Influence of sand topdressing on bermudagrass thatch decomposition

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ABSTRACT

Methods to control thatch layers in mature turfgrasses have relied on sand-topdressing and/or mechanical removal. Mechanical removal of thatch through vertical mowing and aerification is effective but disruptive to playing surfaces compared to sand topdressing. As a result, many turf managers have opted to implement sand-topdressing regiments as their primary method for reducing thatch buildup. This research was conducted to 1) determine the effect of cultivar on thatch decomposition and 2) examine the effect of sand topdressing on thatch microenvironment and decomposition. Sand topdressing treatments consisting of sterilized or non-sterilized sand applied at 0.4 cm 14 d^{-1} or as a single application at 1.2 cm and an untreated control to two hybrid bermudagrasses (Cynodon dactylon L.), 'Tifway' and 'Celebration' from May to September in 2008 and 2009. At the initiation of the experiment, Celebration had twice the thatch layer of 'Tifway'. The only treatment that reduced thatch was sand applied every 14 d^{-1} reduced thatch 21% to 34% and 20% to 30% for 'Tifway' and' Celebration', respectively. In contrast, a single sand topdressing application led to net accumulations of 20% to 30% compared to accumulations of 29% to 38% increases in untreated plots. Sand applied more frequently resulted in higher microorganism populations and had no detrimental effect on turfgrass quality. Routine sand applications increased thatch relative humidity (RH) compared to untreated controls for both hybrid-bermudagrass cultivars. Laboratory experiments were conducted to examine the effect of temperature, 20 C and 30 C, and RH (80%, 90%, 95%, >99%) on 'Tifway' and 'Celebration' thatch decomposition. Increasing temperature and RH resulted in 189% to 397% increase in microbial degradation. Failure to provide adequate moisture reduced microbial activity and led to declines of 170% to 243% in decomposition when thatch was subjected to drying conditions. Because thatch tissue composition and response to changes in temperature and RH were similar between cultivars, newer more vigorous hybrid-bermudagrass such as

‘Celebration’ will require a frequent sand topdressing regiment in conjunction with mechanical removal for acceptable thatch control.

CHAPTER 1: LITERATURE REVIEW

Thatch Characteristics

Turfgrass thatch is defined as a loose intermingled organic layer of dead and living shoots, stems, and roots that develops between the green vegetation and the soil surface (Waddington 1992, Ledeboer et al. 1967). The rate at which thatch accumulates is directly proportional to the imbalance of plant tissue deposition and organic matter decomposition. Factors such as species, cultivar, environment and cultural and chemical practices will affect these processes and thus thatch development (Kerek et al. 2002).

Advantages and Disadvantages of Thatch

In general, thatch is viewed as having a negative impact on turfgrass growth. However, depending upon the turfgrass species and function as well as depth, thatch can have several benefits. Appropriate thatch levels provide better surface resiliency; increased wear tolerance, moderation of temperature fluctuations, reduced weed populations, increased pesticide degradation and support a diverse microbial population (Beard 1973, Murrary et al. 1977, Havardi 1984, Rogers and Waddington 1990, Gardner and Branham 2001). On athletic fields, thatch has been shown to act as a cushion for contact sports, an extremely important function in terms of athletic safety (Smith 1979).

An excessive thatch layer can reduce turf aesthetics, while potentially increasing disease and other pest pressures (McCarty et al. 2005). Other drawbacks include uneven playing surfaces which can increase the risk of scalping during mowing and reduce player safety (Smith 1979). Shallow rooting and fluctuations in temperature have also been noted, which have been shown to reduce turfgrass drought, heat and cold tolerances. (Murray et al. 1977, Smith 1979, White et al. 1984, McCarty et al. 2005, Volk 1972, Meinhold et al. 1973) Thatch can also lead to an excess in water holding capacity and poor infiltration rates. Once a thatch layer becomes wet it will begin to hold large amounts of water leading to decreased water movement while creating a favorable environment for disease-causing organisms, shallow rooting, and spongy turf (Harivandi 1984). Because of the various drawbacks associated with excessive thatch, turf managers must continuously implement practices to maintain thatch at acceptable levels.

