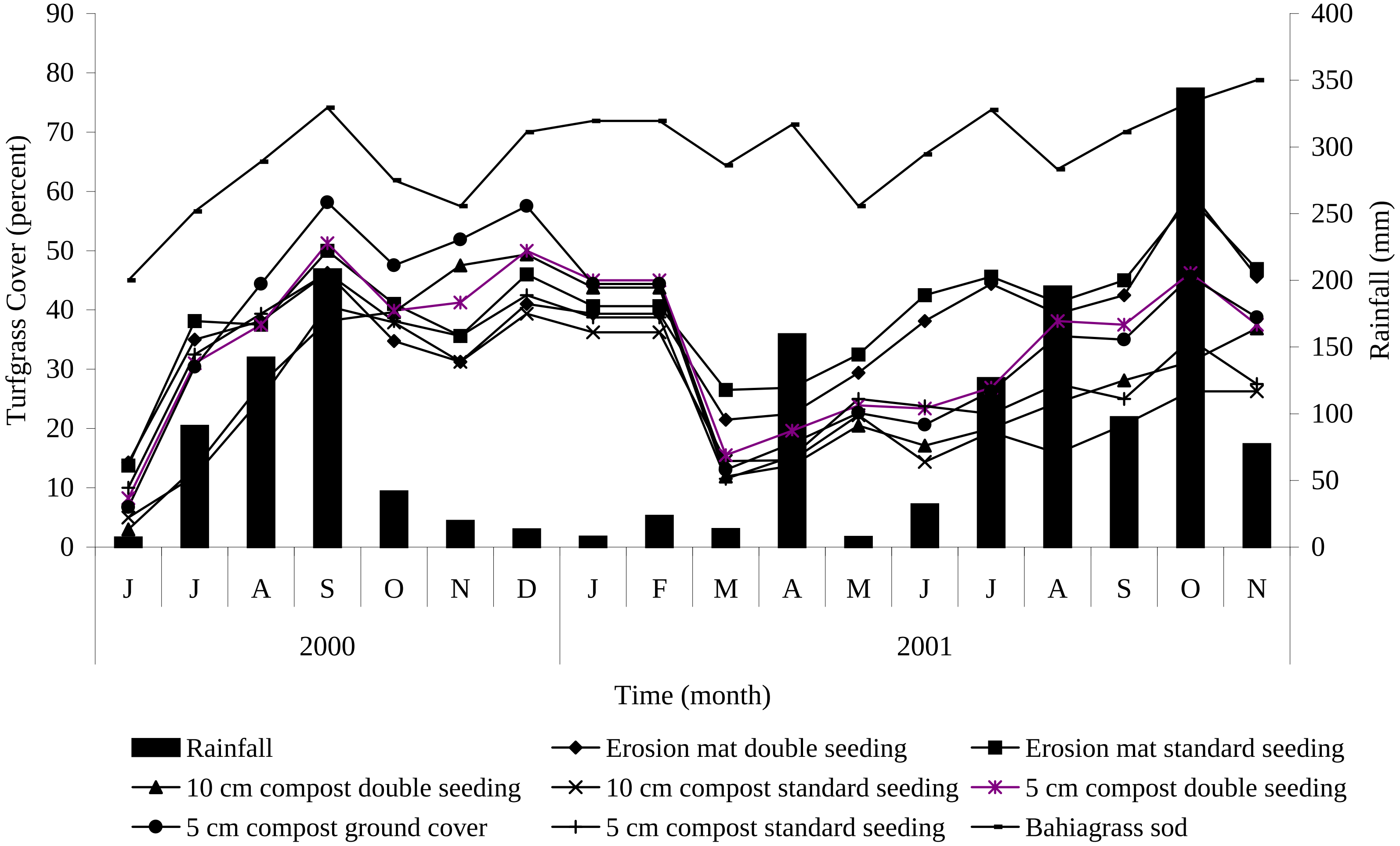

Figure 3-2. Percent turfgrass cover and rainfall over 18 months at the central site.

.

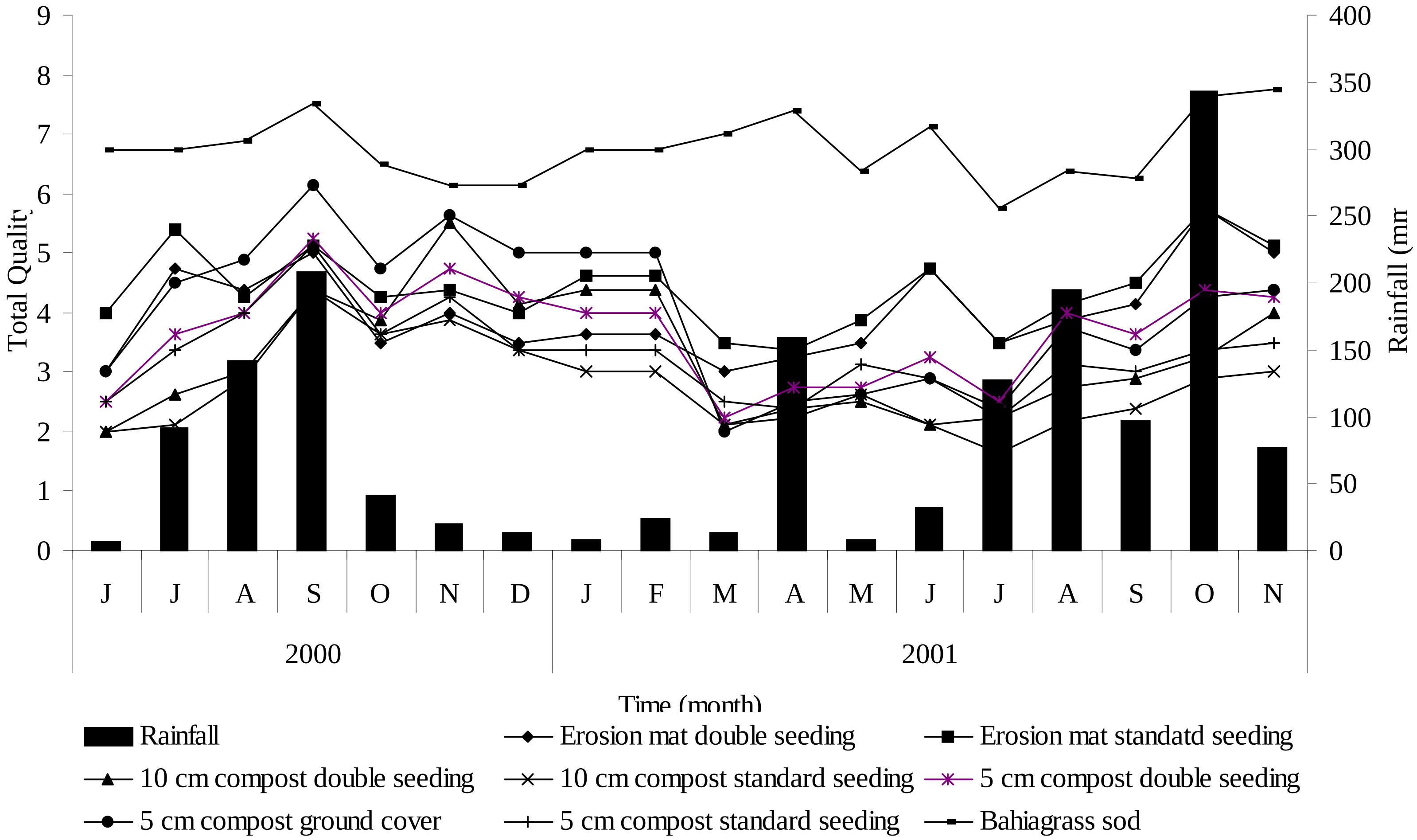

Figure 3-3 Total quality ratings and rainfall over 18 months at the central site. Ratings of total quality were assessed using a 1-9 scale with 9 representing the darkest green color obtainable, best uniformity, and no undesirable species.

Table 3-3. Single degree of freedom orthogonal contrasts between treatments at the central site.

	Month																	
	2000							2001										
Total Vegetation	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N
Standard vs Double Seeding	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
10 cm Compost vs 5 cm	ns	**	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	*	ns	ns	*	ns
Erosion Mat vs Compost	ns	*	ns	ns	ns	ns	ns	ns	ns	**	**	**	**	**	*	*	**	*
Sod vs Compost	**	**	**	**	**	*	**	**	**	**	**	**	**	**	**	**	**	**
Erosion Mat vs Sod	**	**	**	**	**	**	**	**	**	**	**	**	*	*	**	*	*	**
5 cm Compost vs Ground cover	ns	ns	ns	ns	ns	*	*	**	**	ns	ns	ns	ns	ns	ns	ns	ns	ns
Turfgrass Cover																		
Standard vs Double Seeding	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
10 cm Compost vs 5 cm	ns	**	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Erosion Mat vs Compost	*	**	ns	ns	ns	ns	ns	ns	ns	*	*	*	**	**	*	**	ns	*
Sod vs Compost	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Mat vs Sod	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
5 cm Compost vs Ground cover	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Total Quality																		
Standard vs Double Seeding	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
10 cm compost vs 5 cm	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Erosion Mat vs Compost	**	ns	ns	ns	ns	ns	ns	ns	ns	*	*	*	**	**	ns	**	**	*
Sod vs Compost	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Mat vs Sod	*	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	*	**
5 cm Compost vs Ground cover	ns	ns	ns	ns	ns	*	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

*, ** significance at the 0.05 and 0.01 levels of probability, respectively. Standard seeding rate is 110 kg ha^{-1} 80:20 bahiagrass:bermudagrass seed mix.

Table 3-4. Total vegetation, turf cover, and total quality evaluated at 18 months after treatment application at the central site.

Treatment	Total Vegetation	Turf Cover	Total Quality†
	%	%	
Bahiagrass sod	86a‡	79a	7.7a
Erosion mat standard seeding	62b	47b	5.1b
Erosion mat double seeding	60b	46bc	5.0b
5 cm compost standard seeding	46bc	28cd	3.5bc
5 cm compost double seeding	54bc	38bcd	4.3bc
5 cm compost with ground cover	56bc	39bcd	4.4bc
10 cm compost standard seeding	41c	26d	3.0c
10 cm compost double seeding	52bc	37bcd	4.0bc
CV, %	15.0	105.2	31.3

† Ratings of quality were assessed using a 1-9 scale with 9 representing the darkest green color obtainable, best uniformity, and no undesirable species.
‡Means within columns followed by unlike letters are significantly different at the 5% level by Duncan's multiple range test.

