A HOLISTIC APPROACH TO DECREASING DOLLAR SPOT SEVERITY AND OVER-WINTERING INOCULA OF SCLEROTINIA HOMOEOCARPA

by

JOHN BARRETT WORKMAN

(Under the Direction of F.C. Waltz, Jr.)

ABSTRACT

A common fungal disease of warm- and cool-season turfgrasses is dollar spot, caused by *Sclerotinia homoeocarpa*. Epidemics occur when temperatures rise above 10°C, and continue until temperatures exceed 32°C. The disease is characterized by straw-colored sunken spots approximately 5 cm in diameter on closely mown turf. While fungicides are commonly used to control dollar spot, development of fungicide resistant populations and associated costs has stimulated the need to study other methods of disease management. An alternative in disease management is the development and use of composts that can be incorporated into turfgrass maintenance by replacing sand used in topdressings. The objectives of this research were to evaluate compost's ability to limit the severity of dollar spot and to assess microbial activity associated with compost of different origins. Results indicate there is opportunity for compost materials to be incorporated into the turfgrass canopy for disease suppression and potentially mitigate pesticide use.

INDEX WORDS: Biocontrol, compost, microbial ecology, turfgrass

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DEDICATION

I would like to dedicate this thesis to my dad, and to all other golf course superintendents in the state of Georgia. Thanks for all you do to enhance the game of golf and the golf course management profession.

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I would like to thank my entire family for all of their contributions that have allowed me to further my education. This degree would not have been possible without you. I would also like to thank my fellow graduate students for their support and assistance along the way. Lastly, thanks to my major adviser, Dr. Clint Waltz, and to my committee members, Dr. Lee Burpee and Dr. Keith Karnok.

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CHAPTER 1

INTRODUCTION

Purpose of Study

Turfgrass consumes more acreage than any other ornamental crop in the United States (Emmons, 2008). It serves a functional purpose by preventing soil erosion and an aesthetic purpose by contributing beauty to the landscape (Nelson and Boehm, 2002). Turfgrass serves as a ground cover for athletic fields and recreational facilities because it produces a tough, durable surface. Turfgrass offers other advantages including the release of oxygen and the removal of carbon dioxide from the atmosphere (Emmons, 2008). Among the many sports played on turfgrass, golf has the longest and closest association with professional turfgrass managers. The development of turfgrass science and technology is largely the result of efforts by turfgrass scientist and golf course superintendents to improve techniques and solve problems (Turgeon, 2002).

Fungal diseases represent one of the many important limiting factors in maintaining high quality turfgrass. One of the most common and economically important fungal diseases on golf courses, athletic fields, and home lawns is dollar spot, caused by *Sclerotinia homoeocarpa* (Goodman and Burpee, 1991; Vargas, 1994). More money is spent managing dollar spot on golf courses than any other turfgrass disease (Vargas, 1994). Dollar spot epidemics can affect the quality of playing surfaces, influence aesthetic appearance, and cause plant death (Vargas, 1994, Vincelli et al., 1997). Dollar spot affects the majority of warm- and cool-season turfgrass species and is characterized by round, straw-colored sunken spots approximately 5 cm in diameter on fine textured and closely mown turf (Figure 1) (Goodman and Burpee, 1991). On residential lawns, where turf is maintained at higher mowing heights, the dead spots appear larger and more diffuse (5 to 7 cm in diameter). Under these conditions, dollar spot can be distinguished by characteristic foliar lesions that are light tan with a reddish-brown border. A more certain diagnosis of the disease can be made by observing the white cobweb-like aerial mycelia associated with diseased leaves in the early morning before the turfgrass has been mowed (Figure 2).

Figure 1. Dollar spot symptoms

Figure 2. Mycelia of *S. homoeocarpa*

Due to the severity and the destructive nature of dollar spot, multiple fungicide applications are usually required throughout a growing season to meet acceptable turfgrass quality and playability (Kaminski and Fidanza, 2009; Walsh et al., 1999). As a result of numerous applications throughout a growing season, fungicide resistance in *S. homoeocarpa* has led to an ongoing challenge of fewer fungicides being available to control the disease. Therefore, researchers are beginning to seek effective alternative disease management practices. Among the more important disease management strategies emerging from these studies is the utilization of composted organic materials (Nelson and Boehm, 2002).

Composting, the biological decomposition of organic constituents in wastes under controlled conditions, is growing in its popularity as an environmentally sound waste-treatment process (Nelson and Craft, 1992). Organic composts can be introduced into the soil-plant system to support microbial growth and to boost the nutrient content of the soil. Compost-inhabiting microbial populations serve an important biological role in the soil where they are able to contribute to the suppressive activity of the amended soils through competition, antibiosis, parasitism/predation, and systemic induced resistance (Lawton and Burpee, 1990; Hoitink et al. 1993, 1997; Nelson, 1992; Whipps 1997a). Although compost may not control turfgrass diseases like dollar spot to a level that will replace fungicides, integration of compost with current disease management practices may limit disease severity and associated problems like fungicide resistance (Boulter et al., 2002).

Objectives of Study

The objectives of this study were to evaluate compost's ability to limit the severity of dollar spot and decrease the over-wintering inoculum of *S. homoeocarpa*, assess the effect of nitrogen on disease suppression along with the role of microbial populations, and determine if multiple applications of composts combined with recommended low-rate fungicide applications provide acceptable disease control.

CHAPTER TWO

LITERATURE REVIEW

Introduction

Turfgrass is a top commodity worldwide consisting of lawns, golf courses, athletic fields, sod farms, roadsides, etc. (Nelson and Boehm, 2002). Turfgrass scientists and managers have begun working towards sustainable turfgrass management to identify alternative management practices that could be more efficient and require fewer inputs (Diesburg et al., 1997). New turfgrass cultivars, water conservation strategies, and biological control options are being combined with traditional integrated pest management strategies in an effort to reduce turfgrass dependence on natural resources and agrichemicals without reducing turfgrass quality and playability (Cisar, 2004). One of the most important limiting factors to maintaining the aesthetics and functional quality of turfgrasses is the management of fungal diseases (Nelson and Boehm, 2002). Turfgrass pathologists are investigating alternative methods of disease management including the utilization of organic amendments (e.g. composts) for the suppression of turfgrass diseases (Nelson, 1992; Hoitink and Boehm, 1999; Garling and Boehm, 2001; Boulter et al., 2002). Studies have mostly focused on general efficacy and mechanisms of biological control. Other important but limited areas of investigation include compatibilities with fungicides and other pesticides, and application timing and frequency (Nelson, 1996).

A turfgrass disease is caused by four factors occurring simultaneously: a susceptible host, a pathogen capable of infecting the host, environmental conditions that favor the development of disease, and sufficient time for infection to occur. Disease can play a role in determining the success or failure of a turfgrass stand. Most turfgrass diseases occur on a seasonal basis but can reoccur within a growing season (Vargas, 1994). The majority of turfgrass diseases are caused by fungi, simple organisms that do not have the ability to produce food photosynthetically because they lack chlorophyll (Turgeon, 2002). Consequently, they satisfy nutritional needs from living hosts, while some feed solely on organic residue. Most parasitic fungi live as saprophytes until environmental conditions become favorable for infecting host plants. Facultative saprophytes function primarily as parasites but can subsist temporarily on decaying organic residue (Turgeon, 2002).

Classification of *Sclerotinia homoeocarpa* and the Review of Dollar Spot

One of the most commonly researched turfgrass pathogens is dollar spot, caused by the facultative saprophyte *S. homoeocarpa*. It is also considered to be the most economically significant fungal disease on golf courses, athletic fields, and home lawns (Goodman and Burpee, 1991; Vargas, 1994; Smiley et al., 2005). Dollar spot was initially described as a disease in the 1920s when the causal agent was thought to be a *Rhizoctonia* species. It was not until the 1930s that F.T. Bennett reclassified the pathogen as *S. homoeocarpa* (Bennett, 1937; Allen et al., 2005). Bennett chose the genus *Sclerotinia* because of the formation of aggregates of melanized tube-like microsclerotia, which are darkened tissues with hard outer and soft inner cells. All of the isolates Bennett worked with showed different pigmentations, conidia and ascospore production and had different growth requirements (Niver and Boehm, 2004). Grown on potato dextrose agar (PDA), *S. homoeocarpa* can cover a standard petri dish in 3-5 days by producing white cobweb-like aerial mycelia. Approximately three weeks after initial growth on PDA medium, a sclerotized region or stroma appears at the edges of the container around the original source of inoculum. This area continues to expand until the entire surface is covered

(Bennett, 1937; Niver and Boehm, 2004). The classification of *S. homoeocarpa* remains controversial because DNA studies indicate that the fungus is more closely related to members of the genus *Rutstroemia*, *Lanzia*, or *Moellerodiscus* rather than *Sclerotinia* (Monteith and Dahl, 1932; Kohn, 1979; Kohn and Greenville, 1989; Young et al., 2005). Beirn et al. (2012) reported that the current name of the fungus is incorrect. In this study, fungal isolates from the original source of *S. homoeocarpa* collected in 1937 from the United Kingdom, and over 250 preserved fungal specimens from the USDA's National Fungus Collection are being analyzed using DNA fingerprint analysis to determine the true identity of the dollar spot pathogen (Beirn et al., 2012). Proper classification of *S. homoeocarpa* will be valuable for turfgrass managers because it could potentially lead to selection of new fungicides for suppression of dollar spot. It may also give turfgrass managers, who are considering biocontrol, an opportunity to introduce microorganisms that are known to suppress fungi closely related to what is now known as *S. homoeocarpa* into the turfgrass ecosystem.

The dollar spot fungus survives during the winter months as mycelium in infected thatch just below the soil surface living off dead organic materials (Smiley et al., 1992; Latin, 2009). The pathogen has an unusual cycle of development, in that, it remains inactive for most of the year. When environmental conditions become favorable it can rapidly develop into an epidemic growth phase (Harman et al., 2005). Epidemics typically occur when temperatures rise above 15°C, and can persist until temperatures exceed 32°C (Tredway et al., 2009). There may be two strains of the fungus: one which occurs during cool weather when the temperature is below 23°C; and the second which is favored by high humidity (> 85%) and warmer temperatures (27 to 32°C) (Endo, 1966; Couch, 1995). When either of these conditions is met, the fungus will grow on the surface of leaf blades and infects via direct penetration, wounds, and natural openings (Vargas, 1994; Burpee, 1997). Differences between strains of the pathogen have led pathologists to differing hypothesis regarding its taxonomic classification. Studies conducted by Powell and Vargas (2001) suggest *S. homoeocarpa* is a single species with differing vegetative compatibility groups, while Kohn (1979) suggested that the pathogen might include different species. Conversely, other studies have suggested that there is limited diversity (Hsiang et al., 2000). Further knowledge of the genetic diversity of the pathogen is important because if variation is wide, the pathogen may respond differently to management practices (Harman et al., 2005).

Dollar spot symptoms are most commonly observed in the spring and fall on warm- and cool-season turfgrass species (Emmons, 2008), while warm-season species can remain susceptible throughout the early summer months (Lucus, 1998). On fine textured and closely mown turf, such as golf course putting greens and fairways, disease symptoms are characterized by round, straw-colored, sunken patches approximately 5 cm in diameter (Figure 1) (Goodman and Burpee, 1991; Vargas, 1994). If the disease becomes severe, individual patches may coalesce forming larger, irregular patches of blighted turfgrass that can die back to the soil surface. On residential lawns, where turf is maintained at higher mowing heights, the dead spots appear larger and more diffuse (6 to 12 cm diameter) (Couch, 1995). Under these conditions, dollar spot can be distinguished by characteristic lesions that are light tan to white with reddish-brown borders, and usually radiate from the margins of the leaf blades. Foliar lesions can expand, extending across the entire leaf. In addition, lesions may form at the tip of leaves and extend downward. Individual leaf blades may have a single lesion, many small lesions, or be entirely blighted. White cobweb-like aerial mycelium of *S. homoeocarpa* observed in early morning before infected turf has been mown, or during extended periods of high relative humidity, is a good diagnostic sign (Figure 1) of dollar spot (Monteith and Dahl, 1932; Vargas, 1994). The mycelium of the fungus can usually be seen spreading outward from the infected lesions to adjacent host tissues.

Dollar spot can affect both warm- and cool-season turfgrass species. Susceptible species include Kentucky bluegrass (*Poa pratensis*), bentgrass (*Agrostis* spp.), tall fescue (*Festuca* spp.), zoysiagrass (*Zoysia* spp.), bermudagrass (*Cynodon* spp.), and seashore paspalum (*Paspalum vaginatum*) (Treadway et al., 2009). 'Sea Isle Supreme' seashore paspalum and 'SR 1020' creeping bentgrass were chosen for this research because of their known susceptibility to *S. homoeocarpa* (Beard and Sifers, 1997; DiMarco et al., 2000). Sea Isle Supreme is a low growing and rapidly spreading semi-dwarf type turfgrass that can tolerate a wide range of mowing heights while maintaining good turf density and quality (Raymer and Braman, 2005). Its spreading growth habit makes Sea Isle Supreme a popular turfgrass for golf courses because it allows for rapid establishment and recovery from wear and use. SR 1020 bentgrass is good for golf course putting greens because of its fine leaf texture and uniform dark green color. Advantages of SR-1020 include a dense turf stand, deeper root system, and greater recuperative ability during the summer months (Whitlark et al., 1997). It also has exhibited superior heat and drought tolerance compared to other bentgrass varieties including Pencross and Crenshaw (Whitlark et al., 1997).

Cultural Management of Dollar Spot

Turfgrass cultural practices such as proper nitrogen fertility and dew removal are recommended for limiting the development of dollar spot (Markland et al., 1969; Williams et al., 1996; Landschoot and McNitt, 1997). Turfgrasses that are maintained under low nitrogen fertility are more susceptible to infection, and they are slow to recover from dollar spot symptoms (Watkins and Wit, 1995; Allen et al., 2005). Research has revealed that N fertilization can be an important management tool if applied to coincide with disease outbreaks. Markland et al. (1969) observed that bentgrass receiving high rates of available N (e.g. ammonium nitrate) had less dollar spot injury compared to non-fertilized turfgrass. They concluded that vigorous turfgrass growth reduces susceptibility to *S. homoeocarpa*. In a similar study, Landschoot and McNitt (1997) demonstrated that disease suppression was positively correlated with actively growing dark green creeping bentgrass, indicating that as N availability increased, dollar spot severity decreased. Therefore, research has revealed that spring and fall applications of N fertilizers can potentially allow susceptible turfgrass species to outgrow the pathogen and promote quicker recovery from disease injury.