Turfgrass Species And Thatching Tendency

Differences in thatch accumulation between turfgrass species and cultivars have been reported on extensively (Sherman et al. 1980, Beard 1992). Species that exhibit vigorous, prostrate growth habits produce more stem tissues, in the form of stolons and/or rhizomes, generally have greater thatch buildup (Harivandi 1984). Cool-season turfgrass species such as creeping bentgrass (*Agrostis palustris*), Kentucky bluegrass (*Poa pratensis*), and creeping red fescue (*Festuca rubra*) are more prone to thatch development compared to bunch-type turfgrasses such as tall fescue (*Festuca arundinacea*) and perennial ryegrass (*Lolium perenne*) (cites). Warm-season turfgrasses with greater thatching tendencies include bermudagrass (*Cynodon dactylon*), seashore paspalum (*Paspalum notatum*), zoysiagrass (*Zoysia japonica*), and St. Augustinegrass (*Stenotaphrum secundatum*) (Landschoot 1997). These warm-season turfgrasses have prostrate growth habits but vary in terms of thatching due to differences in plant vigor. Of course, environmental factors, cultural practices, or breeding efforts that alter turfgrass growth will impact a species' rate of thatch development.

Although the rate of thatch accumulation is largely dependent on species, composition of plant tissues is a significant factor regarding tissue degradation. Of the non-decomposed turfgrass organic matter, approximately 25% of the tissue is comprised of lignin with the remaining 75% composed of cellulose and hemicellulose compounds (Landschoot 1997, Breitenbeck et al. 1986). Tissues with higher lignin concentrations are more resistant to microbial degradation due to the imbalance of carbon and nitrogen (Mancino et al. 1993, Meinhold et al. 1973). Meinhold et al. (1973) reported a direct relationship between increasing lignin concentrations and thatch accumulation for ‘Tifgreen’ bermudagrass. Duble and Weaver (1974) confirmed Meinhold’s findings with research that showed bermudagrass maintained at a height of 25 mm compared to 6 mm had more thatch accumulation as a result of greater lignin concentrations. Therefore, turfgrass species or cultivars that produce highly concentrated lignin tissues are subject to slower degradation rates and prone to thatch accumulation.

Nitrogen Effects On Thatch Accumulation

Plant growth is greatly affected by nitrogen fertilization. Supplemental nitrogen applications enhance turfgrass growth which in turn increases sward density and tissue production (Beard 1993). If plant stem production as a result of nitrogen application outpaces organic matter decomposition, nitrogen applications can enhance thatch accumulation. In fact, it has been shown on nitrogen deficient soils that nitrogen additions slightly increased thatch accumulation (Carrow et al. 1987).

Most research examining nitrogen effects on thatch accumulation have focused on the effects of nitrogen as it pertains to plant growth and turf quality (Meinhold et al. 1973 and Smith 1979). Several studies have evaluated nitrogen fertilizer forms effects on thatch deposition. Meinhold et al. (1973) reported a 30% increase in bermudagrass thatch with higher nitrogen rates as well as differences in thatch accumulation between turfs receiving ammonium sulfate versus milorganite. They suggested the properties of Milorganite® controlled the release of nitrogen so that growth flushes exhibited by grass fertilized with water soluble nitrogen fertilizers did not occur. In a study examining nitrogen forms at various application rates, White and Dickens (1984) found sewage sludge applied at 1020 kg of N ha^{-1} yr^{-1} increased bermudagrass thatch accumulation compared to application of 580 kg of N ha^{-1} yr^{-1} ammonium nitrate. Sartain (1985) found similar results as reported by White and Dickens (1984) and Meinhold et al. (1973) regarding the slow-release N forms such as IBDU. IBDU did not contribute to bermudagrass thatch accumulation compared to fertilization using ammonium sulfate.

Kock (1978) reported fertilizers that decreased thatch pH increased thatch accumulation due to an alteration in microbial activity. Schmidt (1978) supported Kock's findings with research that showed increased thatch at pH 4 compared to pH 5. Further investigations by Potter et al. (1985) resulted in a correlation between acidifying nitrogen fertilizers, increasing fertilizer application rates, and lower earthworm populations. Thatch decomposition of Kentucky bluegrass by earthworm activity was slowed due to less favorable micro-environmental conditions, specifically lower pHs. Therefore, the impact a fertilizer has on microenvironment conditions can greatly reduce fauna decomposition.