Total Vegetation--North Site

Due to significant date, treatment, and date x treatment interactions (Table 3-5), treatment effects over time are represented in Figures 3-4, 3-5, and 3-6. Total vegetation of standard and double seeding rates was generally not different. The bare soil treatment had similar total vegetation to seeded bare soil treatments for all but one rating period. Compost rates of 5 cm had greater total vegetation than 10 cm rates for seven of the first ten months of the study. These treatments showed no difference for the remaining eight months. This can likely be attributed to the burying of existing vegetation with the higher compost rate covering a larger percentage of pre-existing cover. Increased rainfall during the second year resulted in increased vegetation for all treatments at which point 5 and 10 cm compost treatments reached maximum cover between 80 and 90% and were not different. Compost treatments had greater total vegetation than bare soil treatments for all but one rating period. Ground cover treatments and 5 cm compost treatments were generally not different.

Table 3-5. Mean squares for the primary dependant variables and interactions at the north site.

Source	df	Total vegetation	Turfgrass cover	Total quality
Date	17	6425.90**	1325.58**	9.1**
Rep	3	6640.33**	9426.77**	59.2**
Treatment	7	6855.79**	4697.72**	73.4**
Date x Rep	51	199.77**	303.90**	4.0**
Date x Treatment	119	163.96**	139.43**	1.4**
Rep x Treatment	21	514.17**	942.58**	10.1**
Error	357	53.25	69.98	1.30
CV, %		25.6	21.3	26.5

** significance at the 0.01 level of probability.

Turfgrass Cover--North Site

Standard and double seeding rates did not affect turfgrass cover with the exception of three months during the first year where double seeding rates had greater cover. Turfgrass cover of the bare soil treatment was not different than the seeded bare soil treatments throughout the study. Compost rates of 5 cm had greater turfgrass cover than 10 cm rates for 8 rating periods throughout the study. Compost treatments had greater total vegetation than bare soil treatments for all but two rating periods. Ground cover treatments (with 5 cm compost) and 5 cm compost treatments were generally not different. Compost rates of 5 cm were generally not different than ground cover treatments for all but three rating periods where 5 cm compost treatments (seeded) exhibited greater turfgrass cover than ground cover treatments. These data indicate that seeding was ineffective regardless of rate since the 5 cm compost planted with ground cover essentially became an unseeded 5 cm compost treatment when the ground cover died due to extended drought.

Total Quality--North Site

Double seeding rate treatments had higher quality than standard seeding rates for four rating periods, but otherwise were not different. Bare soil treatments were not different than seeded bare soil treatments for all but one rating period. Compost rates of 5 cm had greater total quality than 10 cm rates for eight rating periods throughout the study, but were not different for ten rating periods. Compost treatments had greater total quality than bare soil treatments for all but one rating period. Ground cover treatments and 5 cm compost treatments were generally not different.

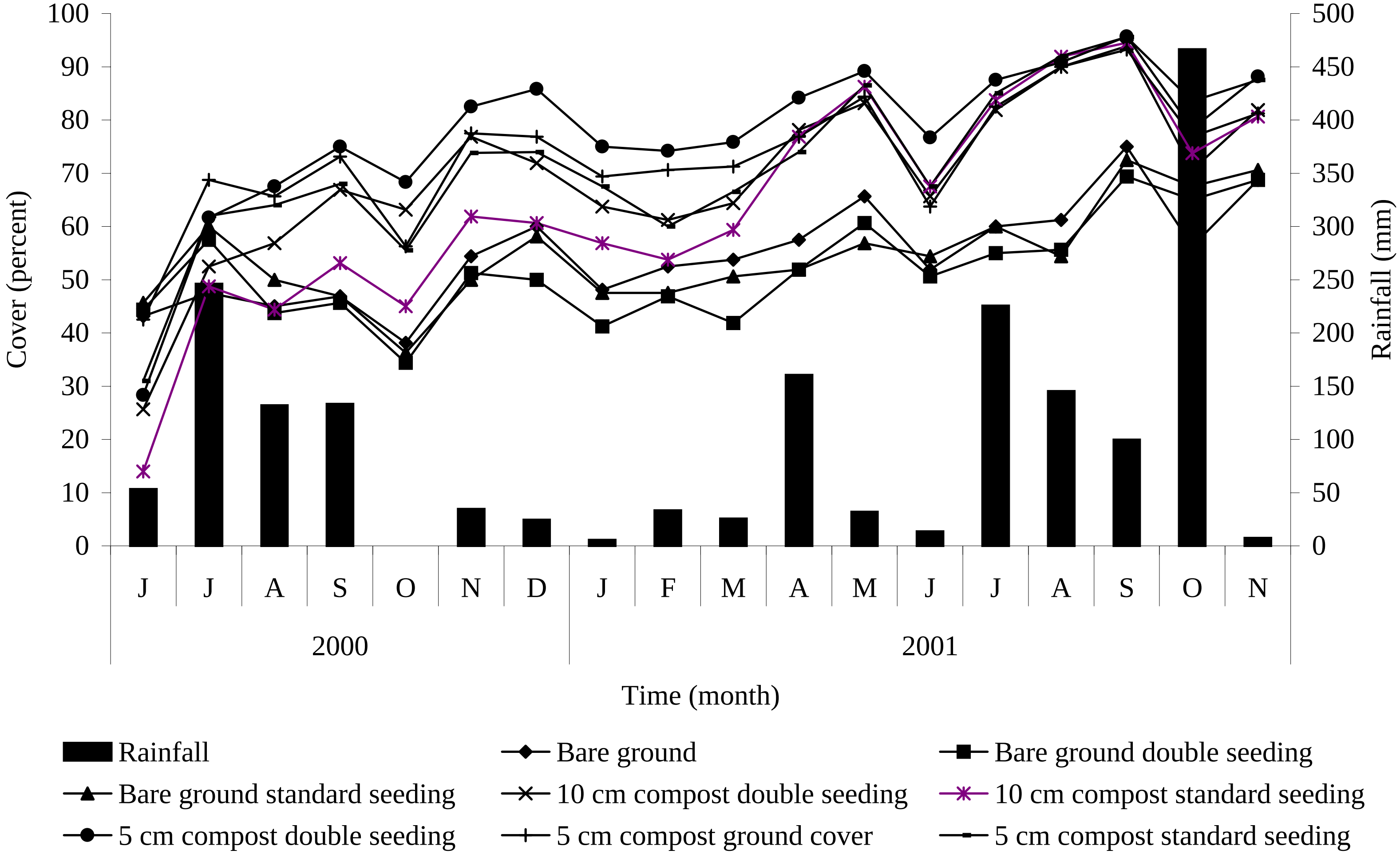

Figure 3-4 Percent total vegetation and rainfall over 18 months at the north site.

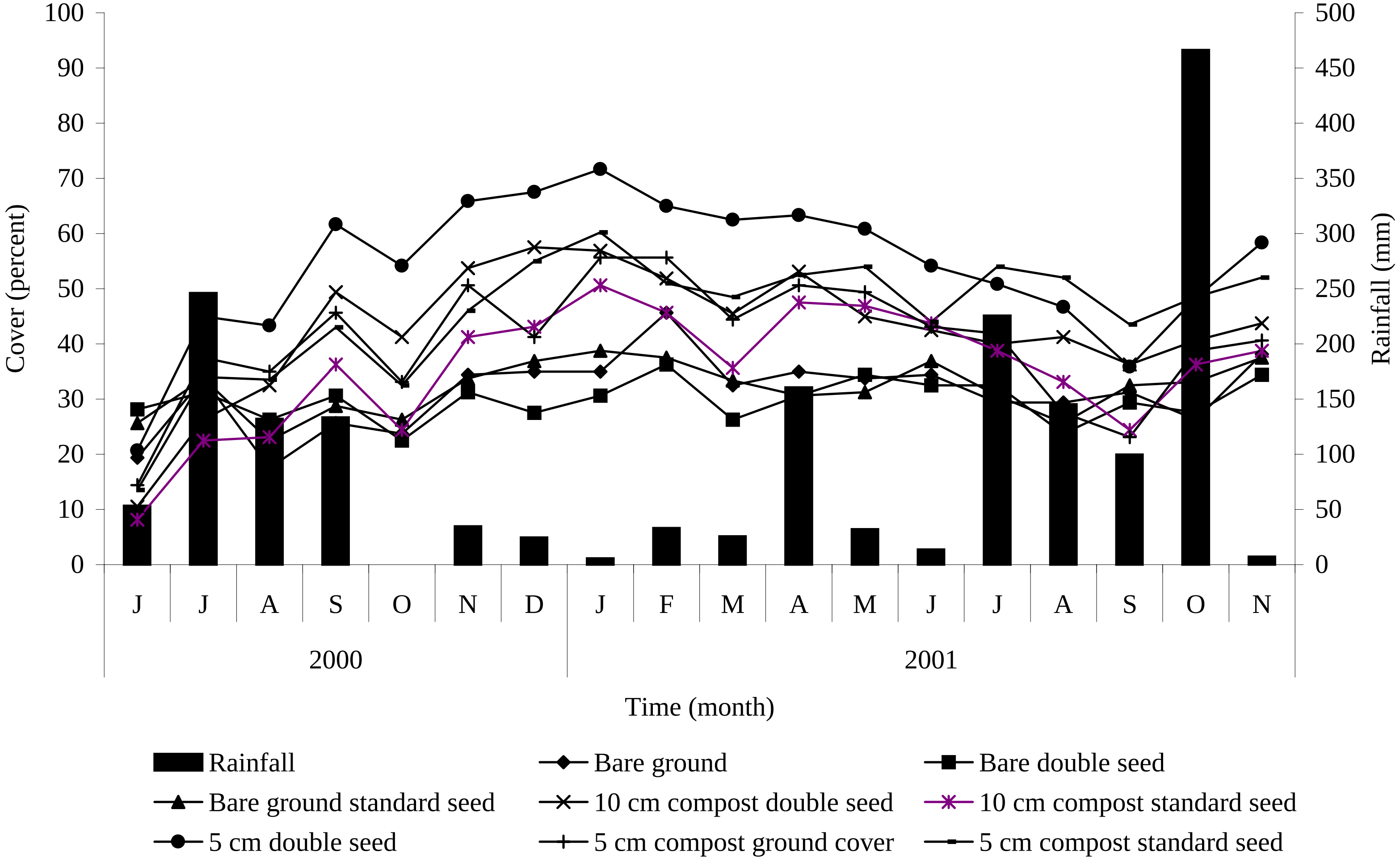

Figure 3-5 Percent turfgrass cover and rainfall over 18 months at the north site.