It has been documented that removing dew from turfgrass by mowing, rolling, or dew whipping in the morning can significantly reduce dollar spot infection (Williams et al., 1996; Giordano et al., 2012). Research has shown that dollar spot is more likely to develop if moisture remains on the surface of the turfgrass for more than 12 h (Williams et al., 1996; Walsh, 2000). Walsh (2000) found that the size of the diseased area increased as leaf wetness duration increased from 12 h to 48 h. Giordano et al. (2012) reported greater reductions in dollar spot counts on creeping bentgrass plots rolled twice daily with the Tru-Turf R52 greens roller, as well as an increase in microbial populations in the upper root zone. Further evaluation of microbial populations via phospholipid fatty acid (PFLA) analysis revealed that rolled treatments exhibited significant increases in PFLA abundances related to common bacteria, as well as a general trend towards increased total bacterial biomarker abundance when compared to the non-rolled control. Results from this study indicated that rolling could have physical and biological effects to disease suppression.

Chemical Control of Dollar Spot

Fungicides have been the most commonly used tool for managing dollar spot for the past 60 years (Walsh et al., 1999). Due to the persistent nature of *S. homoeocarpa* and low disease thresholds on golf courses, multiple applications are usually required to manage dollar spot throughout a growing season to meet acceptable turfgrass quality and playability standards. As a result of numerous fungicide applications, selection of fungicide resistant strains of *S. homoecarpa* has led to an ongoing challenge of fewer materials being available to control the disease (Detweiler et al., 1983; Golembiewski et al., 1995; Burpee, 1997; Hsiang et al., 1997; Miller et al., 2002; Jo et al., 2008). In many cases, strains of *S. homoeocarpa* have been found to exhibit cross resistance (i.e., resistance to more than one fungicide within the same chemical group) or multiple resistance (i.e., resistance to different fungicide classes) (Golembiewski et al., 1995).

Populations of *S. homoecarpa* have developed resistance to one or more classes of fungicides including heavy-metal based compounds, contact fungicides, and systemic fungicides such as dicarboximides, benzimidazoles, and demethylation inhibitors (DMI) (Detweiler et al., 1983; Golembiewski et al., 1995; Burpee, 1997; Hsiang et al., 1997; Miller et al., 2002; Jo et al., 2008). Resistance of *S. homoeocarpa* to DMI fungicides (e.g. propiconazole, triadimefon) and certain benzimidazole fungicides (e.g. thiophanate methyl, benomyl) has been widespread and persistent (Burpee, 1997; Hsiang et al., 1997; Miller et al., 2002). Jo et al. (2008) reported that as few as two sequential benzimidazole applications can lead to a population that is nearly 100% resistant. Burpee (1997) conducted laboratory and field studies on the efficacies of several fungicides including propiconazole and thiophanate-methyl to find that *S. homoeocarpa* was resistant to these fungicides. Resistance to the benzimidazoles usually occurred the first or second year they were used, and resistant strains to these fungicides were found to have persisted for more than 20 years on some golf courses (Vargas et al., 1992).

The development of resistance to DMI fungicides like triadimefon, fenarimol, and propiconazole occurred much slower compared to the benzimidazole fungicides (Miller et al., 2002). Although both are site specific inhibitors (Burpee, 1997), its believed the DMIs developed slower resistance because they can be used at low application rates and at long application intervals, which can limit the selection of resistant strains (Koller and Scheinpflug, 1987). Mycelial growth assays have been used to detect resistance of *S. homoeocarpa* to the DMI fungicides at sites in Illinois, Kentucky, and Michigan where resistance was previously observed (Vargas et al., 1992; Golembiewski et al., 1995). Miller et al. (2002) revealed reduced sensitivity to propiconazole in isolates of *S. homoeocarpa* that were collected from different sites in Georgia with a history of propiconazole use. It was concluded that turfgrass managers should implement fungicide resistance management strategies to extend the potential effectiveness of the DMIs and other at-risk fungicides for control of dollar spot in Georgia. Similar assays were used to detect reduced sensitivity to the DMIs in a population of *S. homoeocarpa* in Ontario, Canada, at a site where field resistance to the DMIs had not previously been observed (Hsiang et al., 1997).

Reduced efficacy of certain fungicides for the control of dollar spot could potentially lead to fewer chemical options. Although fungicides have been successful for dollar spot management in the past, increasing levels of fungicide resistance and environmental scrutiny has left turfgrass managers looking for effective alternative disease suppressive practices (Boulter et al., 2002). An alternative in turfgrass disease management is the development and use of composts that may be incorporated into turfgrass maintenance practices by replacing sand used in topdressings.

Compost: An Alternative for Disease Management

Incorporating organic amendments such as compost into turfgrass disease management may be an alternative for dollar spot control (Boulter et al., 2002). Composted amendments were usually the only source that could be used to suppress diseases on golf courses up until the 1930s (Piper and Oakley, 1921; Welton, 1930). The utilization of composts declined dramatically when synthetic fertilizers and fungicides became available to turfgrass managers. These products offered rapid nutrient release and disease suppression, resulting in better turf quality and playability (Westover, 1927). After nearly 60 years of heavy reliance on chemical inputs, there has been resurgence in the use of composted materials for managing high quality turf (Sims, 1990; Barkdoll and Norstedt, 1991; He et al., 1992; Schumann et al., 1993, Boulter et al., 2002).

Composting can be described as the “controlled rotting” of organic matter. It can be used as a biological means for reducing wastes and for creating products with beneficial physical, chemical, and biological characteristics for application to soil systems (Finstein et al., 1983; Adani et al., 1995; Insam et al., 1996; Sesay et al., 1997; Gomez, 1998). The purpose of composting is to convert organic material that is unsuitable and incapable of being incorporated into the soil into a material that can be introduced into the ecosystem. Successful composting of organic matter is achieved through continual supply of oxygen and water to the associated microbial community, resulting in changes in temperatures, carbon to nitrogen ratios, and pH (Boulter et al., 2000).

The composting process is typically divided into three phases (Hoitink and Boehm, 1999). The first phase occurs when elevated microbial populations result in increases in temperatures to 40-60°C. During this phase, sugars and other easily biodegradable substances are utilized and broken down. During the second phase, when temperatures reach 40-70°C, cellulosic and other less biodegradable substances are digested along with lignins and other recalcitrant components. Plants, animals, human pathogens, weed seeds, and beneficial microorganisms such as nitrogen fixing and biological control organisms are destroyed during this heat treatment period. The third phase is known as the curing phase of the composting process. During this phase, temperatures decline to below 40°C which allows microorganisms to recolonize the compost. Some of the beneficial microorganisms that re-inhabit compost after heating has subsided include several bacteria (*Bacillus* spp. and various *Pseudomonas* spp.) and several fungi (*Streptomyces*, *Penicillin*, and *Trichoderma*) (Haggag, 2002). These microbial communities then convert degradable organic matter into more humified forms and products such as CO_2, H_2O, ammonia, nitrate, and methane, releasing heat as a metabolic waste product (Ciavatta et al., 1993). The composting process results in a stable end-product with increased organic components and nutrient availability which can serve as a soil conditioner that may increase soil fertility, structure, porosity, organic matter levels, water holding capacity, cation exchange capacity, as well as contribute to suppression of plant pathogens (Zucconi et al., 1981; Itavaara et al., 1997; Sesay et al., 1997).

Researchers have reported reductions in dollar spot severity following applications of organic fertilizers including Milorganite (Milorganite; Milwaukee, WI U.S.A.) and Ringer Green Restore (Ringer; Harrisburg, PA U.S.A.), as well as certain composts prepared from various sources including soybean mill, bark mix, turkey litter, chicken and cow manure, sewage sludge, and plant material (Nelson and Craft, 1992; Hoitink et al., 1993; Davis and Dernoeden, 2002). However, disease suppression following application of organic fertilizers or compost top-dressings has been inconsistent (Nelson and Craft, 1992; Boulter et al., 2002). The variability currently seen among different composts for control of turfgrass diseases indicates that further research is needed to create uniform standards and performance levels (Liu et al., 1995; Boulter et al., 2000). If variability is lowered to acceptable levels, composts may become commercially acceptable products that provide effective suppression of turfgrass diseases, which could lead to a reduction in fungicide use.

There is interest in the use of compost for dollar spot management because of its potential effect on increasing soil microbial activity. The application of compost to turfgrass ecosystems is thought to introduce large populations of antagonistic microorganisms that may interfere with the activities of plant pathogenic fungi (Nelson, 1992; Boulter et al., 2002). Known bacterial and fungal species in compost include *Fusarium heterosporum, Acremonium* spp., *Rhizoctonia* spp., *Enterobacteria cloacae, Pseudomonas fluorescens* and *P. lindbergii*, all of which have been shown to suppress dollar spot (Boulter et al., 2002). It is often difficult to assess just a single microbial species associated with compost for the suppression of dollar spot because organic matter is infested with a diverse microbial community. Interactions among species may be required to achieve maximum efficacy against a broad array of soil-borne fungal or fungal-like pathogens (Boulter et al., 2002). Successful biological disease suppression from composts is believed to involve a combination of mechanisms including competition for nutrients, antibiosis, production of lytic and other extracellular enzymes and compounds, parasitism and predation, and host mediated induction of resistance (Ko and Lockwood, 1970; Lockwood and Filonow

1981; Hoitink and Fahy 1986; Burpee et al., 1987; Lawton and Burpee, 1990; Nelson, 1992; Hoitink et al., 1993, 1997; Whipps 1997a; Lucus, 1998).

In addition, disease suppression may be due to enhanced microbial breakdown of soil organic matter, resulting in an increased availability of nutrients, which may stimulate plant recovery from pathogen infection. When compost is incorporated into the soil, certain microorganisms (e.g. nitrogen fixers, nitrifiers, sulphur oxidizers) are introduced which may increase soil fertility and structure (Beffa et al., 1996b). Microorganisms form symbiotic associations with plant roots and synthesize and excrete nutrients, plant growth hormones and chelators, alter physical conditions of soil to optimize plant growth, and decompose or neutralize toxic substances (Nelson, 1992; Hoitink et al., 1997).

Practices involving the introduction of antagonistic microbial communities in the form of soil amendments, especially composts, may reduce the use of fungicides for turfgrass disease management. Consistent and sustained biological control of soil-borne pathogens such as *Pythium, Phytophthora, Rhizoctonia,* and *Fusarium*, has been achieved using compost-amended media, as long as variables such as consistency of parent material, salinity, C/N ratio, and other parameters of the composting process were controlled (Hoitink and Boehm, 1999). One of the greatest obstacles to the widespread use of compost for turfgrass disease control has been the inconsistent performance (Nelson and Boehm, 2002). Problems with the use of composts are a result of an incomplete understanding of microbial ecology and aspects leading to sustained performance of biocontrol agents (Boulter et al., 2000). A key feature of effective suppression is the ability of microbial populations to persist in soil and aggressively colonize within the rhizosphere. Investigation of microbial populations within composts could lead to an improved understanding of microbial ecology and potentially provide more effective, integrated strategies for the control of turfgrass pathogens.

Although it may be unreasonable to expect that natural agents will be a complete substitute for fungicides, the use of materials such as compost can potentially reduce their use. A reduction in the use of fungicides may lead to a reduction in fungicide resistance, a healthier environment, and a better understanding of microbial communities that could suppress diseases like dollar spot to an acceptable level.

CHAPTER THREE

MATERIALS AND METHODS

Description of Composts

Previous research has utilized certain composts prepared from various sources including soybean mill, bark mix, turkey litter, chicken and cow manure, sewage sludge, and plant material to evaluate their ability to suppress dollar spot (Nelson and Craft, 1992; Hoitink et al., 1993; Davis and Dernoeden, 2002;). For this study, four commercially available composts were selected from around the state of Georgia, U.S.A. The composts were selected based on their dissimilar origin and nutrient contents. Sodpro was composted feedstocks and grass clippings (SuperSod; Lakeland, GA U.S.A.); Carbon Peat was mined organic peat and humus (Turfpro USA; Ludowici, GA U.S.A.); Foothills was composted food residuals and yard/wood trimmings (Foothills Compost; Roswell, GA U.S.A.); and Farm Meal was composted blood meal, fish meal, soybean meal, ground corn, and molasses (Bricko Farms; Augusta, GA U.S.A.).

The same source of compost from each lot was used throughout all studies. An analysis was conducted at the University of Georgia's Agriculture and Environmental Services lab to determine the nutrient content of each compost (Table 1). Analysis included pH, mineral content, and the organic matter content of the composts. The pH was determined using an automated LabFit AS-3000 pH analyzer equipped with direct titration capabilities. The pH was assessed in a sample consisting of a 1:1 soil: 0.01 M $CaCl_2$ suspension. The 0.01 M $CaCl_2$ readings were then converted to soil-water pH readings by adding a conversion factor of 0.6. Extractable P, K, Ca, Mg, Mn, and Zn were determined using the Mehlich-1 extraction method.

Total Carbon, Nitrogen, and Sulfur were combusted in an oxygen atmosphere at 1350°C, converting elemental carbon, sulfur, and nitrogen into CO_2, SO_2, and N_2, respectively. These gases were passed through the IR (infrared) cells to determine the carbon and sulfur content and a TC (thermal conductivity) cell to determine N_2 (Kissel and Sonon, 2008). The organic matter content of each compost was determined by the Loss On Ignition method (Heiri et al., 2001).

Table 1. Chemical analysis of composts

Compost	pH	C	N	S	OM	Ca	K	Mg	Mn	P	Zn
		------------------------------------ ppm --									
Sod Pro	6.3	130	10	2	256	3.0	1.5	1.0	0.1	0.4	0.2
Carbon Peat	3.5	487	11	2	458	0.5	0.1	0.5	0.1	0.1	0.1
Foothills	7.3	191	11	1	347	8.0	1.0	1.0	0.2	0.2	0.2
Farm Meal	7.0	403	15	4	618	7.0	2.0	2.0	0.1	7.0	0.3

<u>Microbial Composition of Composts</u>

Microbial counts were performed in order to isolate and enumerate bacteria and fungi from the composts. Compost (10 g dry weight) was placed in a dilution bottle containing 90 mL of a phosphate buffer. The dilution mixture of compost and phosphate solution was shaken for ten min at 200 rev/min and allowed to sit for approximately ten minutes to dissolve aggregates. Serial dilutions of 10^{-2} to 10^{-7} were prepared by sequentially transferring 1 mL samples onto the first five wells of a 24-multiwell plate containing 9 mL of sterile 0.1% phosphate buffer solution (Boulter et al., 2002). Subsamples were pipetted onto twelve plates each of nutrient agar (NA) and Rose Bengal-glucose (RBG) plates. Nutrient agar plates were used to isolate bacteria, while RBG plates were used to isolate fungi. All plates were incubated at 30°C for 48 hours and microbial colonies were counted as colony forming units >0.5 mm on those plates that had 30-300 colonies per plate (Boulter et al., 2002). Agar plates with >300 colonies were recorded as too numerous to count (Boulter et al., 2002).