In general, fertilization management practices to reduce thatch accumulation have focused on nitrogen rates and forms to prevent excessive turfgrass growth. In a summary of thatch studies by Waddington (1993), he suggests the totality of the research indicates increased fertilization (2x to 3x) above optimal levels do not result in greater thatch applications. However, in the case of dense, ultradwarf bermudagrasses, researchers have shown a strategy of more frequent reduced rates of nitrogen resulted in less thatch build-up compared to higher nitrogen rates applied less frequently (Hollingsworth et al. 2005). Because of the thatching tendency of these grasses, many turfgrass managers have adopted a spoon feeding type of strategy to curb thatch accumulation.

In addition to affecting plant growth, nitrogen also plays a pivotal role in organic matter decomposition. Available nitrogen within the soil and plant tissues can severely limit the activity of microbial decomposers. Lower carbon to nitrogen tissue ratios will lead to an increase in microbial degradation and thus reduced thatch amounts (Kopp et al. 2004) Plant tissues with a carbon to nitrogen ratios equal to or greater than 30:1 are considered highly resistant to microbial degradation (Camberato 2001). Therefore, depending on nitrogen status of the thatch or soil, microbial activity can benefit from supplemental nitrogen (Puhulla et al. 1999).

The effect of nitrogen on plant growth, thatch accumulation and thatch decomposition is complex. Because most turfgrass studies have focused on nitrogen as it effects plant growth, more specific studies are needed to address nitrogen effects on microbial degradation of turfgrass thatch.

Thatch Decomposition

Most thatch is decomposed by microbial activity. The rate at which organic matter is broken-down will depend on several factors such as fluctuations in microbial populations and activity as result of environment. Compared to underlying soils, thatch layers tend to provide a more desirable environment for microorganisms (Islam et al. 2004). Elliot and Des Jardins (1999) reported turfgrasses grown on sandy soils had high populations of bacteria followed by fungi and actinomyces. As discussed earlier, soil pH can have a dramatic effect on earthworms, but also greatly affects microbial activity. Microorganisms grow and perform best in environments with temperatures between 60 and 85 F, neutral to slightly basic pHs, conditions with a balance of inorganic nutrients, particularly nitrogen, air and water filled pore spacing (50-60% water holding capacity), and an abundance of organic substances (Zuberer 1997). Modification in any one of these factors can alter microbial growth and activity such as compacted and poorly structured soils that contain low amounts of microbial activity (Kerek et al. 2002, Landschoot 1997).

Another factor worth discussing is the effect of fungicides on thatch decomposition. Early research by Smiley and Craven (1978) showed chemicals with fungicidal properties affected thatch layers. Halisky et al. (1981) and Goss et al. (1980) reported greater thatch accumulation for Kentucky bluegrass and creeping bentgrass, respectively, with certain fungicides. Conversely, Meinhold (1973) found decreasing thatch levels on bermudagrass treated with fungicides. He posited that fungicides acted as a nutrient source. Other reseachers have reported changes in decomposition between leaves and stem tissues after fungicide applications (Duble and Weaver, 1974). Because many of the fungicides tested regarding thatch have been removed from the market we have no means to conduct experiments in order to determine the effectiveness of these products. Currently labeled fungicides are believed to have no effect or slightly positive effects on thatch decomposition.

Methods for Reducing Thatch

Mechanical

For most highly managed turfgrasses, thatch layers are reduced through a combination of cultural and mechanical practices. Numerous studies have shown cultural practices can remove excessive thatch or prevent the build-up of unacceptable thatch conditions (Smith 1979, Eggens 1980, Beard 1993, McCarty et al. 2005).

Mechanical thatch removal can be accomplished through core cultivation, vertical mowing, sand topdressing or a combination of these practices. Carrow et al. (1987) reported an 8% decline in 'Tifway' bermudagrass thatch with vertical mowing twice a year and a 44 to 62% decrease with sand topdressing. Dunn et al. (1981) reported decreases of 12 to 18% in thatch depth for zoysiagrass over five years with vertical mowing. Greater reductions in thatch were reported by Weston and Dunn (1985) on bermudagrass when both vertical mowing and core cultivation were implemented. Today core-aerification is used to help control thatch as well as reduce compaction.