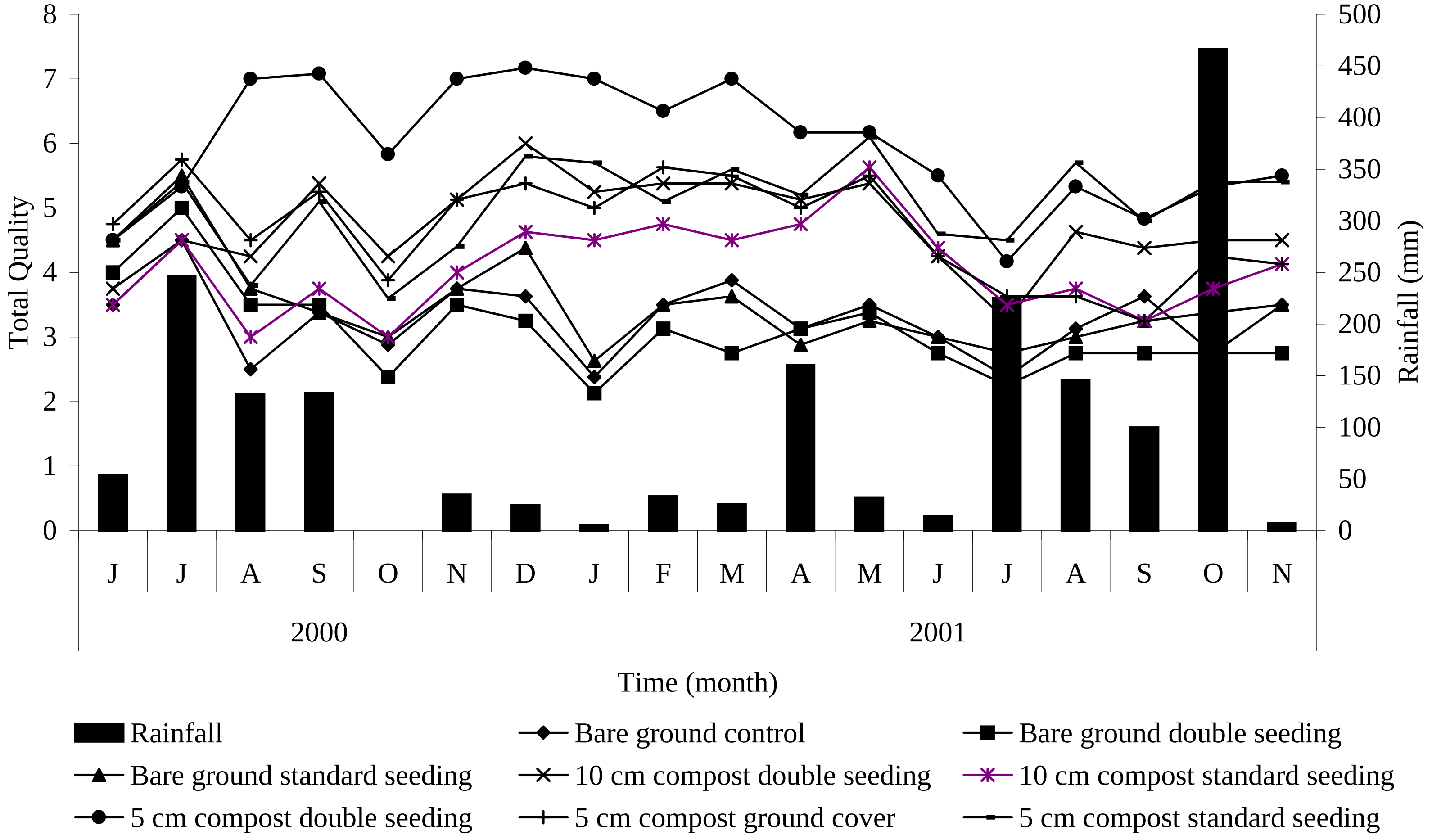

Figure 3-6 Total quality ratings and rainfall over 18 months at the north site. Ratings of quality were assessed using a 1-9 scale with 9 representing the darkest green color obtainable, best uniformity, and no undesirable species.

Table 3-6. Single degree of freedom orthogonal contrasts between treatments at the north site.

	Month																	
	2000							2001										
	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N
Total Vegetation																		
Bare vs composts	**	ns	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Double seeding vs standard	ns	ns	ns	ns	**	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
High compost vs low	*	**	**	*	ns	ns	*	*	ns	*	ns	ns	ns	ns	ns	ns	ns	ns
Bare no seed vs bare seeded	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Bare vs low compost	**	ns	**	**	**	**	**	**	**	**	**	**	**	**	**	**	*	**
Ground cover vs low compost	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns
Turfgrass Cover																		
Bare vs composts	**	ns	*	**	**	**	**	**	**	**	**	**	**	**	**	ns	**	**
Double seeding vs standard	ns	ns	ns	*	*	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
High compost vs low	*	*	ns	ns	ns	ns	ns	*	ns	*	ns	*	ns	*	**	ns	ns	*
Bare no seed vs bare seeded	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Bare vs low compost	**	ns	*	**	**	**	**	**	**	**	**	**	**	**	**	ns	**	**
Ground cover vs low compost	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	**	ns	ns	*
Total Quality																		
Bare vs composts	**	ns	*	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Double seeding vs standard	ns	ns	*	*	ns	*	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns
High compost vs low	ns	ns	**	*	ns	ns	ns	*	ns	*	ns	ns	ns	*	**	ns	*	*
Bare no seed vs bare seeded	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Bare vs low compost	**	ns	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Ground cover vs low compost	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	**	*	ns	*

*, ** significance at the 0.05 and 0.01 levels of probability, respectively. Standard seeding rate is 110 kg ha^{-1} 80:20 bahiagrass:bermudagrass (wt:wt) seed mix.

Table 3-7. Total vegetation, turf cover, and total quality at 18 months after treatment application at the north site.

Treatment	Total Vegetation	Turf Cover	Total Quality†
	%	%	
Bare ground control	69b‡	38bc	3.5bc
Bare ground standard seeding	70b	38bc	3.5bc
Bare ground double seeding	69b	34c	2.8c
5 cm compost standard seeding	88a	52ab	5.4a
5 cm compost double seeding	88a	58a	5.5a
5 cm compost with ground cover	81ab	41bc	4.1abc
10 cm compost standard seeding	81ab	39bc	4.1abc
10 cm compost double seeding	82ab	44abc	4.5ab
CV, %	11.8	23.4	23.4

† Ratings of quality were assessed using a 1-9 scale with 9 representing the darkest green color obtainable, best uniformity, and no undesirable species.

‡Means within columns followed by unlike letters are significantly different at the 5% level by Duncan's multiple range test.

Sediment Loss

Compost treatments had no measurable sediment loss. Sediment loss for bare soil treatments after the first year of rainfall averaged 10.8 Mg ha $^{-1}$. Sediment collected monthly during the last 6 months of the study averaged 2.6 Mg ha $^{-1}$ per month (reduced collection area of 12 m^2). Over the course of a year, this would amount to approximately 3 times the amount of sediment collected during the first year (10.8 vs 31.2 Mg ha $^{-1}$). These differences are likely due to a combination of factors influencing the amount of soil lost from the test plots. At the time of treatments application, significant amounts of compost settled on each of the bare soil treatments from adjacent compost treated plots, resulting in decreased sediment loss values due to the influence of the compost. The smaller silt fence catchments used during the last 6 months reduced the influence from the bordering plots and allowed more accurate collection and measurement of the eroded soil. The amount of rainfall was also a factor. Rainfall for the first year of the study (895 mm) was less than half of the total rainfall (1952 mm) for the 18 months of the experiment.

Greenhouse Study

Due to significant date, treatment, and date x treatment interactions (Table 3-8), seedling emergence over time is shown in Figure 3-7.

Table 3-8. Mean squares for the primary dependant variables and interactions for the greenhouse study.

Source	df	Mean Squares
Date	5	1549.79**
Rep	3	50.50*
Treatment	3	121.75**
Date*rep	15	13.49
Date*treatment	15	126.88**
Rep*treatment	9	80.49
Error	45	19.83
CV, %		32.3

*, ** significance at the 0.05 and 0.01 levels of probability, respectively.

The number of seedlings for compost with seed incorporated treatments and erosion mat treatments were not different for the first eight weeks of the experiment (Table 3-9). Treatments with seed placed on top of the compost performed poorly during this time. These results are likely due to the low irrigation rate (8 mm 24-h^{-1}) applied initially. Most seeds were suspended in the coarse compost and could not imbibe enough water to germinate. Germination results of erosion mat treatments whether seeded above or below were not different throughout the study. Seed placed above erosion mats tended to settle below the mat over time due to movement initiated by irrigation water. After irrigation intensity was increased to simulate heavy summer rainfall (Figure 3-7), treatments where seed was placed on top of the compost had a greater number of seedlings than all other treatments. The delay in seedling growth was likely due to the initial lack of sufficient moisture necessary for seedling germination at low irrigation intensities. Seedling growth of the compost seeded above treatments exceeded all other treatments at the conclusion of the study.

Table 3-9. Number of turfgrass seedlings over time as affected by seed placement for the greenhouse study.