<u>Extraction and Quantification of Total DNA from Composts</u>

DNA was extracted from 0.5 g of each compost sample using the PowerSoil DNA Isolation Kit (MO BIO Laboratories; Carlsbad, CA, USA). Each compost was added to a bead beating tube for thorough homogenization. Total genomic DNA was captured on a silica membrane in a spin column then washed and eluted from the membrane (Ranjard et al., 2000). The intergenic spacers between the small- and large-subunit rRNA genes were amplified using the primers S-D-Bact-1522-b-S-20 (eubacterial rRNA small subunit, 5'-TGCGGCTGGATCCCCTCCTT – 3') and L-D-Bact-132-a-A-18 (eubacterial rRNA large subunit, 5' CCGGGTTTCCCCATTCGG-3') (Normand et al., 1996). Amplification was carried out using a thermocycler (T personal, Biometra, Gottingen, Germany) with an initial denaturation step of 5 min at 94°C, followed by 25 cycles of 94°C for 1 min, annealing at 55°C for 1 min and elongation at 72°C for 5 min. Polymerase chain reaction products were loaded on a 3% agarose gel that was run for 1.5 h at 70 V in 1x TAE buffer.

Fragments ranging in size from approximately 300 to 1100 bp were resolved on 0% (w/vol) nondenaturing polyacrylamide-Tris-borate-EDTA gels (1.5 mm thick, 30 cm long). Gels were run at constant temperature (20°C) for 12 h at 60 V and 5 mA (DSG20002, C.B.S. Scientific, Del Mar, Ca) and further stained with SYBR Green (FMC Bioproducts, Le Perray en

Yvelines, France) according to the manufacturer's instructions (Ranjard et al., 2000). The banding patterns were then photographed with Ilford FP4 film with a 302 nm UV source.

Pathogen and Inoculum Preparation

The dollar spot inocula were prepared from strains of *S. homoeocarpa* isolated from infected seashore paspalum (cultivar SeaIsle Supreme) and creeping bentgrass (cultivar Penncross) located on the UGA Griffin Campus in Griffin, GA. For long term storage, isolates were grown on autoclaved grain at 25°C for approximately 2 weeks. The infested grain was air-dried for 24 h at room temperature in a micro-void hood, and then placed in an incubator at -4°C. To prepare inoculum of each isolate, frozen infested grains were placed in petri dishes containing PDA and incubated for 3 days at room temperature (approximately 25°C). One mycelial plug (6-mm-diameter) was removed from the edge of each actively growing fungal colony and placed in a glass tube (16 by 100 mm) containing approximately 3 g of sterilized rye grains. Grain cultures were incubated for 3 weeks at 20°C to allow the fungus to colonize the rye grains prior to inoculation (Miller et al., 2002).

Greenhouse Studies

Three separate greenhouse studies were conducted in 2011 at the University of Georgia Griffin Campus in Griffin, GA. Evaluations of the effects of composts on dollar spot were conducted on SR-1020 bentgrass grown in 9 cm diameter pots (Figure 3). SR-1020 was selected because of its known susceptibility to dollar spot (Beard and Sifers, 1997; DiMarco et al., 2000). Bentgrass was seeded at a rate of 21 g/m^2 in a sand based medium. Pots were placed under a mist chamber maintained at 100% relative humidity, day and night temperatures of 20 and 26°C, respectively, with a 12-h photoperiod. Seven days after seeding, the pots were transferred to a greenhouse where the bentgrass was allowed to mature for 6 weeks before inoculation. A liquid fertilizer (10 N – 3 P_2O_5 – 5 K_2O) was applied at 25 kg N ha^{-1} to all pots 4 weeks prior to treatment to promote turfgrass growth. Bentgrass pots were inoculated with a bentgrass isolate of *S. homoeocarpa* on the same day of compost treatments (see Experiments 1-3 below). Turf was cut with scissors to 0.5 cm every 4 – 7 days (clippings were removed).

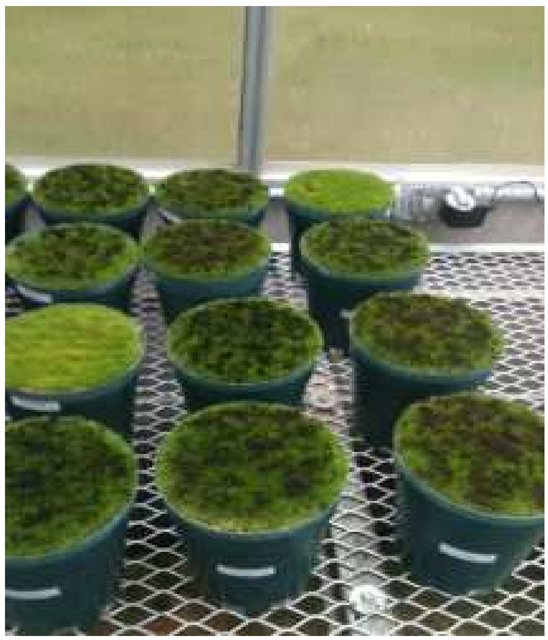

Figure 3. Compost applications in greenhouse experiments.

Experiment 1: A preliminary greenhouse study was conducted to assess composts ability to suppress dollar spot. Each compost was applied to the turf surface by hand at a rate of 2500 kg ha^{-1} and incorporated into the canopy with 2 cm of irrigation. Treatments were applied on 28 February and 1 September for runs 1 and 2, respectively. A non-treated control was included. All treatments were arranged in randomized complete block design with four replications.

Experiment 2: To further assess the ability of compost materials to suppress dollar spot, each compost was applied either being sterilized (e.g. no microorganisms) or non-sterilized (e.g. microorganisms present). Composts were sterilized in an autoclave set for 30 min at 121°C to eliminate microorganisms (O'Neill, 1982; Nelson and Craft, 1992). All compost treatments were applied to the turf surface by hand at a rate of 2500 kg ha^{-1} and incorporated into the canopy with 2 cm of irrigation. For comparative purposes, ammonium sulfate and a non-treated control (NTC) were included. Ammonium sulfate was applied alone at a rate of 25 kg N ha^{-1}. All treatments were applied on 4 April and 30 September for runs 1 and 2, respectively. Treatments were arranged in a randomized complete block design with four replications.

Experiment 3: To assess the effect of synthetic nitrogen fertilizers on dollar spot, calcium nitrate and ammonium sulfate were applied at a rate of 25 kg N ha^{-1}. Treatments were applied on 28 February and 1 September for runs 1 and 2, respectively. A non-treated control was included. All treatments were arranged in a randomized complete block design with 3 replications.

Turfgrass quality, a visual assessment including uniformity and color of the turfgrass canopy, was evaluated on a 1-9 scale, 1 = poor quality or dead turf and 9 = high quality or healthy turf, 6 was considered minimally acceptable. Visual color was rated on a 1 to 9 scale, 1 = brown dead turf and 9 = dark green grass, 6 was considered minimally acceptable. Symptomless foliage was visually assessed on a percent scale, 0 = diseased dead turf and 100 = no disease symptoms or healthy turf.

Field Studies

The field study was conducted at two locations beginning in March 2011. The first site was established on Sea Isle Supreme paspalum (*Paspalum vaginatum*) located at the University of Georgia Griffin Campus in Griffin, GA (GPS coordinates N 33 16.99 / W 84 14.937). The second site was established on SR-1020 bentgrass (*Agrostis stolonifera*) at Cateechee Golf Club in Hartwell, GA (GPS coordinates N 34 22.251 / W 82 55.719). The cultivars SR-1020 and Sea Isle Supreme paspalum were chosen based on their high susceptibility of dollar spot (Beard and Sifers, 1997; DiMarco et al., 2000). Plots at the UGA Griffin site were 3 x 2 m main plots divided into three 1 x 2 m subplots. Plots were maintained under golf course fairway conditions mowed 3 times a week at a height of 15 cm. Soil was a sandy loam (77.9% sand, 12.0% silt, and 10.1% clay). Due to space limitations, plots at the Cateechee site were smaller, measuring 3 x 1 m main plots divided into three 1 x 1 m subplots. The site was constructed on a sand-based rootzone according to United States Golf Association specifications (Table 2) and plots were maintained under golf course putting green conditions mowed 5 to 6 times per week at a height of 0.4 cm. Grass clippings were collected when mown at both locations, and the sites were irrigated to prevent stress. Testing was initiated 15 March and 31 March, 2011 for the Cateechee Golf Club and UGA Griffin sites, respectively, and continued at both sites until April 7, 2012. Dates of application for the Cateechee Golf Club site (15 March, 8 April, 13 May, 10 June, 15 July, 19 Aug., 25 Sept., 21 Oct., and 18 Nov.) and the UGA Griffin site (21 April, 27 May, 24 June, 29 July, 26 Aug., 30 Sept., 28 Oct., 11 Nov.) included composts, SCU, and boscalid.

Table 2. Cateechee Golf Club sand fraction analysis.

Sand Fraction					
Gravel (8)[1]	Very Course (10)	Course (35)	Medium (60)	Fine (120)	Very Fine (pan)
3.99%	1.23%	49.30%	38.79%	9.74%	0.95%

[1] US sieve size

The experimental design for both sites was a strip-plot design with three replications. Composts were arranged as whole plot treatments with two fungicide treatments as strip-plot factors. All compost treatments were applied to the turf surface at a rate of 2500 kg ha^{-1} and incorporated into the canopy with 2 cm of irrigation (Figures 4, 5). Extra maintenance practices were required following compost applications at the Cateechee Golf Club site. Composts were worked into the canopy using a push broom and then watered in with 2 cm of irrigation. Any remaining compost was collected and weighed to avoid contamination of plots from mowing (APPENDIX D). For comparative purposes, a synthetic nitrogen treatment and a non-treated control were included. Sulfur-coated urea (SCU) was applied alone at a rate of 25 kg N ha^{-1} once a month. The composts and the SCU were applied by hand with shaker jars. The fungicide, boscalid (3-pyridinecarboxamide, 2-chloro-N-(4'chloro[1,1'biphenyl]-2-yl) was applied to subplots within the labeled rate range at a low-rate of 71 kg ai ha^{-1} and a high-rate of 98 kg ai ha^{-1}. Both fungicide treatments were applied once a month, except for the control plots which received no fungicide treatment. All fungicide applications were made using a CO_2 sprayer with XR Tee-Jet #8003VS spray tips at a pressure of 207 kPa and a carrier volume of 486 L ha^{-1}. Plots were inoculated with an isolate of *S. homoeocarpa* on 15 March and 31 March, 2011 for the Cateechee Golf Club and UGA Griffin sites, respectively.

Figure 4. Compost applied at 2500 kg ha^{-1} to SR-1020 bentgrass plots at Cateechee Golf Club field trial.

Figure 5. Compost applied at 2500 kg ha^{-1} to Sea Isle Supreme seashore paspalum plots at UGA Griffin field trial.

Turfgrass quality, a visual assessment including uniformity and color of the turfgrass canopy, was evaluated on a 1-9 scale, 1 = poor quality or dead turf and 9 = high quality or healthy turf, 6 was considered minimally acceptable. Visual color was rated on a 1 to 9 scale, 1 = brown dead turf and 9 = dark green grass, 6 was considered minimally acceptable. Color was also measured using digital imaging technology (DIA) (Richardson et al., 2001). Symptomless foliage was visually assessed on a percent scale, 0 = diseased dead turf and 100 = no disease symptoms or healthy turf. Relative dollar spot severity (i.e. low, moderate, or severe) was determined primarily from disease activity in plots that were not treated with fungicide. Disease severity was also assessed by counting the number of infection centers in each plot. Counts were performed by inserting a golf tee into each infection center. All plots were evaluated for dollar spot symptoms, quality, and color on a range of 7-to 14-day intervals from March through November. To assess composts ability to limit the overwintering inocula of *S. homoeocarpa*, dollar spot severity was measured again the following spring as environmental conditions became favorable for dollar spot infection.

Data were analyzed using SAS (SAS Institute, 2002-2010). The PROC GLM command was used to separate means through F-protected Fisher's least significant difference (LSD) test ($p \leq 0.05$ at $\alpha = 0.05$).

CHAPTER FOUR

RESULTS

Microbial Counts

Bacterial and fungal counts were performed to enumerate microorganisms within each compost. Microbial activity in composts is considered to be an important component for reducing dollar spot (Hoitink and Fahy, 1986; Boulter et al., 2002). Bacterial counts for composts were equal to or greater than 9.00 ± 0.25 log c.f.u. /g on NA at 48 h (Table 3), while fungal colonies were equal to or greater than 7.25 ± 0.30 log c.f.u. /g on RBG at 48 h (Table 3). Previous studies reported similar results with counts equal to or greater than 8.95 ± 0.25 and 7.03 ± 0.21 c.f.u. /g for bacterial and fungal colonies, respectively (Kabir et al., 1995; Beffa et al., 1996b; Boulter et al., 2002). Counts are typically highest in organic-rich media like compost because the survival and growth of microorganisms depends largely on the availability of organic carbon (Sylvia et al., 2005). Microbial counts were also performed on the sterilized composts. At 48 h after plate inoculation no colony formation was observed (Table 3), which confirmed that microorganisms were eliminated during sterilization.

RISA Results

rRNA Intergenic Spacer Analysis (RISA) was conducted to provide a means to determine differences in microbial community structure within the different compost sources (Ranjard et al., 2000). RISA profiles differed in their complexity based on the number of bands (Table 4) (Figure 6). Based on the profiles, Carbon Peat and Farm Meal had a more complex genetic diversity of microbial communities than Sod Pro and Foothills. Profiles of Carbon Peat and

Farm Meal exhibited a significantly higher number of bands compared to Sod Pro and Foothills (Table 4). Results revealed differences in genetic structure among bacterial and fungal taxa within the different compost sources. This is important because it reveals the diversity of microbial communities within compost and it allows insight into the structural organization of microenvironments within different sources of compost. Although it is beyond the scope of this research, the next microbiological step would be to determine the specific genera of bacteria and fungi present within each compost material.