Unfortunately, mechanical thatch removal as a means of thatch control is extremely disruptive to the turf surface. Any reduction in less disruptive mechanical methods would be desirable. (McCarty et al. 2005) As a result, there has been a greater reliance on sand topdressing as a means to control thatch. White (1984) reported that topdressing is the most effective cultural practice for controlling large amounts of thatch accumulation. Other studies have supported these findings that topdressing with sand is an extremely effective mechanical method for thatch control (Murrary et al. 1977, Turgeon 1986, McCarty 2005, Carrow et al. 1987). Today, topdressing is an integral component of many turfgrass managers thatch control programs. However, guidelines for rates of sand application, amendments to topdressing, and frequency vary greatly.

Nutritional and Chemical Effects on Thatch Accumulation

Nutrients such as calcium, potassium, and phosphorus may affect thatch accumulation or decomposition. As is the case with nitrogen, most studies evaluating these macro- and micro-nutrients have focused on plant growth. Unfortunately many of these studies have shown the addition of these nutrients have little to no effect on the rates of thatch accumulation (McCarty et al. 2005). Only under extremely deficient conditions would supplemental additions of these nutrients probably alter thatch conditions.

Methods to accelerate thatch decomposition have involved the use of chemical products such as wetting agents and introduction of micro-organisms. Loadeboer and Skogley (1967) believe thatch degradation without disrupting the soil surface would be tremendous for the turfgrass industry. Wetting agent applications, typically used for soil moisture retention, were hypothesized to help the thatch retain water for increased microbial decomposition. However, studies showed these chemicals tended to promote plant growth resulting in greater thatch accumulation or no change (Callahan et al. 1998). Other researchers have focused on supplemental microbial additions. The premise for biological application is that through the introduction of advantageous microorganisms, thatch degradation will be increased with higher decomposing microbial populations. To date most biological studies for accelerating thatch decomposition have had varied success. Gibeault et al. (1976) found no significant reduction in thatch with three biological dethatching materials. Sartain and Volk (1984), who evaluated several white-rot fungi on various turfgrass species for thatch decomposition, reported variable success dependent on fungi and grass species. In a more current study evaluating the application of the commercially available product, Thatch-X®, McCarty et al. (2005) reported Thatch-X® was an ineffective means for promoting thatch degradation when compared to more traditional methods.

Methods for Thatch Measurement

Several methods for thatch measurement have been used by researchers. Early methods focused on thatch depth, as measured from the top of the thatch layer to the soil surface, for assessing changes in thatch levels. Although this method is rather simple, it may fail to adequately describe changes in thatch composition. Other researchers have relied on digestion, loss-on-ignition, or oven-dry weights of the organic fraction as a method to more fully characterize changes within the thatch layer (Callahan et al. 1997).

In order to simplify the process, Volk (1972) developed the 'thatchmeter' for a rapid method to measure thatch conditions. This instrument was made up of a base with a lever that could be loaded over a vertical cylinder. Changes in thatch or comparisons in thatch were the depression differences between samples. The thatchmeter does appear to be accurate and much faster compared to other methods (Callahan et al. 1997). However, more studies are needed to establish reliable limits for the thatchmeter as an established method for thatch measurement. (Volk 1972)

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CHAPTER 2. THATCH DECOMPOSITION OF TWO BERMUDAGRASS CULTIVARS

Introduction

Managing turfgrass thatch, a loose intermingled organic layer of dead and living shoots, stems, and roots that develops between vegetation and the soil surface, is a continuous cultural challenge in maintaining fine warm-season turfgrasses (Ledeboer et al. 1964, McCarty et al. 2005). Excessive thatch reduces turf aesthetics and increases disease and pest pressures (McCarty et al. 2005). Other drawbacks include uneven playing surfaces that can lead to scalping and poor player safety (Smith 1979), shallow rooting; excess water holding capacity; decreased water infiltration rates, increased pesticide and nutrient binding, and greater temperature fluctuations that reduce plant drought, heat and cold tolerances. (Harivandi, 1984; Murray et al., 1977, Smith 1979, White et al, 1984, McCarty et al. 2005, Volk 1972, Meinhold et al. 1973).

Differences in thatch accumulation between turfgrass species and cultivars have been reported (Sherman et al., 1980; Beard, 1992). Warm-season turfgrass species such as bermudagrass (*Cynodon dactylon*), zoysiagrass (*Zoysia japonica*) and St. Augustine (*Stenotaphrum secundatum*) that exhibit vigorous, prostrate growth habits, in the form of stolons and/or rhizomes, are more susceptible to thatch accumulation (Harivandi 1984). Therefore, as more vigorous hybrid-bermudagrass cultivars are introduced, more intense management practices will be needed to maintain acceptable thatch levels.