Treatment	Week					
	2	4	6	8	10	12
MSB	5ab†	13a	16a	12ab	23b	22b
MSA	2bc	6ab	9ab	9ab	21b	20b
CSA	0c	1b	3b	3b	37a	36a
CSIN	6a	11a	14a	15a	26b	25b

†Means within columns followed unlike letters are significantly different at the 5% level by Duncan’s multiple range test. (MSB= erosion mat seeded below; MSA= erosion mat seeded above; CSA= compost seeded above; CSIN=compost seed incorporated)

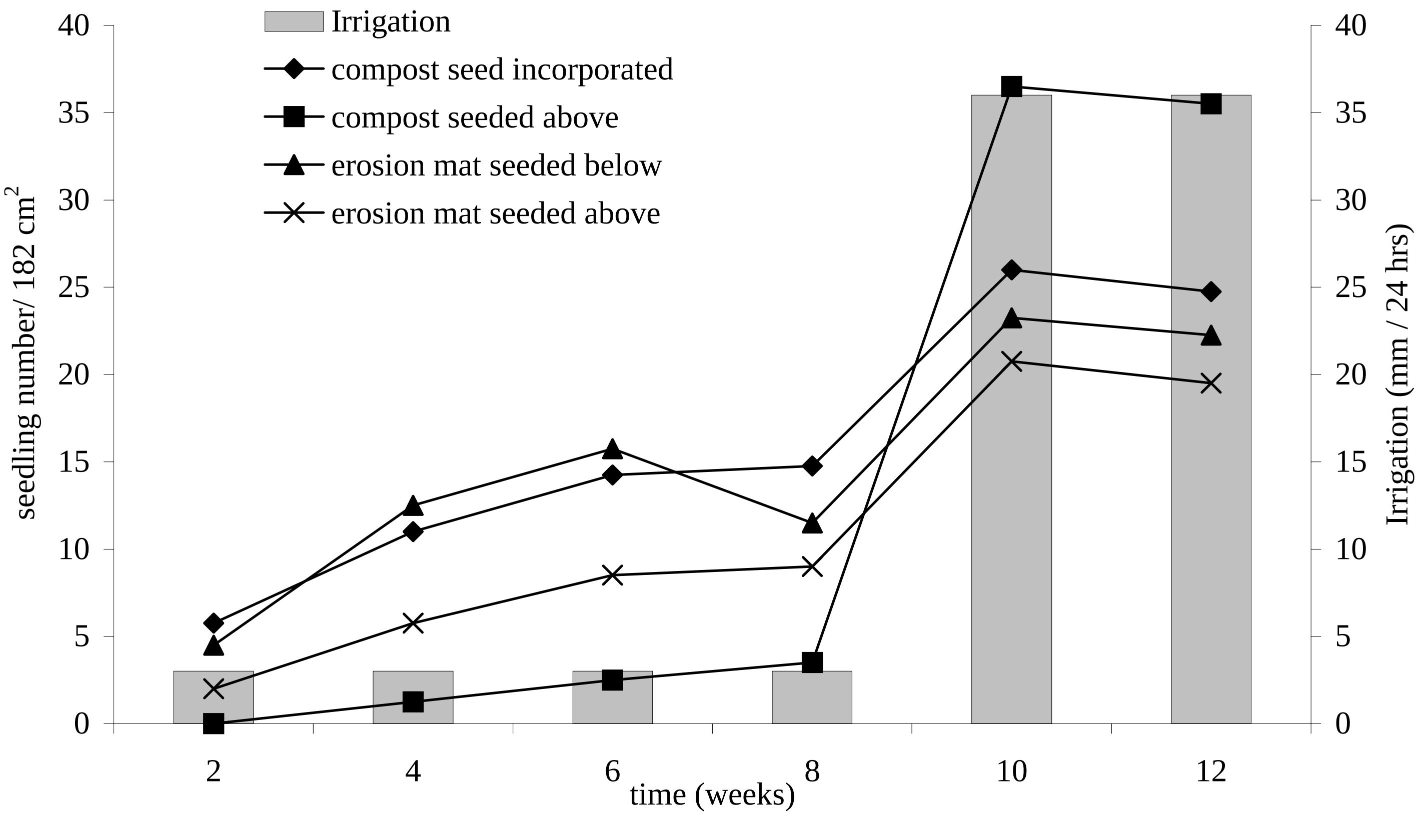

Figure 3-7. Effects of seed placement and irrigation on turfgrass plants over 12 weeks in the greenhouse study.

Conclusion

Results from the erosion control study indicate that compost mulch can effectively control erosion, but does not necessarily facilitate the growth and establishment of turfgrass or other vegetation. It can provide slope stability for periods of at least 18 months and probably longer with or without vegetative growth. At the central site, lack of sufficient rainfall did not allow substantial vegetation to grow in compost mulch treated plots. At this location, sod and erosion mat treatments had greater turfgrass and vegetative cover, but all treatments effectively controlled erosion for the duration of the study. At the north site, compost mulch plots had greater total vegetation and turfgrass cover equal to or better than bare soil plots. Given the level of maintenance and watering, nearly all of the ground cover plants died.

Results from the greenhouse seeding experiment indicate that seed incorporation into composted yard waste mulch may not be necessary during periods of abundant rainfall. However, during periods of low rainfall, seed germination will be greater when incorporated into the compost either by hand raking or mixing the seed at depths less than 4 cm with the compost prior to application. This study indicates that erosion control mats can be seeded either above or below without affecting seed germination.

CHAPTER 4
FERTILIZATION OF ROADSIDE VEGETATION WITH COMPOSTED BIOSOLIDS

Introduction

Municipalities throughout the world are facing the ever-increasing problem of disposing of wastes such as biosolids. While quantities are increasing, requirements for disposal are becoming more stringent. One possible solution to this problem is composting, a popular means of turning waste into a useful soil amendment. Additionally, compost applications can have several beneficial effects on soil properties which can result in an improvement in the quality of roadside vegetation.

Poor quality roadside turf is unappealing to the eye and can lead to erosion and shoulder instability. Nitrogen (N) is the nutrient that is most frequently limiting for turfgrass. Inorganic fertilizers can increase turfgrass performance, but can be costly to apply and effects are generally short lived. Compost use can substitute for chemical fertilizers in these situations.

Compost can be used as a nitrogen source. Pure composted biosolids can contain about 2.5 to 3.5 percent N (Garling and Boehm, 2001), which can be used as a plant available N source. However, some compost sources require an additional source of N to avoid immobilized N from a poor C:N ratio. Additional sources of N can be obtained from either an inorganic source, organic source, or can be blended with a feedstock with a higher N content (Stevens and Kostewicz, 1992; Kostewitcz, 1993; Stevens and Kostewicz, 1994).

Garling and Boehm (2001) found that composted biosolids applications to a mixed sward of creeping bentgrass [*Agrostis stolonifera* var. *palustris* (Huds.) Farw.] and annual bluegrass (*Poa annua* L.) improved color, increased growth, and increased foliar N. Composted bisolids increased foliar N by 50% over a 3-yr period when compared to the control. Co-composted biosolids and yardwaste applications increased foliar N by 30% over the control. However, results were not always positive and varied depending on rates, compost maturity, and available N.

Materials and Methods

A field study was conducted from 1 May 2000 through 1 November 2001 to evaluate the effectiveness of composted municipal biosolids (co-composted with yard waste) for improving roadside turf. Test sites were located near Kissimmee, FL (central site) at the intersection of US27 and SR192 (81 W 40’39” 28 N 20’54”) and near Crescent Beach, FL (north site) at the intersection of SR206 and I95 (81W 21’21” 29N 44’10”). Studies were conducted on existing thin stands of bahiagrass [*Paspalum notatum* Flugge] and bermudagrass [*Cynodon dactylon* L.]. Soils were typical disturbed material found on road shoulders. Soils at the central site contained <1 percent organic content while the soil at the north site contained approximately 4 percent organic content by weight. Both soils were predominantly sand with greater than 80 percent of the particles falling into the medium sand category (150-250 μm) for the central site and greater than 95 percent for the north site. Initial turfgrass stands were <25% cover for the central site and <35% cover for the north site.

Treatments consisted of: composted biosolids at 20, 40, and 60 Mg ha $^{-1}$, ammonium nitrate soluble inorganic fertilizer (33.5-0-0) at 98 kg ha $^{-1}$ N, and an untreated control. Rates of N for the compost treatments were approximately 280, 560, and 840 kg ha $^{-1}$ for the initial application and 240, 480, and 720 kg ha $^{-1}$ for the reapplication. Test plots were 3.0 m by 10.0 m. Initial treatment application occurred 1 and 5 May 2000 for the central site and north site, respectively. Reapplication of all treatments occurred 1 and 3 March 2001. Test design was a randomized complete block with five treatments and four replications at each location. Treatments were designed to compare turf density and visual quality for three compost application rates, a soluble fertilizer treatment, and a control.

A standard compost of biosolids (wastewater sludge) and yard trimmings (tree and shrubbery trimmings, grass clippings, and leaves from homeowners and landscaping firms) provided by Palm Beach County Solid Waste Authority (West Palm Beach, FL) was used in this experiment. Compost and soluble fertilizer treatments were applied by hand.

No supplemental water was applied to either site. Mowing occurred once at the central site prior to reapplication of treatments and approximately monthly at the north site during the growing season. Rainfall data was obtained from the Florida Automated Weather Network at the agricultural experiment station located approximately 15 miles from the central site in Lake Alfred, FL and at the agricultural experiment station located approximately 10 miles from the north site in Hastings, FL.

At the time of compost delivery to the specific sites, 2 to 6 random grab samples were taken and combined. Composite samples from each site were then stored at 4^{o} C until analyzed for select chemical and physical properties. Samples were homogenized using Ultra-Turrax T25 (Labrotechnik) and then analyzed for N content as received at the

Suwannee Valley REC Livestock Waste Testing Laboratory (Live Oak, FL) using the semi-micro Kjeldahl method (Bremner and Mulvaney, 1982). The pH in water was determined with a glass electrode using a 1:2.5 sample/water ratio (McLean, 1982). Bulk densities for compost samples from both locations were determined by filling a tared 500 mL beaker. The sample was then shaken to settle and avoid compaction and more sample was added until the desired volume was attained. The recorded mass was divided by the volume to calculate bulk density. Percent moisture was determined gravimetrically by placing a quantity of sample in a beaker, weighing the sample and beaker together, then drying the sample at 105ºC for twenty-four hours. Percent moisture was determined by subtracting the mass of dry sample from the mass of wet sample and dividing by the mass of dry sample.

Density and visual quality data was collected on a monthly basis. Data were obtained by taking the mean value of two raters. Density was a visual estimate of the area covered by vegetation and turf by total plot area. Visual quality data was obtained by rating individual plots on a scale of 1 to 9 with 9 being the highest quality and 5 being minimally acceptable. Factors that where considered with regard to quality were turf color, density, uniformity, and abundance of undesirable vegetation.