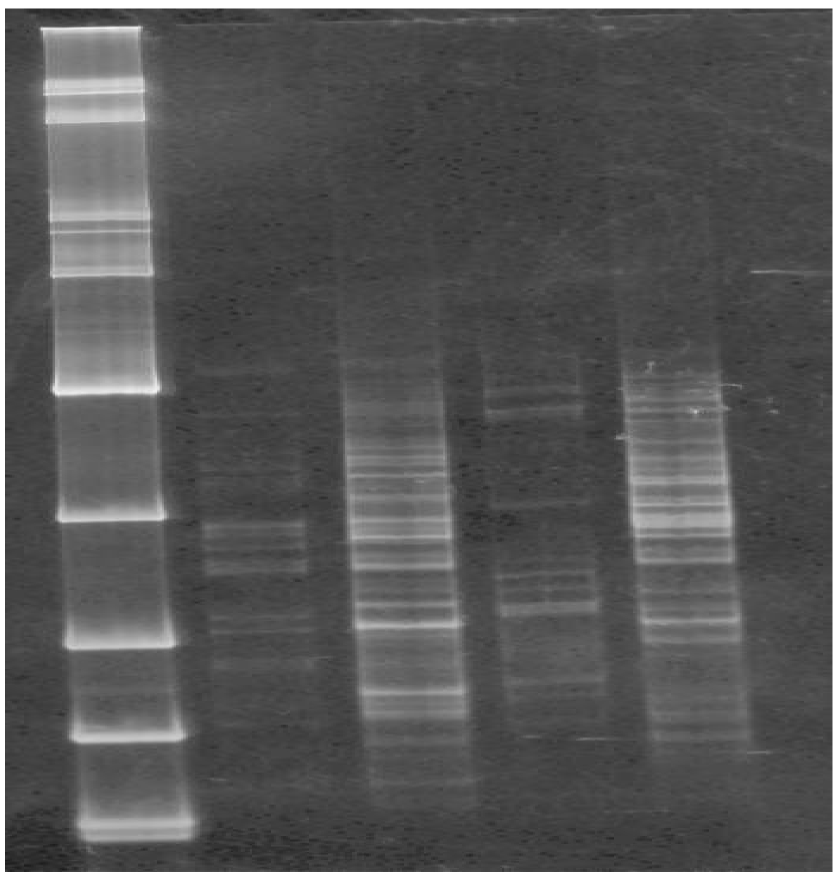

Figure 6. RISA profiles of microbial communities within the four different composts.

Greenhouse Studies

Experiment 1: A preliminary greenhouse study was conducted to evaluate compost's ability to limit the severity of dollar spot. Analysis of variance (ANOVA) indicated no difference between the repeated experiments (Table 5), therefore data were combined and means separated. At 30, 45, and 60 days after treatment (DAT), single applications of compost had significantly greater symptomless foliage compared to the non-treated control (NTC) (Table 6). This supports previous research that compost applications can suppress dollar spot (Nelson and Craft, 1992; Boulter et al., 2002). At 30 DAT, all compost treatments had greater than 60% symptomless foliage. Farm Meal had significantly higher symptomless foliage (70%) compared to Sod Pro (63%) 30 DAT. At 45 and 60 DAT, symptomless foliage decreased among all four compost treatments, and no differences were observed between composts.

Single applications of compost, except for Farm Meal at 30 DAT, provided greater turfgrass quality and color at 30, 45, and 60 DAT compared to the NTC (Table 6). Composts were not significantly different from each other and did not provide acceptable quality (≥ 6) or color (≥ 6) at any rating date.

Experiment 2: Microbial activity within compost is considered to be an important component for the suppression of dollar spot (Nelson and Craft, 1992; Hoitink et al., 1993; Boulter et al., 2002). To further assess the role of microorganisms in disease suppression, each compost was applied either being sterilized or non-sterilized. ANOVA indicated no difference between the repeated experiments (Table 7), therefore data were combined and means separated. At 30 DAT, bentgrass treated with non-sterilized compost had significantly greater symptomless foliage compared to turfgrass treated with sterilized compost (Table 8). This supports previous evidence that microorganisms potentially have a role in dollar spot suppression (Nelson and

Craft, 1992; Hoitink et al., 1993; Boulter et al., 2002). Interestingly, sterilized compost had dollar spot suppression compared to the NTC. The highest percentage of symptomless foliage (93%) at 30 DAT was with one application of ammonium sulfate at 25 kg N ha^{-1}. At 45 DAT, non-sterilized Foothills and Farm Meal had greater symptomless foliage (64%) than Sod Pro (53%), Carbon Peat (52%), all sterilized composts (41 – 50%), and the NTC (38%). However, by 60 DAT compost treatments did not provide significantly greater symptomless foliage compared to the NTC. The highest percentage of symptomless foliage (74%) at 60 DAT was with one application of ammonium sulfate.

Compared to all compost treatments and the NTC, turfgrass quality and color was significantly higher for bentgrass treated with ammonium sulfate during the study (Table 8). Ammonium sulfate was the only treatment that provided acceptable turfgrass quality (≥ 6) and color (≥ 6) on all three rating dates. All compost treatments provided significantly higher turfgrass quality and color 30 DAT compared to the NTC, but were not considered acceptable. At 45 DAT, turfgrass quality remained significantly higher for bentgrass treated with composts compared to the NTC. However, sterilized Sod Pro was the only compost treatment that provided greater turfgrass color compared to the NTC. At 60 DAT, there were no differences in turfgrass quality or color between all compost treatments and the NTC.

Experiment 3: Previous studies have shown that turfgrasses maintained under low nitrogen fertility are more susceptible to dollar spot infection (Watkins and Wit, 1995; Landschoot and McNitt, 1997; Allen et al., 2005). To further assess the effect of nitrogen sources on disease suppression, single applications of ammonium sulfate and calcium nitrate were applied to bentgrass inoculated with *S. homoeocarpa*. ANOVA indicated no difference between the repeated experiments (Table 9); therefore data were combined and means separated.

Single applications of ammonium sulfate and calcium nitrate at 25 kg N ha^{-1} had significantly greater symptomless foliage at 30, 45, and 60 DAT compared to the NTC (Table 10). At 30 DAT, single applications of ammonium sulfate and calcium nitrate had acceptable symptomless foliage (> 80%). At 45 and 60 DAT, ammonium sulfate and calcium nitrate provided greater than 70% symptomless foliage.

Compared to the NTC, turfgrass quality and color were significantly higher at all three rating dates for bentgrass treated with ammonium sulfate and calcium nitrate (Table 10). At 30 DAT, one application of ammonium sulfate provided significantly higher turfgrass quality (7.0) and color (7.0) ratings compared to a single application of calcium nitrate (6.5 and 6.5, respectively). However, both fertilizer treatments provided acceptable turfgrass quality (≥ 6) and color (≥ 6) throughout the 10 week study.

Cateechee Golf Club Field Trial Results

In 2011, dollar spot outbreaks resulted in significant differences between treatments in plots of SR-1020 bentgrass (Table 11). All rating dates except for 15 July and 19 August resulted in significant differences in symptomless foliage and dollar spot counts between plots treated with compost alone and the NTC. Plots that received monthly applications of compost had significantly lower disease levels and greater reductions in dollar spot counts compared to plots that did not receive compost applications (Tables 12 and 13). Compost only treatments were not significantly different from each other at 6 of 8 rating dates. No significant differences were found between treated plots from 15 July through 19 August due to temperatures becoming too severe (>32°C) for the dollar spot fungus to survive on cool-season turfgrass (Appendix A). Plots treated with compost alone failed to reduce dollar spot to within acceptable limits (> 80%) during the study.

There was a significant improvement in symptomless foliage in plots treated with compost + the fungicide treatments (Table 11). Plots treated with compost + boscalid had greater than 90% symptomless foliage on all rating dates and had significantly fewer infection centers compared to plots treated with SCU, composts, and the NTC (Tables 12 and 13). However, there were no differences between plots treated with compost + boscalid and plots treated with boscalid alone. Plots treated with multiple compost applications along with recommended low-rate fungicide applications had acceptable symptomless foliage.

Improvements were also observed in plots treated with SCU compared to plots treated with compost alone. Plots treated with SCU had greater symptomless foliage and had significantly fewer infection centers compared to plots treated with compost alone on all rating dates (Tables 12 and 13). Plots treated with SCU provided greater than 80% symptomless foliage on all rating dates except for 10 June. No significant differences in symptomless foliage or counts were observed in plots treated with SCU + boscalid compared to plots treated with compost + boscalid.

Turfgrass quality and color were not enhanced in plots treated with compost alone when compared to the NTC (Tables 14 and 15). Plots treated with compost alone did not provide acceptable turfgrass quality (≥ 6) or color (≥ 6) during the study. Quality and color for plots treated with compost + boscalid ranged between 5 to 5.9 on 7 of 8 rating dates, and were only acceptable at the beginning of the study on 8 April. Except for plots treated with SCU, all plots had unacceptable quality and color by 13 May. Plots treated with SCU had acceptable turfgrass quality and color on all rating dates. Differences in turfgrass color were further evaluated using digital imaging analysis (Tables 16, 17, and 18). Compared to the NTC, there were no differences among plots treated with compost with regards to saturation, brightness levels, hue, and dark green color index (DGCI) on the 3 rating dates (Tables 16, 17, and 18). Plots treated with SCU had a significantly darker shade of green (i.e. higher hue) than plots treated with compost alone and compost + boscalid. These results were consistent with the visual ratings.

To assess composts ability to limit the overwintering inocula of *S. homoeocarpa*, dollar spot severity was measured weekly from 23 March to 6 April, 2012 as environmental conditions became favorable for dollar spot infection (Table 19). Plots treated with compost alone had greater reductions of *S. homoeocarpa* compared to the NTC. Compost treatments provided up to 14% reduction on 23 March, but were not significantly different from each other on any rating date. There were differences observed between plots treated with SCU + boscalid compared to plots treated with compost + boscalid. Plots treated with SCU + boscalid provided up to 76% reduction on March 23, but were not significantly different from each other on any rating date. Similar trends were observed on the rating dates of 30 March and 6 April.

UGA Griffin Field Trial Results

At the Griffin location, dollar spot symptoms were initially detected on 15 April in non-treated control plots of Sea Isle Supreme seashore paspalum. Dollar spot outbreaks resulted in significant differences between treatments (Table 20). On all rating dates, plots treated with compost alone had significantly greater symptomless foliage compared to the NTC (Table 21). Plots treated with compost alone also had significantly fewer infection centers on all rating dates compared to the NTC (Table 22). Plots with compost alone did not provide acceptable symptomless foliage (> 80%) on any rating date and were not significantly different from one another.

Dollar spot severity was reduced in plots treated with compost + fungicide treatments. Plots treated with compost + boscalid had greater than 90% symptomless foliage on all rating dates and had significantly fewer infection centers compared to plots treated with SCU, composts, and the NTC. No significant differences were observed among any compost treatments when applied along with boscalid at either rate (Table 21). Plots treated with boscalid were not significantly different from plots treated with compost + boscalid at either rate.

Significant improvements were also observed in plots treated with SCU compared to plots treated with compost alone (Table 21). Plots treated with SCU alone had greater than 80% symptomless foliage on all rating dates and had significantly fewer infection centers compared to plots treated with compost alone (Tables 21 and 22). No significant differences in symptomless foliage or counts were observed in plots treated with SCU + boscalid compared to plots treated with compost + boscalid.

Plots treated with compost alone did not provide acceptable turfgrass quality or color (≥ 6) during the study (Tables 23 and 24). When compared to the NTC, no differences were observed in turfgrass quality or color among plots treated with compost alone. Plots treated with compost + boscalid generally ranged between 5.0 to 5.9 for turfgrass quality and color. On all rating dates, plots treated with SCU had acceptable turfgrass quality and color. Differences in turfgrass color were further evaluated using digital imaging analysis (Tables 25, 26, and 27) . Compared to the NTC, there were no differences among plots treated with compost alone with regards to saturation, brightness levels, hue, and dark green color index (DGCI) on the 3 rating dates (Tables 25, 26, and 27). Plots treated with SCU had a significantly darker shade of green (i.e. higher hue); than plots treated with compost alone and compost + boscalid. These results were consistent with the visual ratings.

To assess composts ability to limit the overwintering inocula of *S. homoeocarpa*, dollar spot severity was measured weekly from 24 March to 7 April, 2012 as environmental conditions became favorable for dollar spot infection (Table 28). Plots treated with compost provided significantly greater reductions of *S. homoeocarpa* compared to the NTC at all three rating dates (Table 28). Compost treatments provided up to 27% reduction on 24 March compared to the NTC, but were not significantly different from each other on any rating date. There were differences observed between plots treated with SCU + boscalid compared to plots treated with compost + boscalid. Plots treated with SCU + boscalid provided up to 100% reduction of *S. homoeocarp* on 24 March, but were not significantly different from each other on any rating date. Similar trends were observed on 31 March and 7 April.

Table 3. Results for bacterial and fungal colony counts for dry weight compost 48 h after plate inoculation.

Compost	Agar	Non-sterilized (log c.f.u. /g)	Sterilized	n[1]
		Bacterial Colonies		
Sod Pro	NA[2]	9.00 ± 0.26	0.0	5
Carbon Peat	NA	9.10 ± 0.28	0.0	4
Foothills	NA	9.45 ± 0.25	0.0	3
Farm Meal	NA	9.33 ± 0.28	0.0	5
		Fungal Colonies		
Sod Pro	RBG[3]	7.25 ± 0.30	0.0	5
Carbon Peat	RBG	7.55 ± 0.29	0.0	5
Foothills	RBG	7.34 ± 0.30	0.0	5
Farm Meal	RBG	7.26 ± 0.31	0.0	5

[1] n – number of plates counted
[2] NA – nutrient agar
[3] RBG – Rose Bengal-glucose med

Table 4. Number of bands on RISA profiles associated with the four different composts.

	Sod Pro	Carbon Peat	Foothills	Farm Meal
Total number of bands	13 b	19 a	12 b	20 a

Table 5. Analysis of variance (ANOVA) for runs in greenhouse experiment 1.

	Symptomless Foliage (%)	Turf Quality	Turf Color
Source[1]	----------------------------------	P values	--------------------------------
Run	0.3624	0.1041	0.2937

[1]Source – ANOVA using type III sums of squares of the SAS version 9.3 proc mixed procedure
[2]P values – significance at $P \leq 0.05$

Table 6. Greenhouse experiment 1 results for symptomless foliage of dollar spot, turfgrass quality, and color in SR-1020 bentgrass following single applications of four different composts.

	Symptomless Foliage (%)			Turf Quality (1-9)[1]			Turf Color (1-9)[2]		
Treatments	30 DAT[3]	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
NTC[4]	49.0 c[5]	34.0 b	28.0 b	4.13 b	3.88 b	3.85 b	4.63 b	4.13 b	3.88 b
Sod Pro[6]	63.0 b	56.0 a	44.0 a	5.13 a	4.88 a	4.63 a	5.50 a	5.25 a	5.00 a
Carbon Peat	66.0 ab	49.0 a	48.0 a	5.38 a	5.25 a	4.75 a	5.38 a	5.13 a	4.88 a
Foothills	65.0 ab	55.0 a	46.0 a	5.50 a	5.13 a	5.13 a	5.50 a	5.00 a	5.25 a
Farm Meal	70.0 a	54.0 a	48.0 a	5.50 a	5.13 a	5.00 a	5.13 ab	5.50 a	4.75 a

[1]Turf quality – 1 = poor quality or dead turf and 9 = high quality or healthy turf, 6 was considered minimally acceptable
[2]Turf color – 1 = brown dead turf and 9 = dark green grass, 6 was considered minimally acceptable.
[3]DAT – days after treatment.
[4]NTC – non-treated control
[5]Within a column, values followed by the same letter are not significantly different $\alpha = 0.05$.
[6]Compost treatments – applied at 2500 kg ha^{-1}

Table 7. Analysis of variance (ANOVA) for runs in greenhouse experiment 2.