Current cultural practices to reduce thatch accumulation rely on mechanical removal and/or sand topdressing regiments. Mechanical removal of thatch through vertical slicing or hollow-tine aeration has been reported as effective but disruptive to playing surfaces (Smith

1979, Eggens 1980, Beard 1993, McCarty et al. 2005). As a result, turf managers may fail to implement mechanical practices as often as required to prevent excessive thatch accumulation.

Sand topdressing, a less disruptive alternative compared to mechanical thatch removal, has been shown to be an effective cultural practice for controlling large amounts of bermudagrass thatch (White et al. 1984). Numerous studies have supported these findings showing frequent topdressing applications as one of the most effective non-mechanical methods for reducing thatch accumulation (Murrary et al. 1977, Turgeon 1986, McCarty 2005, Carrow et al. 1987). Although, sand topdressing to reduce thatch accumulation has been widely adopted by turf managers, very little research has specifically addressed the causal effect of sand to reduce thatch accumulation.

Many researchers hypothesize topdressing with sand introduces microorganisms that aid in thatch degradation; alters the micro-environment so that conditions are more conducive for higher microbial activity; or dilutes the thatch layer through the continual deposit of soil (Beard, 174). Because topdressing regiments vary greatly from turf manager to turf manager, insight into the causal effect of sand to accelerate turfgrass thatch decomposition will allow design of more efficient and effective topdressing programs. The objectives of this study were to 1) evaluate the influence of cultivar on hybrid-bermudagrass thatch decomposition 2) Determine micro-environmental effects of sand topdressing within the thatch layer 3) investigate effects of changes in micro-environmental conditions on thatch decomposition.

Materials and Methods

Site Description

Field studies in 2008 and 2009 were conducted on two mature bermudagrass cv. 'Tifway' and ‘Celebration’ swards growing on an Oliver silt loam (fine-silty, mixed, thermic, Typic Fragiudalf) soil at the Louisiana State University Agricultural Center Burden Research Station located in Baton Rouge, LA. Hybrid-bermudagrass cultivars chosen for the study represent the most commonly grown hybrid-bermudagrass, ‘Tifway’, and more recently introduced cultivar ‘Celebration’.

Each hybrid-bermudagrass cultivar was established vegetatively from sprigs at 500 bu. ha^{-1} in June 2004. General maintenance prior to and throughout the study included mowing at 2.5 cm 3 times wk^{-1} using a reel-mower, fertility of 250 kg N ha^{-1} yr^{-1} and irrigation applied as needed to prevent drought stress. No mechanical cultural practices to reduce thatch were performed between establishment and initiation of the field and laboratory experiments. Six months prior to the study all pesticide applications were ceased.

Field Experiment

In each bermudagrass cultivar, 3 m x 3 m plots received sand topdressing treatments consisting of sterilized or un-sterilized sand applied at 0.4 cm 14 d^{-1} or as a single application at 1.2 cm and an untreated control. Sand topdressing met United States Golf Association green complex specifications with 84% being a medium texture and <3% clay or silt fractions (USGA, 2004). Sterilized sand treatments were sterilized in an autoclaved (Market Forge Sterilmatic, Everett, MA) at 125 C at 7 kg cm^{-2} for 2 hours. All sand treatments were applied using a drop spreader within 1 hr post-sand sterilization with sand lightly brushed into the canopy using a flat bristled broom.

Data Collected

Thatch depth was recorded at the initiation of the study in May and again in September in 2008 and 2009. For thatch depth, cores (15 cm diameter) were harvested with thatch depth measured in mm. Turfgrass quality, a measurement of texture, color, density and uniformity, was recorded from May to September of each year using the National Turfgrass Evaluation Program (NTEP) rating scale of 1 to 9, 1 = bare soil or dead grass, 6 = acceptable quality and 9 = ideal quality.

Relative humidity was measured for 56 d beginning 15 May and ending 12 July for each year in thatch layers receiving unsterilized sand top-dressing treatments for the hybrid-bermudagrass cv ‘Celebration’. Relative humidity sensors (EM-50 datalogger, Decagon Devices Inc., Pulham, WA) were placed within the bottom third of the ‘Celebration’ thatch layer but just above the soil surface. Data was recorded daily every 60 minutes for the duration of the experiment. Both Air temperatures and precipitation were also recorded daily throughout the experiment.