Results and Discussion

Selected characteristics of composts used at the central and north sites each year are shown in Table 4-1. Bulk densities for initial application and reapplication of treatments were similar. Percent moisture values for initial application were similar. Percent moisture values were much greater at reapplication which would have reduced total volume of dry material applied to the test plots since treatments were applied by weight as received. The pH values were alkaline ranging from 7.5 for the north site at the initial treatment application to 8.6 for both sites for treatment reapplications. These values are consistent with values obtained by Jackson (1997) who used compost from the same source. Values obtained by Bugbee and Elliot (1998) were slightly lower for a similar compost of biosolids and yard waste obtained from a different source. Total N values were similar for all sites and applications ranging from 12 g kg^{-1} to 14 g kg^{-1}. These values were substantially less than those obtained by Bugbee and Elliot (1998) who determined total N of 21 g kg^{-1}.

Table 4-1. Bulk density, percent moisture, pH, and total N (as received basis) of composted biosolids with yard waste applied at north and central sites.

Source	Bulk density	Percent moisture	pH	Total N
	g cm^{-3}	%		g kg^{-1}
2000				
Central site	0.38	35.2	8.1	14
North site	0.42	36.8	7.5	13
2001				
Central Site	0.43	50.4	8.6	12
North Site	0.43	50.4	8.6	12

Due to significant date, treatment, location, date x treatment, and location x treatment interactions (Table 4-2), changes for total vegetation and total quality for central and north sites over time were analyzed separately and presented in Figures 4-1, 4-2, 4-3, and 4-4.

Table 4-2. Mean squares for primary dependant variables and interactions at the central site.

Source	df	Total Vegetation	Total Quality
Date	17	7343.82**	23.04**
Location	1	59978.63**	112.59**
Rep	3	151.42**	1.79**
Treatment	4	5425.32**	33.44**
Date x Rep	51	62.92**	0.98**
Date x Treatment	68	149.58**	2.83**
Date x Location	17	1812.80**	17.36**
Location x Rep	3	393.21**	6.43**
Location x Treatment	4	2372.22**	12.69**
Treatment x Rep	12	142.93**	1.35**
Date x Location x Rep	51	53.73**	1.12**
Error	488	29.63	0.54**

** significance at the 0.01 level of probability.

Central Site

Total vegetation for control and soluble fertilizer treatments was not different for all but one rating period. This indicates the ineffectiveness of soluble inorganic fertilizer applications during this study. Compost treatments had greater total vegetation than the control and fertilizer treatments for nearly all of the rating periods. The greatest differences in total vegetation occurred in October 2000, where the 60, 40, and 20 Mg ha^{-1} rates of compost had 38%, 27%, and 21% greater cover than the control, respectively.

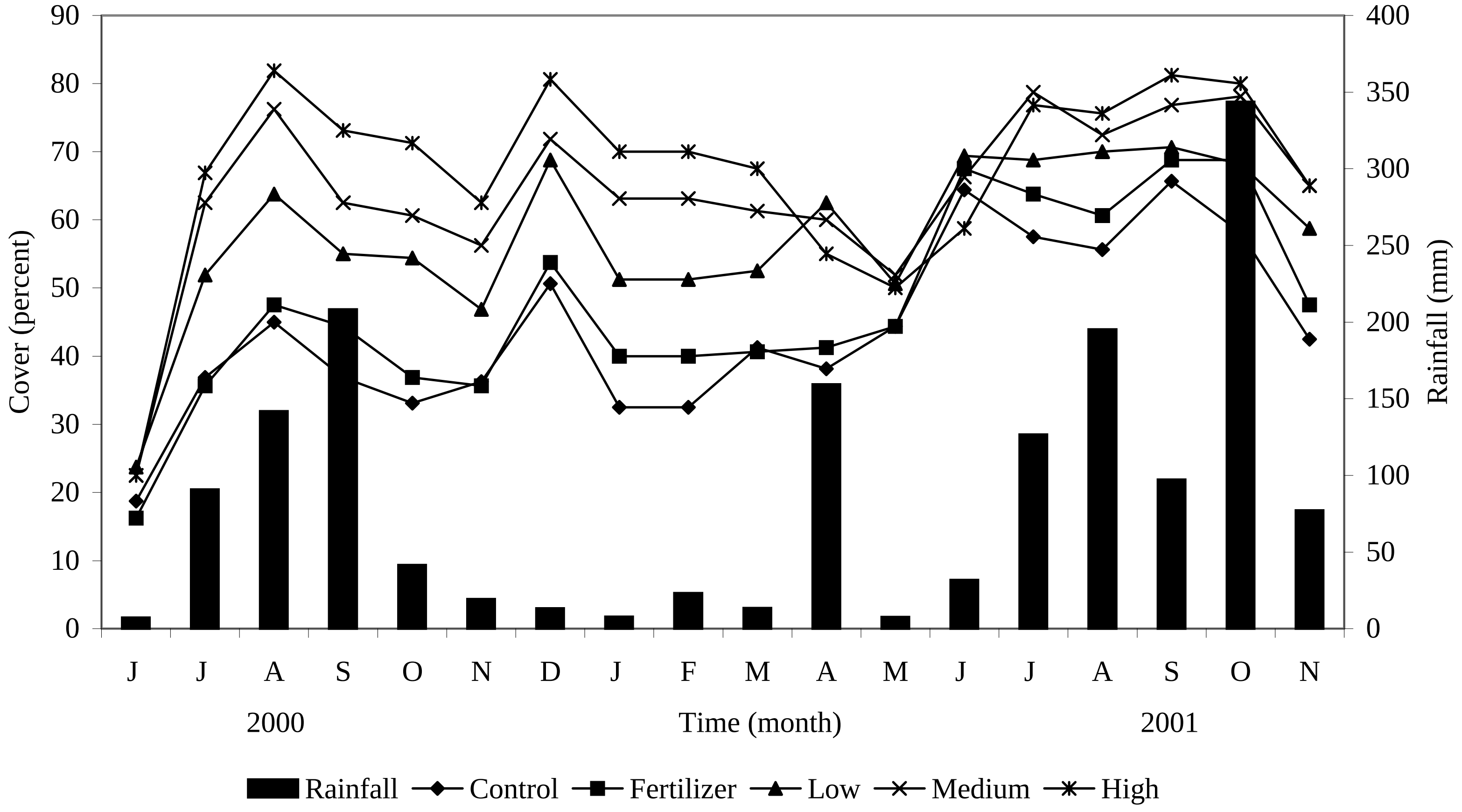

Figure 4-1. Percent vegetation and rainfall over 18 months at the central site. Low, medium, and high treatments are 20, 40, and 60 Mg ha $^{-1}$ composted biosolids, respectively. Fertilizer treatment was ammonium nitrate (33.5-0-0) at 98 kg ha $^{-1}$ N.

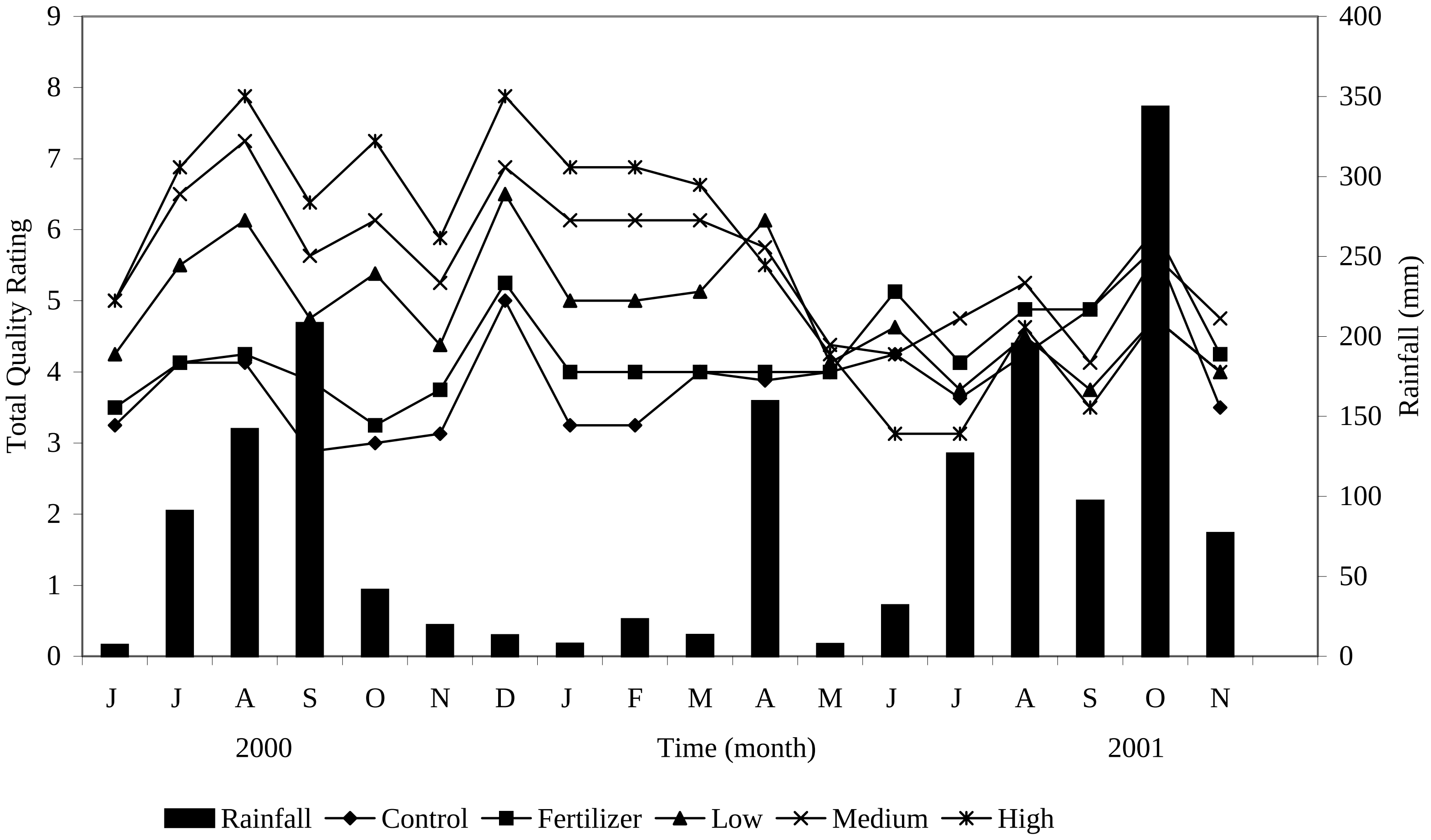

Figure 4-2. Total quality ratings and rainfall over 18 months at the central site. Low, medium, and high treatments are 20, 40, and 60 Mg ha $^{-1}$ composted biosolids, respectively. Fertilizer treatment was ammonium nitrate (33.5-0-0) at 98 kg ha $^{-1}$ N. Ratings of quality were assessed using a 1-9 scale with 9 being the highest quality representing the darkest green color obtainable, best uniformity, and no undesirable species.