	Symptomless Foliage (%)	Turf Quality	Turf Color
Source[1]	----------------------------------	P values[2]	--------------------------------
Run	0.1635	0.3264	0.3465

[1]Source – ANOVA using type III sums of squares of the SAS version 9.3 proc mixed procedure
[2]P values – significance at $P \leq 0.05$

Table 8. Greenhouse experiment 2 results for symptomless foliage of dollar spot, turfgrass quality, and color in SR-1020 bentgrass following single applications of four different sterile and non-sterile composts.

	Symptomless Foliage (%)			Turf Quality (1-9)[1]			Turf Color (1-9)[2]		
Treatments	30 DAT[3]	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
NTC[4]	53.0 d[5]	38.0 e	41.0 bc	4.3 c	3.9 c	4.5 b	4.4 c	4.3 c	4.1 b
Sod Pro[6]	71.0 b	53.0 c	38.0 c	5.8 b	5.1 b	4.4 b	5.3 b	4.6 bc	4.0 b
Carbon Peat	73.0 b	52.0 c	46.0 bc	5.6 b	4.8 b	4.4 b	5.4 b	4.5 bc	4.5 b
Foothills	74.0 b	64.0 b	54.0 b	5.6 b	4.8 b	4.3 b	5.3 b	4.8 bc	4.3 b
Farm Meal	72.0 b	64.0 b	44.0 bc	5.7 b	5.0 b	4.2 b	5.4 b	4.5 bc	4.4 b
(S)[7] Sod Pro	66.0 c	50.0 cd	34.0 c	5.4 b	5.1 b	4.0 b	5.4 b	5.0 b	4.2 b
(S) Carbon Peat	66.0 c	43.0 de	38.0 c	5.1 b	4.7 b	4.3 b	5.4 b	4.8 bc	4.4 b
(S) Foothills	66.0 c	41.0 de	36.0 c	5.1 b	5.0 b	4.4 b	5.5 b	4.6 bc	4.0 b
(S) Farm Meal	64.0 c	48.0 cd	36.0 c	5.3 b	5.0 b	4.5 b	5.5 b	4.5 bc	4.2 b
Ammonium Sulfate[8]	93.0 a	80.0 a	74.0 a	6.8 a	6.3 a	6.0 a	6.4 a	6.3 a	6.0 a

[1]Turf quality – 1 = poor quality or dead turf and 9 = high quality or healthy turf, 6 was considered minimally acceptable
[2]Turf color – 1 = brown dead turf and 9 = dark green grass, 6 was considered minimally acceptable
[3]DAT – days after treatment
[4]NTC – non-treated control
[5]Within a column, values followed by the same letter are not significantly different $\alpha = 0.05$.
[6]Compost treatments – applied at 2500 kg ha^{-1}
[7]S – sterilized before application
[8]Ammonium sulfate – applied at 25 kg N ha^{-1}

Table 9. Analysis of variance (ANOVA) for runs in greenhouse experiment 3.

	Symptomless Foliage (%)	Turf Quality	Turf Color
Source[1]	----------	P values[2]	----------
Run	0.3421	0.3421	0.2654

[1]Source – ANOVA using type III sums of squares of the SAS version 9.3 proc mixed procedure
[2]P values – significance at $P \leq 0.05$

Table 10. Greenhouse experiment 3 results for symptomless foliage of dollar spot, turfgrass quality, and color in SR-1020 bentgrass treated with single applications of two different nitrogen sources.

		Symptomless Foliage (%)			Turf Quality (1-9)[1]			Turf Color (1-9)[2]		
Treatments	Rate (kg N ha^{-1})	30 DAT[3]	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
NTC[4]		53.0 b[5]	52.0 b	37.0 b	4.8 c	4.5 b	3.8 b	4.8 c	4.5 b	3.3 b
Ammonium Sulfate	25	88.0 a	75.0 a	74.0 a	7.0 a	6.5 a	6.2 a	7.0 a	6.1 a	6.0 a
Calcium Nitrate	25	87.0 a	72.0 a	75.0 a	6.5 b	6.6 a	6.2 a	6.5 b	6.0 a	6.0 a

[1]Turf quality – 1 = poor quality or dead turf and 9 = high quality or healthy turf, 6 was considered minimally acceptable
[2]Turf color – 1 = brown dead turf and 9 = dark green grass, 6 was considered minimally acceptable
[3]DAT – days after treatment
[4]NTC – non-treated control
[5]Within a column, values followed by the same letter are not significantly different $\alpha = 0.05$

Table 11. Analysis of variance (ANOVA) for symptomless foliage of dollar spot and infection center counts in SR-1020 bentgrass.

	8 April	13 May	10 June	15 July	19 Aug.	25 Sept.	21 Oct.	18 Nov.
Source – Symptomless Foliage (%)	P values							
Composts	0.2134	0.1662	0.2543	0.2354	0.2465	0.2342	0.1394	0.1456
Composts*boscalid	0.0253	0.0154	0.0254	0.3461	0.2543	0.0100	0.0030	0.0201
boscalid*rate	0.3276	0.1383	0.2745	0.1953	0.2645	0.4021	0.1467	0.2645
Composts*boscalid*rate	0.3412	0.3421	0.4312	0.2543	0.5452	0.2543	0.2435	0.1243
Source – Infection center	P values							
Composts	0.1243	0.1034	0.2425	0.3421	0.2453	0.2201	0.2321	0.1294
Composts*boscalid	0.0356	0.0105	0.0035	0.3284	0.5241	0.0056	0.0041	0.0205
boscalid*rate	0.2579	0.2465	0.1483	0.5247	0.1485	0.5241	0.2984	0.3574
Composts*boscalid*rate	0.5214	0.3654	0.2418	0.1295	0.8541	0.2564	0.2487	0.5463

[1]Source – ANOVA using type III sums of squares of the SAS version 9.3 proc mixed procedure
[2]P values – significance at $P \leq 0.05$

Table 12. Symptomless foliage of dollar spot in SR-1020 bentgrass plots following monthly applications of four different composts, SCU, and boscalid.

	Symptomless Foliage (%)							
Treatments	8 April	13 May	10 June	15 July	19 Aug.	25 Sept.	21 Oct.	18 Nov.
NTC[1]	39.0 d[2]	32.0 d	30.0 d	NS[3]	NS	39.0 d	34.0 d	29.0 d
Sod Pro[4]	50.0 c	43.0 c	36.0 c	NS	NS	51.0 c	45.0 c	48.0 c
Carbon Peat	52.0 c	44.0 c	40.0 c	NS	NS	52.0 c	43.0 c	46.0 c
Foothills	56.0 c	45.0 c	44.0 c	NS	NS	58.0 c	47.0 c	45.0 c
Farm Meal	52.0 c	43.0 c	41.0 c	NS	NS	57.0 c	42.0 c	49.0 c
SCU[5]	81.0 b	80.0 b	78.0 b	NS	NS	83.0 b	83.0 b	82.0 b
Sod Pro + boscalid A[6]	93.0 a	96.0 a	94.0 a	NS	NS	95.0 a	96.0 a	96.0 a
Carbon Peat + boscalid A	95.0 a	94.0 a	95.0 a	NS	NS	94.0 a	93.0 a	90.0 ab
Foothills + boscalid A	95.0 a	95.0 a	95.0 a	NS	NS	94.0 a	92.0 a	95.0 a
Farm Meal + boscalid A	90.0 ab	95.0 a	96.0 a	NS	NS	96.0 a	94.0 a	91.0 ab
SCU + boscalid A	93.0 a	97.0 a	97.0 a	NS	NS	100.0 a	95.0 a	100.0 a
Sod Pro + boscalid B[6]	100.0 a	97.0 a	99.0 a	NS	NS	99.0 a	100.0 a	100.0 a
Carbon Peat + boscalid B	100.0 a	96.0 a	100.0 a	NS	NS	97.0 a	100.0 a	100.0 a
Foothills + boscalid B	100.0 a	93.0 a	97.0 a	NS	NS	100.0 a	100.0 a	100.0 a
Farm Meal + boscalid B	100.0 a	99.0 a	100.0 a	NS	NS	99.0 a	98.0 a	97.0 a
SCU + boscalid B	100.0 a	96.0 a	100.0 a	NS	NS	100.0 a	100.0 a	100.0 a
boscalid A	90.3 a	93.0 a	94.0 a	NS	NS	94.0 a	94.0 a	94.0 a
boscalid B	100.0 a	96.0 a	99.0 a	NS	NS	100.0 a	100.0 a	98.0 a

[1] NTC – non-treated control
[2]Within a column, values followed by the same letter are not significantly different $\alpha = 0.05$.
[3]NS – not significant
[4]Compost treatments – applied at 2500 kg ha^{-1}
[5]SCU – sulfur-coated urea applied at 25 kg N ha^{-1}
[6]A – boscalid applied at 71 kg ai ha^{-1}
[7]B – boscalid applied at 98 kg ai ha^{-1}

Table 13. Dollar spot counts in SR-1020 bentgrass plots following monthly applications of four different composts, SCU, and boscalid.

	Infection Center Counts							
Treatments	8 April	13 May	10 June	15 July	19 Aug.	25 Sept.	21 Oct.	18 Nov.
NTC[1]	44.0 a[2]	51.2 a	55.0 a	NS[3]	NS	52. 3 a	60.2 a	70.0 a
Sod Pro[4]	23.6 b	31.3 b	36.4 b	NS	NS	31. 4 b	45.0 b	53.0 b
Carbon Peat	25.0 b	29.8 b	40.0 b	NS	NS	30.4 b	43.3 b	49.0 b
Foothills	19.7 b	28.5 b	32.4 b	NS	NS	32.9 b	46.5 b	53.0 b
Farm Meal	27.8 b	34.7 b	43.0 b	NS	NS	31.7 b	41.7 b	49.3 b
SCU[5]	8.0 c	8.5 c	15.3 c	NS	NS	16.2 c	19.2 c	22.1 c
Sod Pro + boscalid A[6]	4.3 d	2.4 d	6.0 d	NS	NS	3.1 d	2.0 d	4.6 d
Carbon Peat + boscalid A	6.0 d	4.3 d	4.1 d	NS	NS	3.5 d	3.0 d	4.9 d
Foothills + boscalid A	3.3 d	3.6 d	3.0 d	NS	NS	2.5 d	3.0 d	3.5 d
Farm Meal + boscalid A	5.0 d	2.9 d	4.0 d	NS	NS	2.1 d	2.0 d	3.9 d
SCU + boscalid A	2.0 d	3.2 d	1.2 d	NS	NS	0.0 d	2.5 d	0.0 d
Sod Pro + boscalid B[7]	0.0 d	2.0 d	2.3 d	NS	NS	0.5 d	0.0 d	0.0 d
Carbon Peat + boscalid B	0.0 d	3.1 d	0.0 d	NS	NS	1.2 d	0.0 d	0.4 d
Foothills + boscalid B	0.0 d	3.2 d	2.0 d	NS	NS	0.0 d	0.0 d	1.4 d
Farm Meal + boscalid B	0.0 d	0.6 d	0.0 d	NS	NS	0.3 d	0.0 d	2.5 d
SCU + boscalid B	0.0 d	3.0 d	0.0 d	NS	NS	0.0 d	0.0 d	0.0 d
boscalid A	6.0 d	4.6 d	5.0 d	NS	NS	4.1d	5.1 d	3.1 d
boscalid B	0.0 d	2.1 d	3.0 d	NS	NS	0.0 d	0.0 d	2.7 d

[1] NTC – non-treated control
[2] Within a column, values followed by the same letter are not significantly different $\alpha = 0.05$.
[3] NS – not significant
[4] Compost treatments – applied at 2500 kg ha^{-1}
[5] SCU – sulfur-coated urea applied at 25 kg N ha^{-1}
[6] A – boscalid applied at 71 kg ai ha^{-1}
[7] B – boscalid applied at 98 kg ai ha^{-1}

Table 14. Turf quality in SR-1020 bentgrass plots following monthly applications of four different composts, SCU, and boscalid.

Treatments	Turf Quality (1 – 9 scale)[1]							
	8 April	13 May	10 June	15 July	19 Aug.	25 Sept.	21 Oct.	18 Nov.
NTC[2]	3.5 c[3]	3.6 c	2.9 c	2.5 c	2.2 c	3.0 c	3.3 c	3.7 c
Sod Pro[4]	3.8 c	4.0 c	3.0 c	2.6 c	2.4 c	3.5 c	3.6 c	4.0 c
Carbon Peat	4.1 c	3.9 c	2.8 c	2.1 c	2.5 c	3.4 c	4.0 c	3.9 c
Foothills	4.3 c	4.1 c	3.0 c	2.6 c	2.9 c	3.0 c	3.6 c	4.1 c
Farm Meal	3.7 c	4.2 c	3.1 c	2.8 c	2.6 c	3.5 c	3.7 c	4.1 c
SCU[5]	7.0 a	7.5 a	6.5 a	6.0 a	6.0 a	6.5 a	7.0 a	7.5 a
Sod Pro + boscalid A[6]	6.2 b	5.8 b	5.4 b	4.1 b	4.3 b	5.5 b	5.5 b	5.6 b
Carbon Peat + boscalid A	6.3 b	5.6 b	5.3 b	4.5 b	4.8 b	5.8 b	5.7 b	5.8 b
Foothills + boscalid A	6.4 b	5.9 b	5.1 b	4.6 b	4.2 b	5.5 b	5.4 b	5.3 b
Farm Meal + boscalid A	6.0 b	5.5 b	5.5 b	4.0 b	4.3 b	5.5 b	5.6 b	5.9 b
SCU + boscalid A	7.2 a	7.3 a	6.6 a	6.0 a	6.0 a	6.8 a	7.5 a	7.5 a
Sod Pro boscalid B	6.5 b	5.7 b	5.5 b	4.4 b	4.0 b	5.6 b	5.9 b	5.9 b
Carbon Peat + boscalid B[7]	6.3 b	5.8 b	5.0 b	4.4 b	4.5 b	5.0 b	5.6 b	5.9 b
Foothills + boscalid B	6.0 b	5.4 b	5.0 b	4.3 b	4.0 b	5.6 b	5.5 b	5.5 b
Farm Meal + boscalid B	6.3 b	5.7 b	5.2 b	4.3 b	4.5 b	5.4 b	5.9 b	5.7 b
SCU + boscalid B	7.4 a	7.7 a	6.7 a	6.4 a	6.2 a	7.0 a	7.5 a	7.5 a
boscalid A	6.2 b	5.4 b	5.5 b	4.5 b	4.0 b	5.3 b	5.5 b	5.6 b
boscalid B	6.5 b	5.8 b	5.3 b	4.8 b	3.9 b	5.5 b	5.8 b	5.7 b

[1]Turf quality – 1 = poor quality or dead turf and 9 = high quality or healthy turf, 6 was minimally acceptable
[2]NTC – non-treated control
[3]Within a column, values followed by the same letter are not significantly different $\alpha = 0.05$.
[4]Compost treatments – applied at 2500 kg ha^{-1}
[5]SCU – sulfur-coated urea applied at 25 kg N ha^{-1}
[6] A – boscalid applied at 71 kg ai ha^{-1}
[7] B – boscalid applied at 98 kg ai ha^{-1}

Table 15. Turf color in SR-1020 bentgrass plots following monthly applications of four different composts, SCU, and boscalid.