In addition to RH measurements, thatch microbes were enumerated using the most probable number (MPN) technique in April and July 2009 on ‘Celebration’ hybrid-bermudagrass (Coyne and Thompson 2006). Thatch was collected 4 days after sand topdressings treatments were applied in July. One gram samples of thatch were diluted in 50 mL of phosphate buffer followed by serial dilutions. One mL of each dilution was placed on nutrient agar plates with all plate dilutions replicated three times. Plates were incubated at 22 C for 7 d before analyses. The procedure was only used to enumerate the microorganism population and did not differentiate microorganism species.

Thatch Chamber Experiments

Thatch Collection and Storage

Chamber experiments were conducted to assess temperature and RH effects on microbial decomposition of bermudagrass thatch. Microbial decomposition was measured as a function of C-CO_2 production. Bermudagrass thatch used for the experiments was collected adjacent to field trials from mature ‘Tifway’ and ‘Celebration’ bermudagrasses. Thatch was collected in May 2008 and 2009 using a vertical mower set to a depth of 5 cm. Samples were hand-shaken to remove adhering soil and debris, air-dried for 24 to 48 hrs, and placed in polyethylene bags for storage at 4 C. Five gram tissue samples for each cultivar were measured for lignin, cellulose, hemicelluloses concentrations at the LSU Agricultural Center Southeastern Research Station Forages Laboratory.

Temperature and Relative Humidity Chamber Experiment

In order to evaluate temperature and RH effects on bermudagrass thatch decomposition, 20 g of each bermudagrass cultivar was placed within desiccators containing 500 mL glycerol-water solutions at 80%, 90%, 95% or >99% RH. Glycerol-water solution ratios were adjusted to achieve each RH based on the procedures outlined in ASTM-D5032-97 (2003). Equations for the preparation of glycerol-water solutions for each RH are as follows:

$$SG = [-0.189(RH) + 19.9]^{0.0806}$$

SG: specific gravity of glycerol-water solution needed to produce specific RH

RH: Desired percent of relative humidity

$$G_w = 383\ (SG) - 383$$

G_w: % glycerol by weight in the solution

$$G_v = (G_W\ W_T)/(100 \times 1.262)$$

G_V: volume of glycerol (ml)

W_T: total weight of the solution (g)

$$H_v = [(100-G_W)W_T]/(100 \times 1.0)$$

H_V: volume of water (ml)

Incubation temperatures were 20 C and 30 C for all RH. To ensure RHs were achieved by the glycerol-water solutions, RH was recorded using humidity sensors attached to an EM-50 datalogger (Decagon Devices Inc., Pulham, WA) for 14 d (data not presented).

After 14 d acclimation to treatment environmental conditions, 1 g fresh weight thatch from each temperature and RH treatment combination were dried at 60 C for 48 hrs to determine tissue water content. Fresh weight thatch samples equivalent to 1 g dry weight from each temperature and RH combination were placed into 473 mL air-tight containers fitted with a rubber septum for periodic air sampling (Martin and Beard 1975). In each container, 50 mL glycerol-water solutions were used to maintain RH of 80%, 90%, 95% or >99%. Containers were sealed, flushed with CO_2-free air and returned to respective temperature regiments of 20 C or 30 C. Each temperature and relative humidity combination was replicated three times for a total of 48 containers each experiment.

During the 21 day incubation period, headspace was sampled every three to four days and analyzed for CO_2. Carbon dioxide was analyzed by gas chromatography (Varian 3800, Varian

Inc., Palo Alto, CA) using a 27.5 m x 0.53 mm long capillary column coated with poraplot-Q. The injector and detector temperatures were maintained at 60 C and 250 C, respectively. The gas chromatographer was calibrated using CO_2 standards purchased from Scotty's specialty gases (Scotty Gas, Plumsteadville, PA). Carbon dioxide production was calculated as the area under the curve and expressed as mg CO_2-C g biomass^{-1}. After each air sampling, glycerin-water solutions were replenished and the headspace flushed with CO_2-free air before containers were returned to respective chambers.

Wetting and Drying Cycle Experiment

A second chamber experiment was conducted to determine the effect of wetting and drying cycles on microbial decomposition of thatch. Twenty grams of thatch was acclimated to >99 % RH at 30 C in desiccators filled with the appropriate glycerol-water solution. The temperature and RH selected for these experiments were based on results from the temperature and RH experiment examining thatch decomposition.