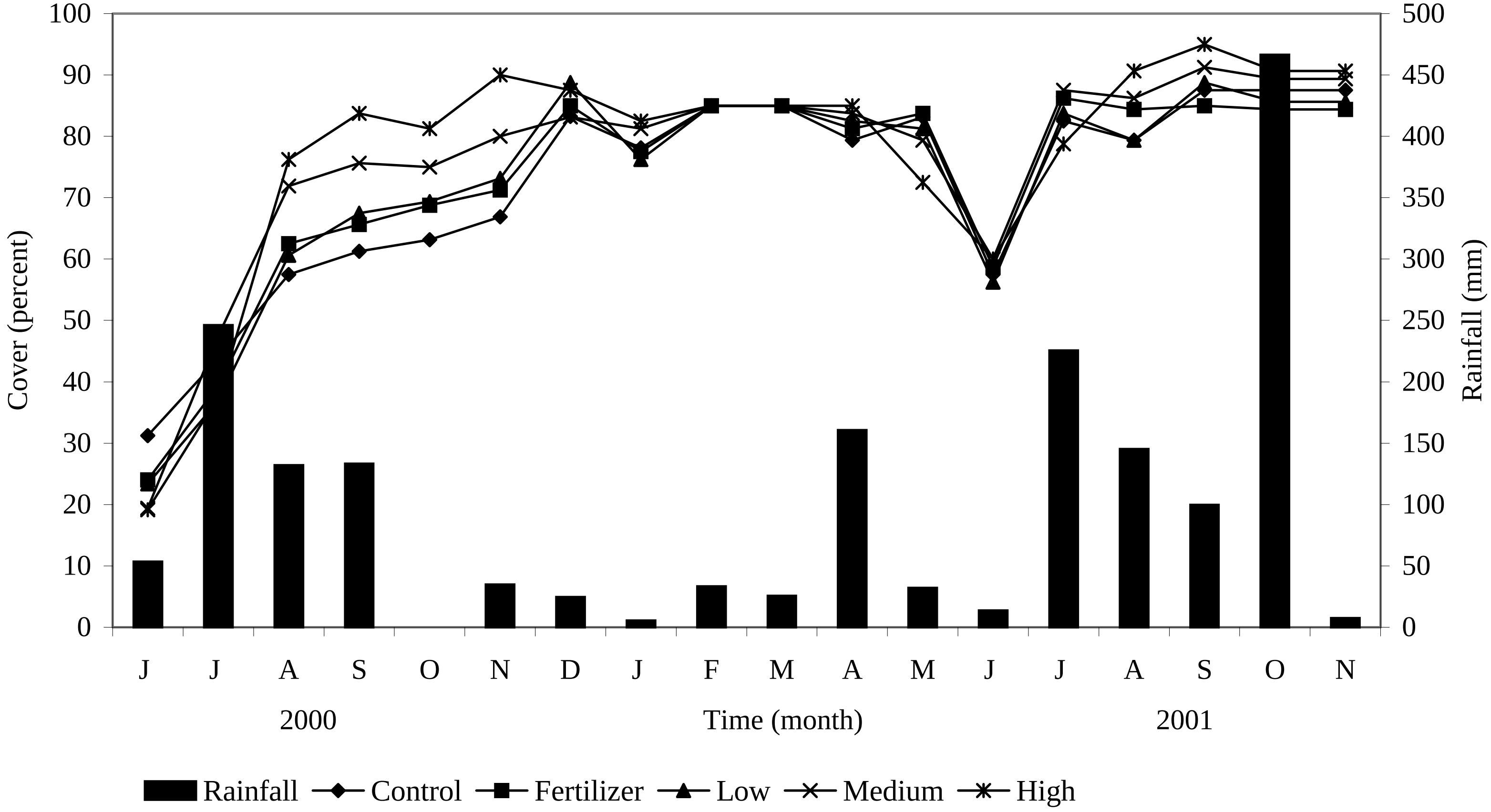

Figure 4-3. Percent vegetation and rainfall over 18 months at the north site. Low, medium, and high treatments are 20, 40, and 60 Mg ha $^{-1}$ composted biosolids, respectively. Fertilizer treatment was ammonium nitrate (33.5-0-0) at 98 kg ha $^{-1}$ N.

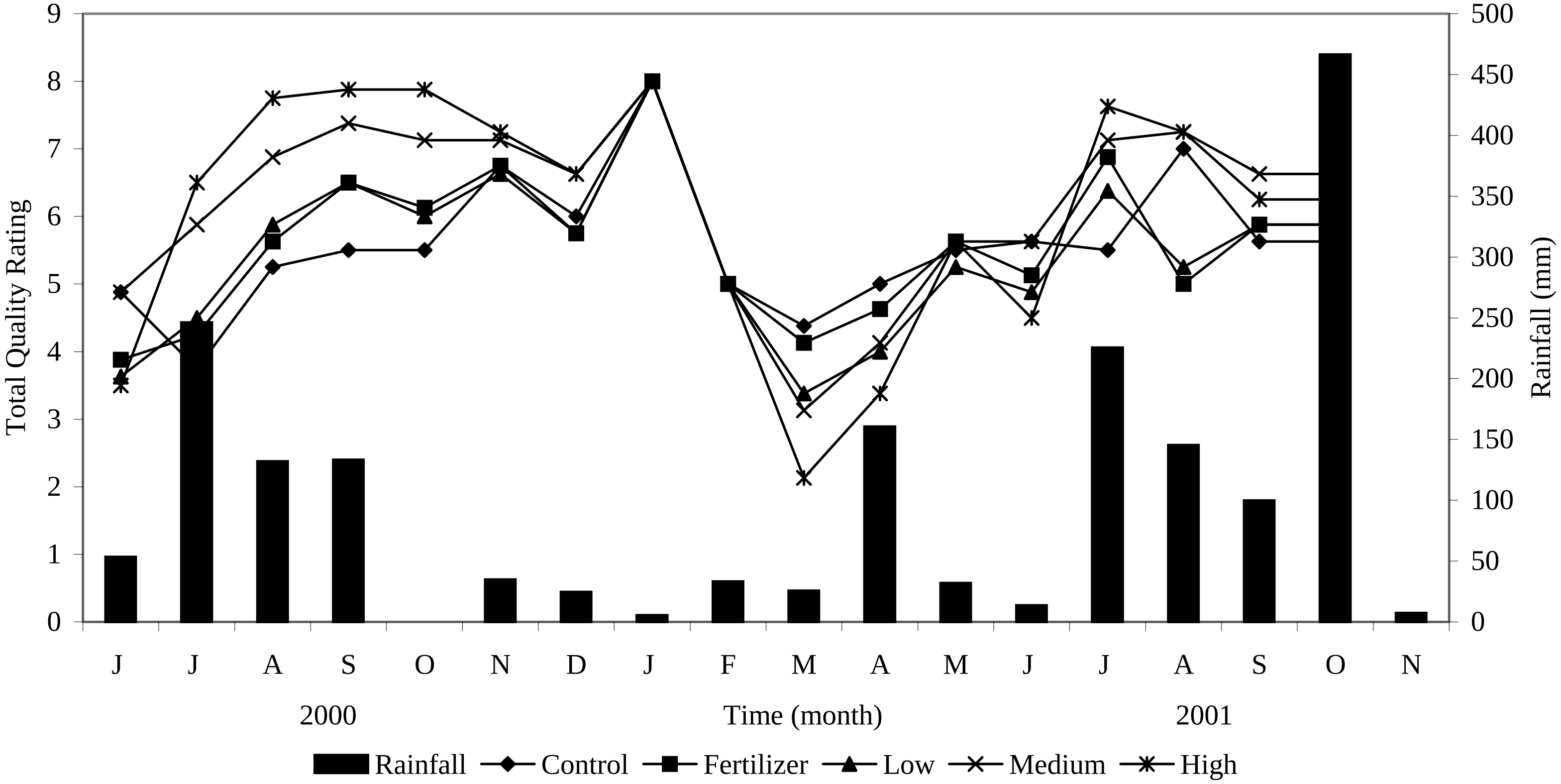

Figure 4-4. Total quality ratings and rainfall data over 18 months at the north site. Low, medium, and high treatments are 20, 40, and 60 Mg ha $^{-1}$ composted biosolids, respectively. Fertilizer treatment was ammonium nitrate (33.5-0-0) at 98 kg ha $^{-1}$ N. Ratings of quality were assessed using a 1-9 scale with 9 being the highest quality representing the darkest green color obtainable, best uniformity, and no undesirable species.

Table 4-3. Single degree of freedom orthogonal contrasts between treatments at the central site for each month.