Treatments	Turf Color (1 – 9 scale)[1]							
	8 April	13 May	10 June	15 July	19 Aug.	25 Sept.	21 Oct.	18 Nov.
NTC[2]	3.6 c[3]	3.3 c	3.0 c	2.6 c	2.0 c	3.3 c	3.3 c	4.0 c
Sod Pro[4]	4.0 c	3.9 c	3.2 c	2.8 c	2.6 c	3.9 c	3.6 c	3.9 c
Carbon Peat	3.9 c	3.8 c	3.7 c	2.9 c	2.7 c	3.1 c	4.0 c	4.1 c
Foothills	4.1 c	4.0 c	3.4 c	2.7 c	2.8 c	3.2 c	3.6 c	3.9 c
Farm Meal	4.2 c	3.8 c	3.5 c	2.9 c	2.0 c	3.6 c	3.7 c	4.0 c
SCU[5]	7.5 a	7.0 a	6.5 a	6.0 a	5.9 a	7.0 a	7.0 a	7.5 a
Sod Pro + boscalid A[6]	6.1 b	5.5 b	5.4 b	4.9 b	4.0 b	5.5 b	5.5 b	5.4 b
Carbon Peat + boscalid A	6.1 b	5.8 b	5.3 b	4.5 b	4.5 b	5.5 b	5.7 b	5.5 b
Foothills + boscalid A	6.4 b	5.5 b	5.0 b	4.9 b	4.0 b	5.8 b	5.4 b	5.5 b
Farm Meal + boscalid A	6.1 b	5.6 b	5.3 b	4.6 b	3.9 b	5.3 b	5.6 b	5.5 b
SCU + boscalid A	7.3 a	7.5 a	7.0 a	6.3 a	6.0 a	7.5 a	7.5 a	7.6 a
Sod Pro boscalid B[7]	6.0 b	5.8 b	5.3 b	4.8 b	4.1 b	5.6 b	5.9 b	5.9 b
Carbon Peat + boscalid B	6.2 b	5.5 b	5.5 b	4.6 b	4.3 b	5.7 b	5.6 b	5.6 b
Foothills + boscalid B	6.2 b	5.6 b	5.3 b	4.6 b	4.1 b	5.6 b	5.5 b	5.7 b
Farm Meal + boscalid B	6.0 b	5.5 b	5.5 b	4.5 b	4.0 b	5.4 b	5.9 b	5.8 b
SCU + boscalid B	7.7 a	7.5 a	7.0 a	6.5 a	6.3 a	7.5 a	7.5 a	7.4 a
boscalid A	6.0 b	5.5 b	5.1 b	5.0 b	3.9 b	6.0 b	5.5 b	5.6 b
boscalid B	6.0 b	5.8 b	5.3 b	4.9 b	3.8 b	6.0 b	5.9 b	5.7 b

[1]Turf color – 1 = brown dead turf and 9 = dark green grass, 6 was considered minimally acceptable
[2]NTC – non-treated control
[3] Within a column, values followed by the same letter are not significantly different $\alpha = 0.05$.
[4]Compost treatments – applied at 2500 kg ha^{-1}
[5]SCU – sulfur-coated urea applied at 25 kg N ha^{-1}
[6] A – boscalid applied at 71 kg ai ha^{-1}
[7] B – boscalid applied at 98 kg ai ha^{-1}

Table 16. Digital color analysis in SR-1020 bentgrass plots following monthly applications of four different composts, SCU, and boscalid, (8 April 2011).

Treatments	Hue[1] (Degrees)	Saturation[2] (%)	Brightness[3] (%)	DGCI[4]
NTC[5]	64.67 c[6]	67.56 a	29.36 a	0. 34 c
Sod Pro[7]	64.67 c	68.45 a	29.45 a	0.35 c
Carbon Peat	63.55 c	67.64 a	28.56 a	0.36 c
Foothills	62.56 c	67.87 a	28.55 a	0.37 c
Farm Meal	63.55 c	67.98 a	29.76 a	0.32 c
SCU[8]	78.45 a	60.56 c	22.12 c	0.49 a
Sod Pro + boscalid A[9]	73.56 b	67.78 b	26.98 b	0.42 b
Carbon Peat + boscalid A	72.89 b	64.98 b	26.98 b	0.40 b
Foothills + boscalid A	74.87 b	64.22 b	26.54 b	0.41 b
Farm Meal + boscalid A	71.45 b	64.65 b	26.78 b	0.41 b
SCU + boscalid A	80.78 a	61.89 c	22.65 c	0.48 a
Sod Pro + boscalid B[10]	74.76 b	64.45 b	26.34 b	0.41 b
Carbon Peat + boscalid B	73.76 b	64.35 b	26.65 b	0.42 b
Foothills + boscalid B	72.88 b	64.34 b	26.76 b	0.42 b
Farm Meal + boscalid B	73.67 b	64.46 b	26.12 b	0.40 b
SCU + boscalid B	80.09 a	60.23 c	22.78 c	0.48 a
boscalid A	74.75 b	64.24 b	26.78 b	0.44 b
boscalid B	73.56 b	64. 56 b	26.55 b	0.43 b

[1] 0° = red, 60° = yellow, 120° = green, 180° = cyan, 240° = blue, and 300° = magenta
[2] 0% = gray and 100% = white
[3] 0% = black and 100% = white
[4] Dark green color index: DGCI = [(Hue – 60)/(60 + (1- Saturation) + (1 – Brightness)]/3
[5] NTC – non-treated control
[6] Within a column, values followed by the same letter are not significantly different $\alpha = 0.05$.
[7] Compost treatments – applied at 2500 kg ha^{-1}
[8] SCU – sulfur-coated urea applied at 25 kg N ha^{-1}
[9] A – boscalid applied at 71 kg ai ha^{-1}
[10] B – boscalid applied at 98 kg ai ha^{-1}

Table 17. Digital color analysis in SR-1020 bentgrass plots following monthly applications of four different composts, SCU, and boscalid, (10 June 2011).

Treatments	Hue[1](Degrees)	Saturation[2](%)	Brightness[3](%)	DGCI[4]
NTC[5]	55.61 c[6]	68.36 a	28.16 a	0. 24 c
Sod Pro[7]	60.57 c	68.45 a	27.95 a	0.25 c
Carbon Peat	62.35 c	68.44 a	28.47 a	0.27 c
Foothills	62.59 c	69.88 a	29.15 a	0.22 c
Farm Meal	63.00 c	68.78 a	29.36 a	0.21 c
SCU[8]	71.25 a	58.66 c	21.32 c	0.41 a
Sod Pro + boscalid A[9]	68.46 b	64.77 b	25.78 b	0.34 b
Carbon Peat + boscalid A	67.99 b	64.98 b	25.48 b	0.30 b
Foothills + boscalid A	67.87 b	64.22 b	24.94 b	0.31 b
Farm Meal + boscalid A	68.43 b	64.65 b	25.38 b	0.35 b
SCU + boscalid A	73.58 a	60.99 c	20.55 c	0.44 a
Sod Pro + boscalid B[10]	67.56 b	64.15 b	25.14 b	0.31 b
Carbon Peat + boscalid B	67.46 b	63.85 b	24.95 b	0.33 b
Foothills + boscalid B	68.58 b	64.11 b	25.66 b	0.34 b
Farm Meal + boscalid B	67.52 b	65.00 b	24.92 b	0.31 b
SCU + boscalid B	72.09 a	60.13 c	21.88 c	0.43 a
boscalid A	67.45 b	64.14 b	26.10 b	0.34 b
boscalid B	68.66 b	64. 66 b	26.10 b	0.32 b

[1] 0° = red, 60° = yellow, 120° = green, 180° = cyan, 240° = blue, and 300° = magenta
[2] 0% = gray and 100% = white
[3] 0% = black and 100% = white
[4] Dark green color index: DGCI = [(Hue – 60)/(60 + (1- Saturation) + (1 – Brightness)]/3
[5] NTC – non-treated control
[6] Within a column, values followed by the same letter are not significantly different $\alpha = 0.05$
[7] Compost treatments – applied at 2500 kg ha^{-1}
[8] SCU – sulfur-coated urea applied at 25 kg N ha^{-1}
[9] A – boscalid applied at 71 kg ai ha^{-1}
[10] B – boscalid applied at 98 kg ai ha^{-1}

Table 18. Digital color analysis in SR-1020 bentgrass plots following monthly applications of four different composts, SCU, and boscalid, (21 Oct. 2011).

Treatments	Hue[1](Degrees)	Saturation[2] (%)	Brightness[3](%)	DGCI[4]
NTC[5]	64.57 c[6]	67.26 a	28.96 a	0. 31 c
Sod Pro[7]	64.48 c	68.35 a	28.95 a	0.32 c
Carbon Peat	63.26 c	67.61 a	28.76 a	0.33 c
Foothills	62.18 c	67.17 a	28.85 a	0.38 c
Farm Meal	63.47 c	68.08 a	29.56 a	0.35 c
SCU[8]	78.36 a	60.56 c	22.02 c	0.50 a
Sod Pro + boscalid A[9]	73.41 b	67.78 b	26.18 b	0.43 b
Carbon Peat + boscalid A	72.79 b	64.58 b	26.28 b	0.41 b
Foothills + boscalid A	74.25 b	64.21 b	26.34 b	0.41 b
Farm Meal + boscalid A	71.29 b	64.35 b	26.38 b	0.44 b
SCU + boscalid A	80.12 a	61.00 c	22.65 c	0.51 a
Sod Pro + boscalid B[10]	74.29 b	64.14 b	26.35 b	0.42 b
Carbon Peat + boscalid B	73.69 b	63.15 b	25.95 b	0.41 b
Foothills + boscalid B	72.78 b	63.35 b	26.13 b	0.43 b
Farm Meal + boscalid B	73.78 b	63.96 b	26.02 b	0.42 b
SCU + boscalid B	80.19 a	59.23 c	22.14 c	0.51 a
boscalid A	74.54 b	64.94 b	26.58 b	0.43 b
boscalid B	73.50 b	64. 76 b	26.47 b	0.44 b

[1] 0° = red, 60° = yellow, 120° = green, 180° = cyan, 240° = blue, and 300° = magenta
[2] 0% = gray and 100% = white
[3] 0% = black and 100% = white
[4] Dark green color index: DGCI = [(Hue – 60)/(60 + (1- Saturation) + (1 – Brightness)]/3
[5] NTC – non-treated control
[6] Within a column, values followed by the same letter are not significantly different α = 0.05
[7] Compost treatments – applied at 2500 kg ha^{-1}
[8] SCU – sulfur-coated urea applied at 25 kg N ha^{-1}
[9] A – boscalid applied at 71 kg ai ha^{-1}
[10] B – boscalid applied at 98 kg ai ha^{-1}

Table 19. Severity of dollar spot in spring 2012 from over-wintering inoculum of *S. homoeocarpa* in SR-1020 bentgrass plots following monthly applications of four different composts, SCU, and boscalid in 2011.

	Dollar Spot Infection (%)		
	23 March	30 March	6 April
Treatments	---- 2012 ----		
NTC[1]	51.0 a[2]	54.0 a	56.0 a
Sod Pro[3]	45.0 b	48.0 b	50.0 b
Carbon Peat	44.0 b	49.0 b	50.0 b
Foothills	46.0 b	46.0 b	51.0 b
Farm Meal	44.0 b	47.0 b	51.0 b
SCU[4]	17.0 c	20.0 c	20.0 c
Sod Pro + boscalid A[5]	16.0 c	19.0 c	20.0 c
Carbon Peat + boscalid A	17.0 c	18.0 c	19.0 c
Foothills + boscalid A	14.0 c	19.0 c	18.0 c
Farm Meal + boscalid A	16.0 c	20.0 c	20.0 c
SCU + boscalid A	5.0 d	5.0 d	9.0 d
Sod Pro + boscalid B[6]	16.0 c	19.0 c	20.0 c
Carbon Peat + boscalid B	17.0 c	18.0 c	20.0 c
Farm Meal + boscalid B	14.0 c	17.0 c	21.0 c
SCU + boscalid B	4.0 d	6.0 d	9.0 d
boscalid A	18.0 c	20.0 c	21.0 c
boscalid B	15.0 c	19.0 c	19.0 c

[1]NTC – non-treated control
[2] Within a column, values followed by the same letter are not significantly different $\alpha = 0.05$.
[3]Compost treatments – applied at 2500 kg ha^{-1}
[4]SCU- sulfur-coated urea applied at 25 kg N ha^{-1}
[5]boscalid A - boscalid applied at low rate 71 kg ai ha^{-1}
[6]boscalid B – boscalid applied at 98 kg ai ha^{-1}

Table 20. Analysis of variance (ANOVA) for symptomless foliage of dollar spot and infection centers in plots of Sea Isle Supreme seashore paspalum.

	21 April	27 May	24 June	29 July	26 Aug.	30 Sept.	28 Oct.	11 Nov.
Source – Symptomless Foliage (%)	P values							
Composts	0.2651	0.1214	0.2453	0.2154	0.2874	0.1284	0.2361	0.2453
Composts*boscalid	0.0043	0.0052	0.0153	0.0151	0.0143	0.0124	0.0131	0.0311
boscalid*rate	0.2461	0.1587	0.2641	0.1564	0.5413	0.4185	0.2147	0.1451
Composts*boscalid*rate	0.2132	0.2471	0.5332	0.4513	0.4472	0.1533	0.1458	0.3234
Source – Infection center	P values							
Composts	0.2543	0.2141	0.2554	0.2452	0.2514	0.1542	0.1521	0.1545
Composts*boscalid	0.0025	0.0005	0.0034	0.0002	0.0035	0.0025	0.0014	0.0025
boscalid*rate	0.2514	0.1264	0.2413	0.2514	0.1452	0.6324	0.1254	0.2541
Composts*boscalid*rate	0.1524	0.2341	0.2841	0.1264	0.2541	0.3681	0.1547	0.2598

[1]Source – ANOVA using type III sums of squares of the SAS version 9.3 proc mixed procedure
[2]P values – significance at $P \leq 0.05$

Table 21. Symptomless foliage of dollar spot in Sea Isle Supreme seashore paspalum plots following monthly applications of four different composts, SCU, and boscalid.