After 14 d acclimation to treatment environmental conditions, 2 g fresh weight thatch was dried at 60 C for 48 hrs to determine tissue water content. Fresh weight thatch samples equivalent to 1 g dry weight were placed into 473 mL air-tight containers fitted with a rubber septum for air sampling every 3 d for a period of 21 d. In one-half of the thatch samples, tissue was continuously under a >99 % RH environment while the remaining samples were adjusted every 3 d to ~200 % water tissue content through the addition of water to simulate irrigation or precipitation post CO_2 sampling. Carbon dioxide was analyzed and quantified using gas chromatography as describe previously. After each sampling and tissue water content adjusted, tissues were enclosed in air-tight containers with each container's headspace flushed with CO_2-free air for 5 min before being returned to 30 C.

Data Analysis

Field data from the five sand topdressing treatments applied to two hybrid bermudagrass cultivars were arranged as a 2 x 3 factorial design with 3 replications. Data were analyzed according to the Analysis of Variance (ANOVA; α=0.05) using the mixed procedure in the statistical software SAS (SAS Institute, 2000). Post-hoc testing was performed using a Fisher's protected least significant difference (Fisher's LSD; α=0.05) with the exception of RH data that is presented graphically with standard error bars. Laboratory experiments were analyzed as completely randomized design using the general linear method in the statistical software SAS (SAS Institute, 2000). Post-hoc testing was performed using a Fisher's protected least significant difference (Fisher's LSD; α=0.05).

Results

Field Experiments

Initial thatch for 'Celebration' was generally twice that of 'Tifway' with thatch increasing over each growing season for single sand topdressing applications and untreated controls (table 2.1 and 2.2). Over the sixteen month study, untreated control thatch increased from 27 mm to 35 mm and 44 mm to 61 mm for 'Tifway' and 'Celebration', respectively, representing a 30% and 38% increase in thatch accumulation. During this same time period, sand applied every 14 d^{-1} reduced thatch 21% to 34% for 'Tifway' and 20% to 30% for 'Celebration', showing sand applications applied routinely result in the greatest amount of thatch decomposition.

Table 2.1. ANOVA table for temperature and relative humidity experiments.

Effect	Degrees of Freedom	F Value	Pr > F
Experiment	1	37.8	0.0035
Cultivar	1	2.56	0.115
Cultivar*exp	1	0.04	0.8473
Temperature	1	45.52	<.0001
Temperature*exp	1	2.3	0.135
Cultivar*temperature	1	0.92	0.3407
Cultivar*temperature*exp	1	1.23	0.2721
Relative humidity	3	34.71	<.0001
Relative humidity*exp	3	0.66	0.5818
Cultivar*relative humidity	3	1.04	0.381
Cultivar*relative humidity*exp	3	0.11	0.9559
Temperature*relative humidity	3	2.16	0.1015
Temperature*relative humidity*exp	3	1.26	0.2959
Cultivar*temperature*relative humidity	3	0.09	0.9672
Cultivar*temperature*relative humidity*exp	3	0.17	0.9188

Table 2.2. Effect of sand topdressing on thatch depth of two hybrid-bermudagrass cultivars growing in Baton Rouge, Louisiana from 2008 to 2009.

Cultivar	Treatment	Application frequency	2008				2009			
			May		September		May		September	
			Thatch depth				Thatch depth			
			------------------mm------------------				------------------mm------------------			
Tifway	Unsterilized	14 days regiment	29	a	25	a	23	b	19	c
	Sterilized	14 days regiment	28	a	26	a	23	ab	22	c
	Unsterilized	Single application	24	a	27	a	23	ab	30	ab
	Sterilized	Single application	23	a	26	a	20	b	28	b
	Untreated control		27	a	30	a	26	a	35	a
Celebration	Unsterilized	14 days regiment	41	a	42	b	39	b	33	b
	Sterilized	14 days regiment	43	a	39	b	38	b	30	b
	Unsterilized	Single application	43	a	54	a	49	a	57	a
	Sterilized	Single application	42	a	53	a	45	a	54	a
	Untreated control		44	a	49	a	44	ab	61	a

Topdressing treatments were 0.4 cm 14 $d^{-1,}$ a single application at 1.2 cm $yr^{-1,}$ or an untreated control.
Sterilized sand treatments were autoclaved at at 125 C at 7 kg cm-2 for 2 hours.