	2000							2001										
	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N
<u>Total Vegetation</u>																		
Control vs. Fertilizer	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Control vs Compost	ns	**	**	**	**	**	**	**	**	**	**	**	ns	**	**	**	**	**
Fertilizer vs Compost	*	**	**	**	**	**	**	**	**	**	**	**	ns	*	**	*	ns	**
60 Mg ha^{-1} vs 40 Mg ha^{-1}	ns	ns	ns	**	**	*	*	ns	ns	*	ns	ns	**	ns	ns	ns	ns	ns
40 Mg ha^{-1} vs 20 Mg ha^{-1}	ns	ns	**	*	ns	**	ns	*	*	**	ns	ns	ns	ns	ns	ns	ns	ns
60 Mg ha^{-1} vs 20 Mg ha^{-1}	ns	*	**	**	**	**	**	**	**	**	ns	ns	**	ns	ns	**	*	ns
<u>Total Quality</u>																		
Control vs Fertilizer	ns	ns	ns	*	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Control vs Compost	**	**	**	**	**	**	**	**	**	**	**	ns	ns	ns	ns	**	ns	ns
Fertilizer vs Compost	**	**	**	**	**	**	**	**	**	**	**	ns	**	ns	ns	**	ns	ns
60 Mg ha^{-1} vs 40 Mg ha^{-1}	ns	ns	ns	ns	**	*	**	ns	ns	ns	ns	ns	*	**	ns	ns	ns	ns
40 Mg ha^{-1} vs 20 Mg ha^{-1}	ns	*	*	*	*	**	ns	**	**	**	ns	ns	ns	*	ns	ns	ns	ns
60 Mg ha^{-1} vs 20 Mg ha^{-1}	ns	**	**	**	**	**	**	**	**	**	ns	ns	**	ns	ns	ns	ns	ns

*, ** significance at the 0.05 and 0.01 levels of probability, respectively.

Table 4-4. Single degree of freedom orthogonal contrasts between treatments at the north site for each month.

				2000									2001					
	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N
Total Vegetation																		
Control vs Fertilizer	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns
Control vs Compost	ns	ns	*	**	**	**	*	ns	ns	ns	ns	ns	ns	ns	**	*	ns	ns
Fertilizer vs Compost	ns	ns	ns	*	**	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	**	ns	ns
60 Mg ha^{-1} vs 40 Mg ha^{-1}	ns	*	ns	ns	*	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
40 Mg ha^{-1} vs 20 Mg ha^{-1}	ns	**	ns	ns	*	*	*	ns	ns	ns	ns	ns	ns	ns	**	ns	ns	ns
60 Mg ha^{-1} vs 20 Mg ha^{-1}	ns	ns	*	**	**	**	**	ns	ns	ns	ns	ns	ns	ns	**	*	ns	ns
Total Quality																		
Control vs Fertilizer	ns	*	ns	ns	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns
Control vs Compost	ns	*	*	**	**	**	ns	ns	ns	ns	**	ns	ns	ns	*	ns	ns	ns
Fertilizer vs Compost	ns	ns	ns	*	**	*	ns	ns	ns	ns	*	ns	ns	ns	ns	*	ns	ns
60 Mg ha^{-1} vs 40 Mg ha^{-1}	ns	**	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns
40 Mg ha^{-1} vs 20 Mg ha^{-1}	ns	*	ns	ns	*	*	ns	ns	ns	ns	ns	ns	ns	ns	**	*	ns	ns
60 Mg ha^{-1} vs 20 Mg ha^{-1}	ns	ns	*	**	**	**	*	ns	ns	ns	*	ns	ns	ns	**	*	ns	ns

*, ** significance at the 0.05 and 0.01 levels of probability, respectively.

Compost rates of 60 Mg ha^{-1} had greater total vegetation than 40 Mg ha^{-1} rates at the end of the first year, but differences were only evident at two rating periods during the second year. Compost rates of 40 Mg ha^{-1} had greater cover than 20 Mg ha^{-1} rates for most of the rating periods during the first 10 months, however there were no differences for the last eight months of the study. Compost rates of 60 Mg ha^{-1} had greater total vegetation than 20 Mg ha^{-1} rates at the end of the first year and during the first 3 months of the second year. However, these treatments were generally not different for the last 8 months of the study. Sufficient rainfall during the first four months of the study (Figure 4-1) yielded the greatest increase in total vegetation for all treatments. The six months following had less than 130 mm of total rainfall resulting in a decrease in total vegetation prior to the reapplication of treatments March 2001. Total vegetation for all treatments peaked following abundant rainfall during the summer months of 2001.

Total quality for control and soluble fertilizer treatments was not different for all but two rating periods. Compost treatments had greater total quality than the control and fertilizer treatments for the first 11 months of the study, but were generally not different for the remaining 7 months. Drought conditions from October 2000 through March 2001 resulted in a general decline in total quality for compost treatments (Figure 4-2). The 60 Mg ha^{-1} compost rates had greater total quality than 40 Mg ha^{-1} rates at the end of the first year, but were generally not different for the second year with the exception of June and July when weed infestations following the reapplication of treatments resulted in decreased quality of 60 Mg ha^{-1} compost rates compared to 40 Mg ha^{-1} rates. Compost rates of 60 Mg ha^{-1} exhibited higher quality than 20 Mg ha^{-1} rates until treatment reapplications at which point the total quality of treatments were generally not different through the conclusion of the study. Lack of mowing of the test plots resulted in increased weed populations during the last 7 months of the study thus decreasing quality of all treatments (Figure 4-2) despite an increase in total vegetation (Figure 4-1). The influence of weed infestations on total quality was most evident for the compost treatments. Regular mowing would have likely resulted in decreased weed populations thus increasing total quality for all treatments with the greatest effect on the compost treatments where the high N content of the compost (Table 4-1) would have favored turfgrass growth.

North Site

Percent total vegetation of the control and fertilizer treatments was not different for most of the rating periods indicating a general lack of efficacy of the soluble fertilizer treatments. Compost treatments had greater total vegetation than the control during the last 5 months of the first year, but were not different for all but two rating periods during the second year. This may be attributed to the generally high percentage of total vegetation (Figure 4-3) for all treatments approaching the greatest percent cover attainable. The percent cover values obtained approached the maximum percent cover possible for roadside vegetation during the second year of the study. The greatest differences in total vegetation occurred in November 2000, where the 60 and 40 Mg ha^{-1} rate had 23% and 13% greater cover than the control, respectively. The 60 Mg ha^{-1} compost rates vegetative cover was similar to 40 Mg ha^{-1} rates for all but three rating periods during the course of the study. Differences between the 40 Mg ha^{-1} and the 20 Mg ha^{-1} rates were slightly more evident, while differences between the 60 Mg ha^{-1} and

20 Mg ha^{-1} rates were evident during the last 5 months of the first year, but were similar during most of the second year.

Total quality of the control and fertilizer treatments was not different for most of the rating period. Compost treated plots generally exhibited greater total quality than the control throughout the first year, but were not different for all but two rating periods during the second year. Infrequent mowing of the test plots generally favored weed populations following reapplication of treatments in March 2001, but populations decreased substantially when regular mowing resumed in July 2001(Figure 4-4). Compost treatments exhibited higher quality ratings than the fertilizer treatments for three months during the first year, but were similar throughout most of the second year. The 60 Mg ha^{-1} compost rates had similar quality to 40 Mg ha^{-1} rates for all but two rating periods during the course of the study. Differences between the 40 Mg ha^{-1} and the 20 Mg ha^{-1} rates were slightly more evident with the 40 Mg ha^{-1} rate yielding better quality ratings. The 60 Mg ha^{-1} rate outperformed the 20 Mg ha^{-1} rate during the last 5 months of the first year, but generally were similar during the second year. Total quality of all treatments decreased substantially following drought conditions from September 2000 through February 2001 (Figure 4-4). Quality increased to acceptable levels following an increase in rainfall amounts for the remainder of the study.

Conclusion

Composted biosolids treatments had greater vegetative cover than the control and soluble fertilizer treatments at both locations during the first year. During the second year, compost treatments at the central site continued to exhibit greater vegetation than the soluble fertilizer and control plots, likely due to the greater influence of the added organic matter to a soil with <1% organic matter. The effects of the addition of organic matter had less of an impact at the north site. Soil at the north site contained approximately 4% organic matter prior to compost applications and had greater initial cover. The difference in percent cover between compost treatments and the control was greatest at the central site and least at the north site. This was likely a result of the organic content of the soils prior to treatment applications, total rainfall, and the topography of the test sites. Rainfall at the central and north sites totaled 1615 and 1952 mm, respectively for the 18 months of the study. Test plots at the central site were elevated and well drained, while the test plots at the north site were low lying often with standing water visible within 10 m of the plots.

Composted biosolids can improve total vegetative cover and total quality of roadside turf when applied as a topdressing. The beneficial effects of the addition of compost were more evident on soils with little organic matter and thin existing stands of turf. Effects of the compost remained for the duration of the 18 month study with varying degrees of improved turf density and quality. Special consideration to mowing frequency should be considered to avoid favoring weed populations.

CHAPTER 5
SUMMARY AND CONCLUSIONS

Data collected for the erosion control study suggest that compost mulch rates of 5 or 10 cm provide complete control of erosion for a period of 18 months and probably longer. The effect of the mulch on roadside vegetation varied with slope and soil characteristics prior to treatment application. Heavy applications of compost mulch tended to bury existing vegetation. The 5 cm compost mulch rate exhibited greater vegetative cover than the 10 cm rate throughout most of the study. Compost mulch applications on the lesser slope at the central site (approximately 12°) had a negative effect on roadside vegetation, while the effects were generally positive at the north site which had greater slope (approximately 26-27°).

The results of the seeding experiment indicate that during periods of anticipated limited rainfall, turfgrass seed applied to compost mulch should be incorporated into the surface to provide the best results. During periods of extensive rainfall, seed applied to the surface can be as effective or more effective than incorporated seed. Seed can be applied either before or after erosion mat installation without affecting germination rates.

The biosolids compost fertilization study showed that roadside vegetation can be improved with various application rates. The effect of the biosolids compost application depends on existing turfgrass cover, soil characteristics, and the topography of the land. Soil at the central site contained <1% organic matter content prior to treatment applications and had the greatest response to biosolids compost amendments with higher rates generally resulting in greater percent vegetation values. The test plots at this location were elevated and well drained. The most extreme difference between the highest compost rate (60 Mg ha $^{-1}$) and the control occurred at the central site. At one point during the study, the highest compost rate had 38% greater vegetative cover than the control. Soils at the north site contained approximately 4% organic matter content prior to treatment applications. The test plots at this location were in a low-lying area with standing water commonly seen within 10 m of the test plosts. The effects of the biosolids compost were less pronounced at this location. The greatest difference in percent vegetation from the highest compost rate to the control was 23%.

Fertilization of roadsides with biosolids compost can have an effect on weed densities as well. Following the reapplication of treatments, sufficient rainfall and lack of regular mowing produced conditions favorable for weed growth. Decreased quality ratings in conjunction with increased percent vegetation values during the second year of the study reflect this. Regular mowing would likely reduce the incidence of weed infestations.