	Symptomless Foliage (%)							
Treatments	21 April	27 May	24 June	29 July	26 Aug.	30 Sept.	28 Oct.	11 Nov.
NTC[1]	40.0 d[2]	37.0 d	30.0 d	40.0 d	43.0 d	37.0 d	34.0 d	30.0 d
Sod Pro[3]	59.0 c	50.0 c	56.0 c	53.0 c	53.0 c	50.0 c	50.3 c	49.0 c
Carbon Peat	55.0 c	58.5 c	55.0 c	50.0 c	59.0 c	55.0 c	59.6 c	48.0 c
Foothills	59.0 c	53.0 c	53.0 c	59.0 c	56.0 c	58.0 c	55.8 c	45.0 c
Farm Meal	56.0 c	56.0 c	50.0 c	51.0 c	55.0 c	54.0 c	59.0 c	50.0 c
SCU[4]	82.0 b	80.0 b	81.0 b	80.0 b	86.0 b	82.0 b	80.0 b	83.0 b
Sod Pro + boscalid A[5]	94.0 a	94.0 a	94.0 a	94.0 a	96.0 a	93.0 a	96.0 a	97.0 a
Carbon Peat + boscalid A	93.0 ab	94.0 a	97.0 a	98.0 a	96.0 a	94.0 a	94.0 a	90.0 ab
Foothills + boscalid A	95.0 a	93.0 a	94.0 a	95.0 a	95.0 a	94.0 a	97.0 a	95.0 a
Farm Meal + boscalid A	93.0 a	90.0 ab	93.0 a	94.0 a	96.0 a	93.0 a	94.0 a	93.0 a
SCU + boscalid A	97.0 a	100.0 a	100.0 a	95.0 a	100.0 a	100.0 a	96.0 a	100.0 a
Sod Pro + boscalid B[7]	97.0 a	96.0 a	100.0 a	100.0 a	100.0 a	97.0 a	100.0 a	100.0 a
Carbon Peat + boscalid B	96.0 a	100.0 a	96.0 a	100.0 a	99.0 a	97.0 a	99.0 a	100.0 a
Foothills + boscalid B	96.0 a	100.0 a	100.0 a	95.0 a	98.0 a	100.0 a	100.0 a	100.0 a
Farm Meal + boscalid B	100.0 a	94.0 a	99.0 a	100.0 a	100.0 a	100.0 a	99.0 a	97.0 a
SCU + boscalid B	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a
boscalid A	90.0 ab	93.0 a	91.0 ab	95.0 a	96.0 a	91.0 ab	90.0 ab	92.0 ab
boscalid B	95.0 a	97.0 a	94.0 a	96.0 a	100.0 a	95.0 a	100.0 a	95.0 a

[1] NTC – non-treated control
[2]Within a column, values followed by the same letter are not significantly different $\alpha = 0.05$.
[3]Compost treatments – applied at 2500 kg ha^{-1}
[4]SCU – sulfur-coated urea applied at 25 kg N ha^{-1}
[5]A – boscalid applied at 71 kg ai ha^{-1}
[6]B – boscalid applied at 98 kg ai ha^{-1}

Table 22. Dollar spot counts in Sea Isle Supreme seashore paspalum plots following monthly applications of four different composts, SCU, and boscalid.

	Infection Center Counts							
Treatments	21 April	27 May	24 June	29 July	26 Aug.	30 Sept.	28 Oct.	11 Nov.
NTC[1]	40.3 a[2]	51.2 a	55.0 a	40.3 a	33.0 a	52. 3 a	60.2 a	70.0 a
Sod Pro[3]	28.3 b	31.3 b	36.4 b	29.4 b	20.2 b	31. 4 b	45.0 b	53.0 b
Carbon Peat	29.1 b	29.8 b	40.0 b	30.1 b	21.3 b	30.4 b	43.3 b	49.0 b
Foothills	25.3 b	28.5 b	32.4 b	26.2 b	22.5 b	32.9 b	46.5 b	53.0 b
Farm Meal	29.3 b	34.7 b	43.0 b	30.3 b	21.9 b	31.7 b	41.7 b	49.3 b
SCU[4]	11.3 c	8.5 c	15.3 c	12.0 c	13.0 c	16.2 c	19.2 c	22.1 c
Sod Pro + boscalid A[5]	2.4 d	2.4 d	6.0 d	2.3 d	1.5 d	3.1 d	2.0 d	4.6 d
Carbon Peat + boscalid A	3.1 d	4.3 d	4.1 d	2.9 d	1.4 d	3.5 d	3.0 d	4.9 d
Foothills + boscalid A	2.1 d	3.6 d	3.0 d	2.0 d	2.0 d	2.5 d	3.0 d	3.5 d
Farm Meal + boscalid A	3.4 d	2.9 d	4.0 d	3.5 d	0.0 d	2.1 d	2.0 d	3.9 d
SCU + boscalid A	2.1 d	3.2 d	1.2 d	2.0 d	0.0 d	0.0 d	2.5 d	0.0 d
Sod Pro + boscalid B[6]	1.5 d	2.0 d	2.3 d	1.7 d	0.0 d	0.5 d	0.0 d	0.0 d
Carbon Peat + boscalid B	1.0 d	3.1 d	0.0 d	1.5 d	1.8 d	1.2 d	0.0 d	0.4 d
Foothills + boscalid B	1.3 d	3.2 d	2.0 d	1.4 d	0.0 d	0.0 d	0.0 d	1.4 d
Farm Meal + boscalid B	0.0 d	0.6 d	0.0 d	0.9 d	0.4 d	0.3 d	0.0 d	2.5 d
SCU + boscalid B	0.0 d	3.0 d	0.0 d	0.5 d	0.0 d	0.0 d	0.0 d	0.0 d
boscalid A	5.4 d	2.6 d	5.0 d	5.6 d	3.5 d	4.1 d	5.1 d	3.1 d
boscalid B	4.2 d	2.1 d	3.0 d	4.3 d	2.3 d	0.0 d	0.0 d	2.7 d

[1] NTC – non-treated control
[2]Within a column, values followed by the same letter are not significantly different $\alpha = 0.05$.
[3]Compost treatments – applied at 2500 kg ha^{-1}
[4]SCU – sulfur-coated urea applied at 25 kg N ha^{-1}
[5]A – boscalid applied at 71 kg ai ha^{-1}
[6]B – boscalid applied at 98 kg ai ha^{-1}

Table 23. Turf quality in Sea Isle Supreme seashore paspalum plots following monthly applications of four different composts, SCU, and boscalid.

Treatments	Turf Quality (1 – 9 scale)[1]							
	21 April	27 May	24 June	29 July	26 Aug.	30 Sept.	28 Oct.	11 Nov.
NTC[2]	3.9 c[3]	4.0 c	4.2 c	4.3 c	4.2 c	3.0 c	3.3 c	3.0 c
Sod Pro[4]	4.0 c	4.3 c	3.9 c	4.6 c	4.4 c	3.2 c	3.5 c	3.2 c
Carbon Peat	4.1 c	4.0 c	3.9 c	4.1 c	3.5 c	3.5 c	3.2 c	3.0 c
Foothills	4.0 c	4.3 c	4.0 c	3.6 c	3.9 c	3.2 c	3.3 c	3.1 c
Farm Meal	3.7 c	3.9 c	4.1 c	3.8 c	3.6 c	3.8 c	3.5 c	3.1 c
SCU[5]	7.0 a	7.5 a	7.3 a	7.5 a	7.0 a	6.5 a	6.6 a	6.4 ab
Sod Pro + boscalid A[6]	5.6 b	5.8 b	5.7 b	5.8 b	5.8 b	5.5 b	5.5 b	5.2 b
Carbon Peat + boscalid A	5.8 b	5.4 b	5.5 b	5.7 b	5.8 b	5.7 b	5.5 b	5.0 b
Foothills + boscalid A	5.6 b	5.4 b	5.5 b	5.6 b	5.8 b	5.6 b	5.3 b	5.5 b
Farm Meal + boscalid A	5.9 b	5.4 b	5.7 b	5.5 b	5.3 b	5.8 b	5.8 b	5.7 b
SCU + boscalid A	7.5 a	7.3 a	7.5 a	8.0 a	7.5 a	6.8 a	7.0 a	7.0 a
Sod Pro + boscalid B[7]	5.5 b	5.9 b	5.8 b	5.9 b	5.5 b	5.8 b	5.7 b	5.1 b
Carbon Peat + boscalid B	5.4 b	5.8 b	5.7 b	5.9 b	5.5 b	5.4 b	5.8 b	5.5 b
Foothills + boscalid B	5.7 b	5.8 b	5.6 b	5.3 b	5.8 b	5.6 b	5.5 b	5.4 b
Farm Meal + boscalid B	5.8 b	5.9 b	5.9 b	5.8 b	5.5 b	5.6 b	5.9 b	5.5 b
SCU + boscalid B	7.4 a	7.7 a	7.5 a	8.0 a	7.9 a	7.0 a	7.0 a	7.0 a
boscalid A	5.8 b	5.6 b	5.5 b	5.5 b	5.8 b	5.0 b	5.3 b	5.1 b
boscalid B	5.6 b	5.8 b	5.8 b	5.8 b	5.9 b	5.4 b	5.8 b	5.4 b

[1]Turf quality – 1 = poor quality of dead turf and 9 = high quality or healthy turf, 6 was considered minimally acceptable
[2]NTC – non-treated control
[3]Within a column, values followed by the same letter are not significantly different $\alpha = 0.05$.
[4]Compost treatments – applied at 2500 kg ha^{-1}
[5]SCU – sulfur-coated urea applied at 25 kg N ha^{-1}
[6]A – boscalid applied at 71 kg ai ha^{-1}
[7]B – boscalid applied at 98 kg ai ha^{-1}

Table 24. Turf color in Sea Isle Supreme seashore paspalum plots following monthly applications of four different composts, SCU, and boscalid.

	Turf Color (1 – 9 scale)[1]							
Treatments	21 April	27 May	24 June	29 July	26 Aug.	30 Sept.	28 Oct.	11 Nov.
NTC[2]	3.1 c[3]	3.5 c	3.5 c	3.6 c	3.4 c	3.3 c	3.6 c	3.1 c
Sod Pro[4]	3.0 c	3.6 c	3.2 c	3.8 c	3.7 c	3.6 c	3.4 c	3.3 c
Carbon Peat	3.2 c	3.5 c	3.8 c	3.9 c	3.3 c	3.1 c	3.7 c	3.8 c
Foothills	3.1 c	3.9 c	3.5 c	3.7 c	3.8 c	3.5 c	3.4 c	3.7 c
Farm Meal	3.2 c	3.5 c	3.0 c	3.9 c	3.0 c	3.8 c	3.5 c	3.0 c
SCU[5]	7.0 a	7.5 a	7.5 a	7.0 a	7.0 a	7.5 a	6.5 a	6.5 a
Sod Pro + boscalid A[6]	5.3 b	5.5 b	5.3 b	5.9 b	5.1 b	5.4 b	5.4 b	5.3 b
Carbon Peat + boscalid A	5.7 b	5.8 b	5.6 b	5.5 b	5.5 b	5.8 b	5.5 b	5.5 b
Foothills + boscalid A	5.4 b	5.4 b	5.2 b	5.9 b	5.0 b	5.0 b	5.6 b	5.3 b
Farm Meal + boscalid A	5.6 b	5.5 b	5.5 b	5.6 b	4.9 b	5.5 b	5.4 b	5.5 b
SCU + boscalid A	7.3 a	8.0 a	8.0 a	7.3 a	7.5 a	7.5 a	7.0 a	6.5 a
Sod Pro boscalid B[7]	5.5 b	5.6 b	5.5 b	5.8 b	5.2 b	5.5 b	5.6 b	5.4 b
Carbon Peat + boscalid B	5.6 b	5.8 b	5.2 b	5.6 b	5.3 b	5.9 b	5.5 b	5.3 b
Foothills + boscalid B	5.2 b	5.5 b	5.3 b	5.6 b	5.1 b	5.5 b	5.1 b	5.4 b
Farm Meal + boscalid B	5.5 b	5.9 b	5.7 b	5.5 b	5.0 b	5.6 b	5.5 b	5.1 b
SCU + boscalid B	7.5 a	8.0 a	8.0 a	7.5 a	7.5 a	7.5 a	7.0 a	6.5 a
boscalid A	5.0 b	5.5 b	5.4 b	5.0 b	5.9 b	5.0 b	5.7 b	5.2 b
boscalid B	5.1 b	5.8 b	5.8 b	5.9 b	5.8 b	5.4 b	5.5 b	5.1 b

[1]Turf color – 1 = poor quality of dead turf and 9 = high quality or healthy turf, 6 was considered minimally acceptable
[2]NTC – non-treated control
[3]Within a column, values followed by the same letter are not significantly different $\alpha = 0.05$.
[4]Compost treatments – applied at 2500 kg ha^{-1}
[5]SCU – sulfur-coated urea applied at 25 kg N ha^{-1}
[6]A – boscalid applied at 71 kg ai ha^{-1}
[7]B – boscalid applied at 98 kg ai ha^{-1}

Table 25. Digital color analysis in Sea Isle Supreme seashore paspalum plots following monthly applications of four different composts, SCU and boscalid, (24 April 2011).

Treatments	Hue[1](Degrees)	Saturation[2](%)	Brightness[3](%)	DGCI[4]
NTC[5]	75.67 c[6]	50.56 a	63.46 a	0. 41 c
Sod Pro[7]	74.67 c	52.45 a	64.45 a	0.41 c
Carbon Peat	73.55 c	52.64 a	63.56 a	0.40 c
Foothills	75.56 c	51.87 a	63.55 a	0.40 c
Farm Meal	76.55 c	53.98 a	64.56 a	0.40 c
SCU[8]	85.56 a	42.86 c	58.12 c	0.52 a
Sod Pro + boscalid A[9]	83.26 b	47.78 b	61.98 b	0.44 b
Carbon Peat + boscalid A	83.12 b	47.98 b	61.88 b	0.46 b
Foothills + boscalid A	82.56 b	48.23 b	61.55 b	0.46 b
Farm Meal + boscalid A	81.89 b	48.55 b	60.98 b	0.45 b
SCU + boscalid A	86.78 a	43.69 c	57.65 c	0.50 a
Sod Pro boscalid B[10]	81.25 b	48.45 b	60.34 b	0.45 b
Carbon Peat + boscalid B	82.45 b	47.35 b	62.65 b	0.45 b
Foothills + boscalid B	82.34 b	47.44 b	62.77 b	0.45 b
Farm Meal + boscalid B	82.45 b	47.46 b	61.92 b	0.46 b
SCU + boscalid B	86.69 a	42.93 c	58.78 c	0.51 a
boscalid A	82.75 b	46.24 b	61.78 b	0.46 b
boscalid B	83.56 b	47.56 b	62.55 b	0.45 b

[1]0° = red, 60° = yellow, 120° = green, 180° = cyan, 240° = blue, and 300° = magenta
[2]0% = gray and 100% = white
[3]0% = black and 100% = white
[4]Dark green color index: DGCI = [(Hue – 60)/(60 + (1- Saturation) + (1 – Brightness)]/3
[5]NTC – non-treated control
[6] Within a column, values followed by the same letter are not significantly different $\alpha = 0.05$.
[7]Compost treatments – applied at 2500 kg ha^{-1}
[8]SCU – sulfur-coated urea applied at 25 kg N ha^{-1}
[9] A – boscalid applied at 71 kg ai ha^{-1}
[10] B – boscalid applied at 98 kg ai ha^{-1}

Table 26. Digital color analysis in Sea Isle Supreme seashore paspalum plots following monthly applications of four different composts, SCU and boscalid, (24 June 2011).