REFERENCES

Avnimelech, Y., D. Shkedy, M. Kochva, and Y. Yotal. 1994. The use of compost for the reclamation of saline and alkaline soils. Compost Sci. and Util. 2(3):6-11.

Barbarick, K.A., J.A. Ippolito, and D.G. Westfall. 1995. Biosolids effect on phosphorous, copper, zinc, nickel, and molybdenum concentrations in dryland wheat. J. Environ. Qual. 24:608-611.

Beard, J.B., and R.L. Green. 1994. The role of turfgrasses in environmental protection and their benefits to humans. J. Environ. Qual. 23:452-460.

Block, D. 2000. Controlling erosion from highway projects. Biocycle. 41(1):59-62.

Brady, N. C., and R. R. Weil. 1999. The nature and properties of soils. Prentice Hall. Upper Saddle River, N.J.

Bremner, J. M. and C. S. Mulvaney. 1982. Total nitrogen. p. 595-624. *In* A. L. Page et al. (ed.) Methods of soil analysis. Part 2. 2nd ed. Agronomy Monogr. 9. ASA. Madison, WI.

Bugbee, J. G. 1999. Effects of hardwood sawdust in potting media containing biosolids compost on plant growth, fertilizer needs, and nitrogen leaching. Commun. Soil. Sci. Plant Anal. 30(5&6):689-698.

Bugbee, J. G., and G. C. Elliot. 1998. Leaching of nitrogen and phosphorous from potting media containing biosolids compost as affected by organic and clay amendments. Bull. Environ. Contam. Toxicol. 60:716-723.

Bugbee, J. G., and G. C. Elliot. 1999. Effects of sucrose and dried alum sludge on the growth of rudbeckia and leaching of nitrogen and phosphorous from potting media containing biosolids compost. Bull. Environ. Contam. Toxicol. 63:766-773.

Carroll, Mark J. 1992. Erosion control: turf and geosynthetics. Grnds. Maint. 27(9):26-30.

Chanyasak, V., A. Katayama, M.F. Hirai, S. Mori, and H. Kubota. 1983. Effects of compost maturity on growth of komatsuna (*Brassica rapa var pervidis*) in Neubauer's pot. Soil Sci. Plant Nutr. 29(3):239-250.

Cisar, J.L. and G. H. Snyder. 1992. Sod production on a solid-waste compost over plastic. HortScience 27(3):219-222.

Collier, B.J., J.L. Thames, J.R. Collier, M.M. Elsunni, E.W. Bush, and D.P. Shepard. 1997. Turfgrass establishment using experimental and commercial erosion control mats. Louisiana Ag. 40(1): 28-29.

Conover, C.A. and R.T. Poole. 1990. Utilization of Agrisoil™ compost in production of foliage plants. Proc. Fla. State Hort. Soc. 103:163-165.

De Haan, F. A. M. 1981. Results of municipal waste compost research over more than fifty years at the institute for soil fertility at Haren Gronigen, The Netherlands. Neth. J. Agric. Sci. 29:49-61.

Dissanayake, N., and J. W. Hoy. 1999. Organic material soil amendment effects on root rot and sugarcane growth and characterization of materials. Plant Disease 83(11):1039-1045.

Duggan, James C. 1973. Utilization of municipal refuse compost: field scale compost demonstrations. Compost Sci. 14(2):24-25.

Elsenbeer, H., D.K. Cassel, and W. Tinner. 1993. A daily rainfall erosivity model for Western Amazonia. J. Soil and Water Cons. 48(5):439-444.

Epstein, E., J.M. Taylor, and R.L. Chaney. 1976. Effects of sewage sludge and sludge compost applied to soil on some soil physical and chemical properties. J. Environ. Qual. 5:422-427.

Ettlin, L., and B. Stewart. 1993. Yard debris compost for erosion control. Biocycle. 34(12):46-47.

Freeman, T. M., and D. L. Cawthorn. 1999. Use of composted dairy cattle solid biomass, poultry litter, and municipal biosolids as greenhouse growth media. Compost Sci. and Utili. 7(3):66-71.

Garling, D. C., and M.J. Boehm. 2001. Temporal effects of compost and fertilizer applications on nitrogen fertility of golf course turfgrass. Agron. J. 93:548-555.

Giordano, P. M., J. J. Mortvedt, and D. A. Mays. 1975. Effect of municipal wastes on crop yields and uptake of heavy metals. J. Environ. Qual. 4(3):394-399.

Giusquiani, P.L., M. Pagliai, G. Gigliotti, D. Businelli, and A. Benetti. 1995. Urban waste compost: effects on physical, chemical, and biochemical soil properties. J. Environ. Qual. 24:175-182.

Haynes, J.F. 1997. Applying compost and mulches to control erosion. Biocycle. 38(5):55-57.

He, X., S. J. Traina, and T. J. Logan. 1992. Chemical properties of municipal solid waste composts. J. Environ. Qual. 21:318-329.

Jackson, S. D. 1997. Enhancing roadside soil properties with compost. M. S. Thesis. Univ. of Florida, Gainesville, FL.

Jokela, E. J., W.H. Smith, and S.R. Colbert. 1990. Growth and elemental content of slash pine 16 years after treatment with garbage composted with sewage sludge. J. Environ. Qual. 19:146-150.

Khaleel, R., K.R. Reddy, and M.R. Overcash. 1981. Changes in soil physical properties due to organic waste applications: a review. J. Environ. Qual. 10:133-141.

Kostewicz, S.R. 1993. Pole bean yield as influenced by composted yard waste soil amendments. Proc. Fla. State Hort. Soc. 106:206-208.

McConnell, D.B., M.E. Kane, and A. Shiralipour. 1990. Growth of pickerelweed in municipal solid waste compost and yard trash compost. Proc. Fla. State Hort. Soc. 103:165-167.

McConnell, D.B. and A. Shiralipour. 1991. Foliage plant growth in potting mixes formulated with composted yard waste. Proc. Fla. State Hort. Soc. 104:311-313.

McLean, E.O. 1982. Soil pH and lime requirements. P. 199-224. *In* A. L. Page et al. (ed.) Methods of soil analysis. Part 2. 2nd ed. Agronomy Monogr. 9. ASA and SSSA, Madison, WI.

McSorley, R. and R.N. Gallaher. 1996. Effect of yard waste compost on nematode densities and maize yield. J. of Nematology 28(4S):655-660.

Mitchell, D. 1997. State transportation departments expand compost use. Biocycle 38:75-79

Mutchler, C.K., C.E. Murphree, and K.C. 1994. McGregor. Laboratory and field plots for erosion research. Soil erosion research methods. St. Lucie Press, Delray Beach, FL.

Oshins, C., and D. Block. 2000. Feedstock composition at composting sites. Biocycle 41(9):31-34.

Ozores-Hampton, M., C.S. Vavrina, and T.A. Obreza. 1999. Yard trimming-biosolids compost: possible alternatives to sphagnum peat moss in tomato transplant production. Compost Sci. and Util. 7(4):42-49.

Pagliai, M. and L.V. Antisari. 1993. Influence of waste organic matter on soil micro- and macrostructure. Bioresource Tech. 43:205-213.

Robinson, C.A., M. Ghaffarzadeh, and R.M. Cruse. 1996. Vegetative filter strip effects on sediment concentrations in cropland runoff. J. Soil and Water Cons. 50(3):227-230.

Roe, N.E., P.J. Stofella, and D. Graetz. 1997. Composts from various municipal solid waste feedstocks affect vegetable crops. I. emergence and seedling growth. J. Amer. Soc. Hort. Sci. 122(3):427-432.

Roe, N.E., P.J. Stofella, and D. Graetz. 1997. Composts from various municipal solid waste feedstocks affect vegetable crops. II. growth, yields, and fruit quality. J. Amer. Soc. Hort. Sci. 122(3):433-437.

SAS Institute. 1987. SAS user’s guide: statistics. 6th ed. SAS Institute, Inc. Cary, NC.

Shiralipour, A. and D. B. McConnell. 1991. Effects of compost heat and phytotoxins on germination of certain Florida weed seeds. Soil and Crop Sci. Soc. Fla. Proc. 50:154-157.

Shiralipour, B.E., and M. Chrowstowski. 1996. Greenhouse broccoli and lettuce growth using co-composted biosolids. Compost Sci. and Util. 4(3):38-43.

Sims, J.T., and J.S. Kline. 1991. Chemical fractionation and chemical uptake of heavy metals in soils amended with co-composted sewage sludge. J Environ. Qual. 20:387-395.

Steutville, R. 1995. The state of garbage in America. Biocycle. 36:54-63.

Stevens, J.M., and S.R. Kostewicz. 1992. Organic soil amendments for Florida vegetable gardens. Proc. Fla. State Hort. Soc. 105:263-267.

Stevens, J.M. and S.R. Kostewicz. 1994. Response of cucumber to organic soil amendments. Proc. Fla. State Hort. Soc. 107:382-384.

Tester, C.F., and J.F. Parr. 1983. Decomposition of sewage sludge compost in soil: IV. effect on indigenous salinity. J. Environ. Qual. 12(1):123-126.

Wischmeier, W.H. and D.D. Smith. 1978. Predicting rainfall erosion losses- a guide to conservation planning. Agric. Handb. 537, USDA, Washington, DC.

BIOGRAPHICAL SKETCH

Michael S. Harrell was born in Louisville, KY, October 26, 1976. He spent most of his childhood in Lexington, KY, graduating from Henry Clay High School in 1995. He received his associate degree from Manatee Community College in Bradenton, FL, in 1997. He subsequently attended the University of Florida and graduated earning a Bachelor of Science degree in turfgrass science with a minor in business. In 2000, he began studies toward earning a Master of Science degree in the environmental horticulture department specializing in turfgrass management. Upon graduation, Michael plans to work towards a doctorate degree at the University of Kentucky.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Grady L. Miller, Chairman
Associate Professor of
Horticultural Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Robert Black
Associate Professor of
Horticultural Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Gerald Kidder
Professor of
Agronomy

This thesis was submitted to the Graduate Faculty of the College of Agricultural and Life Sciences and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Master of Science.

August 2002

Dean, College of Agricultural and
Life Sciences

Dean, Graduate School