Treatments	Hue[1] (Degrees)	Saturation[2] (%)	Brightness[3] (%)	DGCI[4]
NTC[5]	72.56 c[6]	51.36 a	62.16 a	0. 45 c
Sod Pro[7]	71.57 c	51.35 a	61.55 a	0.44 c
Carbon Peat	73.15 c	50.54 a	62.54 a	0.42 c
Foothills	71.36 c	51.11 a	61.95 a	0.44 c
Farm Meal	72.45 c	51.18 a	62.06 a	0.41 c
SCU[8]	83.46 a	40.76 c	54.32 c	0.54 a
Sod Pro + boscalid A[9]	77.36 b	45.88 b	58.78 b	0.49 b
Carbon Peat + boscalid A	78.32 b	46.48 b	58.48 b	0.48 b
Foothills + boscalid A	77.46 b	46.22 b	57.99 b	0.48 b
Farm Meal + boscalid A	77.19 b	45.45 b	56.88 b	0.47 b
SCU + boscalid A	84.58 a	39.19 c	57.15 c	0.55 a
Sod Pro boscalid B[10]	76.95 b	45.15 b	57.34 b	0.48 b
Carbon Peat + boscalid B	78.15 b	46.25 b	55.15 b	0.46 b
Foothills + boscalid B	77.14 b	45.14 b	56.87 b	0.47 b
Farm Meal + boscalid B	76.98 b	44.96 b	57.82 b	0.48 b
SCU + boscalid B	83.19 a	40.83 c	53.58 c	0.56 a
boscalid A	77.35 b	45.14 b	56.88 b	0.44 b
boscalid B	76.16 b	45.66 b	57.45 b	0.45 b

[1] 0° = red, 60° = yellow, 120° = green, 180° = cyan, 240° = blue, and 300° = magenta
[2] 0% = gray and 100% = white
[3] 0% = black and 100% = white
[4] Dark green color index: DGCI = [(Hue – 60)/(60 + (1- Saturation) + (1 – Brightness)]/3
[5] NTC – non-treated control
[6] Within a column, values followed by the same letter are not significantly different $\alpha = 0.05$
[7] Compost treatments – applied at 2500 kg ha^{-1}
[8] SCU – sulfur-coated urea applied at 25 kg N ha^{-1}
[9] A – boscalid applied at low-rate (71 kg ai ha^{-1})
[10] B – boscalid applied at high-rate (98 kg ai ha^{-1})

Table 27. Digital color analysis in Sea Isle Supreme seashore paspalum plots following monthly applications of four different composts, SCU and boscalid, (30 September 2011).

Treatments	Hue[1] (Degrees)	Saturation[2] (%)	Brightness[3] (%)	DGCI[4]
NTC[5]	75.18 c[6]	52.43 a	64.16 a	0. 44 c
Sod Pro[7]	74.25 c	53.15 a	63.13 a	0.40 c
Carbon Peat	73.12 c	54.54 a	64.71 a	0.42 c
Foothills	75.35 c	52.37 a	63.48 a	0.44 c
Farm Meal	76.66 c	53.15 a	64.12 a	0.41 c
SCU[8]	86.46 a	41.56 c	57.99 c	0.56 a
Sod Pro + boscalid A[9]	82.96 b	47.58 b	61.12 b	0.42 b
Carbon Peat + boscalid A	83.52 b	46.88 b	61.56 b	0.46 b
Foothills + boscalid A	83.06 b	47.93 b	62.00 b	0.43 b
Farm Meal + boscalid A	82.89 b	48.41 b	61.58 b	0.44 b
SCU + boscalid A	87.18 a	42.59 c	57.15 c	0.54 a
Sod Pro boscalid B[10]	82.35 b	48.15 b	61.46 b	0.43 b
Carbon Peat + boscalid B	81.45 b	47.95 b	61.95 b	0.47 b
Foothills + boscalid B	81.94 b	48.04 b	62.56 b	0.46 b
Farm Meal + boscalid B	81.15 b	48.06 b	61.13 b	0.44 b
SCU + boscalid B	88.99 a	41.83 c	58.43 c	0.55 a
boscalid A	83.45 b	46.99 b	62.58 b	0.45 b
boscalid B	82.66 b	48.16 b	62.43 b	0.44 b

[1] 0° = red, 60° = yellow, 120° = green, 180° = cyan, 240° = blue, and 300° = magenta
[2] 0% = gray and 100% = white
[3] 0% = black and 100% = white
[4] Dark green color index: DGCI = [(Hue – 60)/(60 + (1- Saturation) + (1 – Brightness)]/3
[5] NTC – non-treated control
[6] Within a column, values followed by the same letter are not significantly different $\alpha = 0.05$
[7] Compost treatments – applied at 2500 kg ha^{-1}
[8] SCU – sulfur-coated urea applied at 25 kg N ha^{-1}
[9] A – boscalid applied at 71 kg ai ha^{-1}
[10] B – boscalid applied at 98 kg ai ha^{-1}

Table 28. Severity of dollar spot in spring 2012 from over-wintering inoculum of *S. homoeocarpa* in Sea Isle Supreme seashore paspalum plots following monthly applications of four different composts, SCU, and boscalid in 2011.

	Dollar Spot Infection (%)		
	24 March	31 March	7 April
Treatments	2012		
NTC[1]	52.0 a[2]	58.0 a	57.0 a
Sod Pro[3]	39.0 b	45.0 b	45.0 b
Carbon Peat	38.0 b	48.0 b	48.0 b
Foothills	37.0 b	44.0 b	50.0 b
Farm Meal	38.0 b	46.0 b	48.0 b
SCU[4]	15.0 c	19.0 c	20.0 c
Sod Pro + boscalid A[5]	15.0 c	16.0 c	19.0 c
Carbon Peat + boscalid A	19.0 c	18.0 c	16.0 c
Foothills + boscalid A	12.0 c	16.0 c	18.0 c
Farm Meal + boscalid A	15.0 c	16.0 c	16.0 c
SCU + boscalid A	0.0 d	2.0 d	5.0 a
Sod Pro + boscalid B[6]	17.0 c	17.0 c	20.0 c
Carbon Peat + boscalid B	15.0 c	20.0 c	20.0 c
Farm Meal + boscalid B	14.0 c	14.0 c	18.0 c
SCU + boscalid B	0.0 d	2.0 d	1.0 a
boscalid A	15.0 c	17.0 c	21.0 c
boscalid B	15.0 c	18.0 c	19.0 c

[1]NTC – non-treated control
[2] Within a column, values followed by the same letter are not significantly different $\alpha = 0.05$.
[3]Compost treatments – applied at 2500 kg ha^{-1}
[4]SCU- sulfur-coated urea applied at 25 kg N ha^{-1}
[5]boscalid A - boscalid applied at 71 kg ai ha^{-1}
[6]boscalid B – boscalid applied at 98 kg ai ha^{-1}

CHAPTER 5

DISCUSSION

SR-1020 bentgrass and Sea Isle Supreme paspalum were top-dressed with four different sources of compost March through November 2011. Both studies were effective in identifying compost as a potential suppressant to dollar spot on cool- and warm-season turfgrasses in Georgia. Previous studies conducted in different regions of the United States (i.e. northeast and northwest) also reported reductions in dollar spot following applications of composts (Nelson and Craft, 1992, Boulter et al., 2002). Plots treated with compost alone significantly suppressed dollar spot compared to the NTC and gave more than 55% symptomless foliage during disease outbreaks. Results from this study support previous findings that composts can suppress dollar spot when applied preventatively as top-dressings on golf course putting greens and fairways (Nelson and Craft, 1992; Hoitink et al., 1993; Davis and Dernoeden, 2002). Nelson and Craft (1992) reported that creeping bentgrass plots treated with different compost sources significantly suppressed dollar spot disease development and gave over 60% control. Boulter et al. (2002) reported that 5 different composted materials applied every 3 weeks reduced dollar spot severity on creeping bentgrass compared to the NTC. Similar to these studies, Liu et al. (1995) reported reductions in dollar spot severity in bermudagrass plots following preventative compost applications. A common trend among all these studies revealed very few differences in dollar spot suppression among the various composted sources. Data suggest that compost producers could add many different composted sources to their products without altering control. In support of this claim, Hoitink (1980) suggested that many components within composts including antagonistic microorganisms, nutrient supply, antibiosis, production of lytic and other extracellular enzymes and compounds are responsible for disease suppression.

Plots treated with compost alone did not result in acceptable symptomless foliage (i.e. > 80%) at either location during the study. However, acceptable symptomless foliage was observed in plots treated with compost + boscalid. It is important to note that plots treated with multiple compost applications along with recommended low-rate fungicide applications provided acceptable symptomless foliage.

Microbial counts were a useful technique for enumerating bacteria and fungi for evaluation as potential antagonists to dollar spot (Table 3). Greenhouse experiment 2 revealed that bentgrass treated with non-sterilized compost had significantly less dollar spot compared to bentgrass treated with sterilized compost 30 DAT. These results revealed that a microbial component within composts may be partially responsible for some disease suppression. Previous studies have also considered microbial activity in composts to be crucial in suppressive media (Davis et al., 1992; Nelson and Craft, 1992; Beffa et al., 1996b). Interestingly, sterilized compost had improved disease suppression compared to the NTC at 30 DAT. In a similar study, O'Neill (1982) reported that a sterilized composted municipal sludge was effective in suppressing brown patch (*Rhizoctonia* spp.) on tall fescue. These results support the hypothesis that composts may have more than one mode of action for suppression of turfgrass pathogens.

Greenhouse and field studies revealed that synthetic nitrogen treatments (i.e. SCU, ammonium sulfate, calcium nitrate) provided greater symptomless foliage and resulted in higher turfgrass quality and color ratings compared to all compost treatments. Compost and synthetic N treatments were not applied at a standardized N rate because of the low N levels in composts (Table 1). Excessively high levels of composts would need to be applied to provide an equivalent amount of N, and would have resulted in an unrealistic application on golf course putting greens and fairways (APPENDIX C). However, the objective of this study was not to investigate the influence of nitrogen from compost for dollar spot suppression. Composts are complex containing a myriad of microorganisms, organic constituents, and are more than mere nitrogen carriers (Nelson and Craft, 1992). Future research could potentially evaluate applying equivalent N rates at sites (i.e. sports fields, commercial properties, or home lawns) where it may be more applicable to apply higher rates of composts (i.e. > 2500 kg ha^{-1}).

Compost offers an innovative approach to turfgrass disease management. However, most golf course superintendents have not incorporated compost into their daily management routines (Nelson and Craft, 1992; Liu et al., 1995; Craft and Nelson, 1996; Nelson, 1996; Landchoot and McNitt, 1997; Boulter et al., 1999, Garling et al., 1999). One of the main concerns of using compost amendments in this way, particularly on sand based putting greens is adding large amounts of organic matter that can potentially clog pores and interfere with the drainage properties of the root zone profile (Nelson and Boehm, 2002). Another reason for this lack of acceptance is the inherent variability in physical and chemical characteristics of compost. For example, compost producers have yet to established specific guidelines for characteristics such as appearance, odor, moisture content, trace metal content, pathogen and weed contamination, and fertility values of composts (Landschoot and McNitt, 1994; He et al., 1992). It is also difficult to determine the suppressive capabilities of compost because of inconsistencies in turfgrass responses within batches of the same compost source and among different sources (Garling and Boehm, 2001). These are just a few reasons why golf course superintendents have continued to rely on inorganic fertilizers, pesticides, and cultural management practices for the control of dollar spot (Landschoot and McNitt, 1997; Garling and Boehm, 2001).

Although compost top-dressings can suppress dollar spot on golf course putting greens and fairways, it is unlikely that it will completely replace commercial fungicides and fertilizers (Boulter et al., 2001). However, composts may become a useful addition to cultural control procedures used in turfgrass disease management programs on golf courses that wish to reduce dependency on chemical inputs. Results from this study indicate there is opportunity for compost materials to be incorporated into the turfgrass canopy for disease suppression and potentially mitigate pesticide use.

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APPENDIX

A. ENVIRONMENTAL DATA FOR CATEECHEE LOCATION 2011

Date	Max Temp. (°C)	Min. Temp. (°C)	Rain (cm)	Soil Temp. (°C)
15 March	12.0	6.8	2.6	12.4
8 April	26.2	13.2	0.0	18.5
13 May	31.8	16.4	0.0	26.8
10 June	34.3	18.2	0.0	30.7
15 July	36.2	20.6	0.0	28.5
19 Aug.	34.7	19.7	0.0	32.0
25 Sept.	30.4	14.8	0.0	25.8
21 Oct.	17.4	3.7	0.0	13.8
18 Nov.	14.0	-3.8	0.0	11.2

B. ENVIRONMENTAL DATA FOR GRIFFIN LOCATION 2011

Date	Max Temp. (°C)	Min. Temp. (°C)	Rain (cm)	Soil Temp. (°C)
31 March	15.3	6.6	0.0	14.1
21 April	28.1	15.5	0.0	19.1
27 May	28.2	17.8	0.0	23.1
24 June	32.5	19.6	1.3	26.2
29 July	32.5	21.6	0.0	28.0
26 Aug.	36.1	20.8	0.0	27.7
30 Sept.	25.2	15.3	0.0	22.3
28 Oct.	23.9	9.6	0.8	17.5
11 Nov.	14.0	-1.2	0.0	12.1

C. INDICATING EQUIVALENT N RATE AND APPLIED COMPOST RATE

D. AVERAGE AMOUNT OF COMPOSTS REMOVED OVER THREE REPLICATIONS FOLLOWING APPLICATIONS AT THE CATEECHEE GOLF CLUB SITE.

	Weight (g)							
Treatments	8 April	13 May	10 June	15 July	19 Aug.	25 Sept.	21 Oct.	18 Nov.
Sod Pro	40.85	38.48	41.32	40.13	39.25	43.21	38.39	40.19
Carbon Peat	34.12	35.13	36.60	34.87	35.38	34.32	32.49	33.97
Foothills	38.34	37.25	39.13	35.86	38.96	36.45	37.13	39.00
Farm Meal	40.36	40.87	41.34	42.18	43.55	41.26	40.49	42.15