'Tifway' and 'Celebration' treatments that received single topdressing sand applications at the beginning of the study had increased thatch of 20% to 22% and 29% to 32%, respectively. Over extended periods of time single sand applications tend to leach from the thatch layer into to soil surface. Because of this leaching the sand can no longer act as an insulator for the thatch layer leading to a decrease in temperature and RH resulting in less decomposition No differences in thatch decomposition occurred between sand topdressing treatments following the same application frequency.

In 2009, microbial populations increased for all treatments with warmer temperatures in July compared to April (table 2.3). The more frequent sand topdressing regiments had higher microbial populations followed by single sand applications and untreated controls. Throughout the study sand topdressing was never detrimental to the turf (table 2.4). Therefore, turf quality data were combined over years with enhancement or detriment to turf during the growing seasons.

Measurements recorded for RH exhibited increased thatch RH shortly after sand topdressing was applied (figures 2.1 and 2.2). For all treatments a pattern of higher RH during night occurred with subsequent decreases in RH with increased temperature from solar radiation. However, sand topdressing treatments maintained higher thatch microenvironmental RHs compared to untreated controls for extended periods during first 12 h as well as achieved higher RH during early evening hours compared to untreated controls 3 days application. Within 45 d, the effects of the single sand topdressing application had dissipated with thatch RH mimicking untreated controls. Only the more frequent sand topdressing regiment was able to affect thatch at an extended period with subsequent topdressing applications.

Table 2.3. Effect of sand topdressing regiment on turfgrass quality of two hybrid-bermudagrass cultivars. Quality rating data are pooled
for 2008 and 2009.

Cultivar	Treatment	Application Frequency	Quality Rating† May		June		July		August		September	
Tifway	Unsterilized	14 days regiment	7.0	a	8.0	a	7.2	ab	7.2	a	7.0	a
	Sterilized	14 days regiment	7.2	a	7.7	a	8.0	a	7.7	a	7.0	a
	Unsterilized	Single application	7.7	a	7.7	a	7.7	a	7.0	a	7.0	a
	Sterilized	Single application	7.0	a	7.2	a	7.0	b	7.0	a	7.2	a
	Untreated control		7.2	a	7.2	a	7.7	a	7.2	a	7.0	a
Celebration	Unsterilized	14 days regiment	8.0	b	7.2	a	7.7	a	7.0	a	7.0	a
	Sterilized	14 days regiment	7.7	ab	8.0	b	7.2	a	6.7	a	7.2	a
	Unsterilized	Single application	7.2	a	7.7	ab	7.7	a	7.2	a	7.0	a
	Sterilized	Single application	7.7	ab	7.0	a	7.2	a	7.0	a	7.2	a
	Untreated control		8.0	b	7.0	a	7.2	a	7.0	a	7.2	a

† Quality ratings are based on the NTEP scale of 1 to 9; 1 = bare soil; 6 = minimally acceptable; and 9 = highest quality.

Topdressing treatments were 0.4 cm 14 $d^{-1,}$ a single application at 1.2 cm $yr^{-1,}$ or an untreated control.

Sterilized sand treatments were autoclaved at at 125 C at 7 kg cm-2 for 2 hours.

Table 2.4. Changes in microorganism populations in the thatch of 'Celebration' hybrid-bermudagrass

Cultivar	Treatment	Application frequency	2009 April		2009 July	
			MPN†			
			-------------x 10^5-------------			
Tifway	Unsterilized	14 days regiment	1.7	a	3.6	a
	Sterilized	14 days regiment	1.3	a	3.7	a
	Unsterilized	Single application	1.5	a	3.1	b
	Sterilized	Single application	1.4	a	3.2	ab
	Untreated control		1.3	a	2.7	b
Celebration	Unsterilized	14 days regiment	1.8	ab	3.4	a
	Sterilized	14 days regiment	1.6	b	3.1	a
	Unsterilized	Single application	1.5	b	3.2	a
	Sterilized	Single application	2.0	a	2.9	a
	Untreated control		1.9	a	2.4	b

† MPN is most probable number for the enumeration of microorganisms

Topdressing treatments were 0.4 cm 14 $d^{-1,}$ a single application at 1.2 cm $yr^{-1,}$ or an untreated control.
Sterilized sand treatments were autoclaved at at 125 C at 7 kg cm-2 for 2 hours.

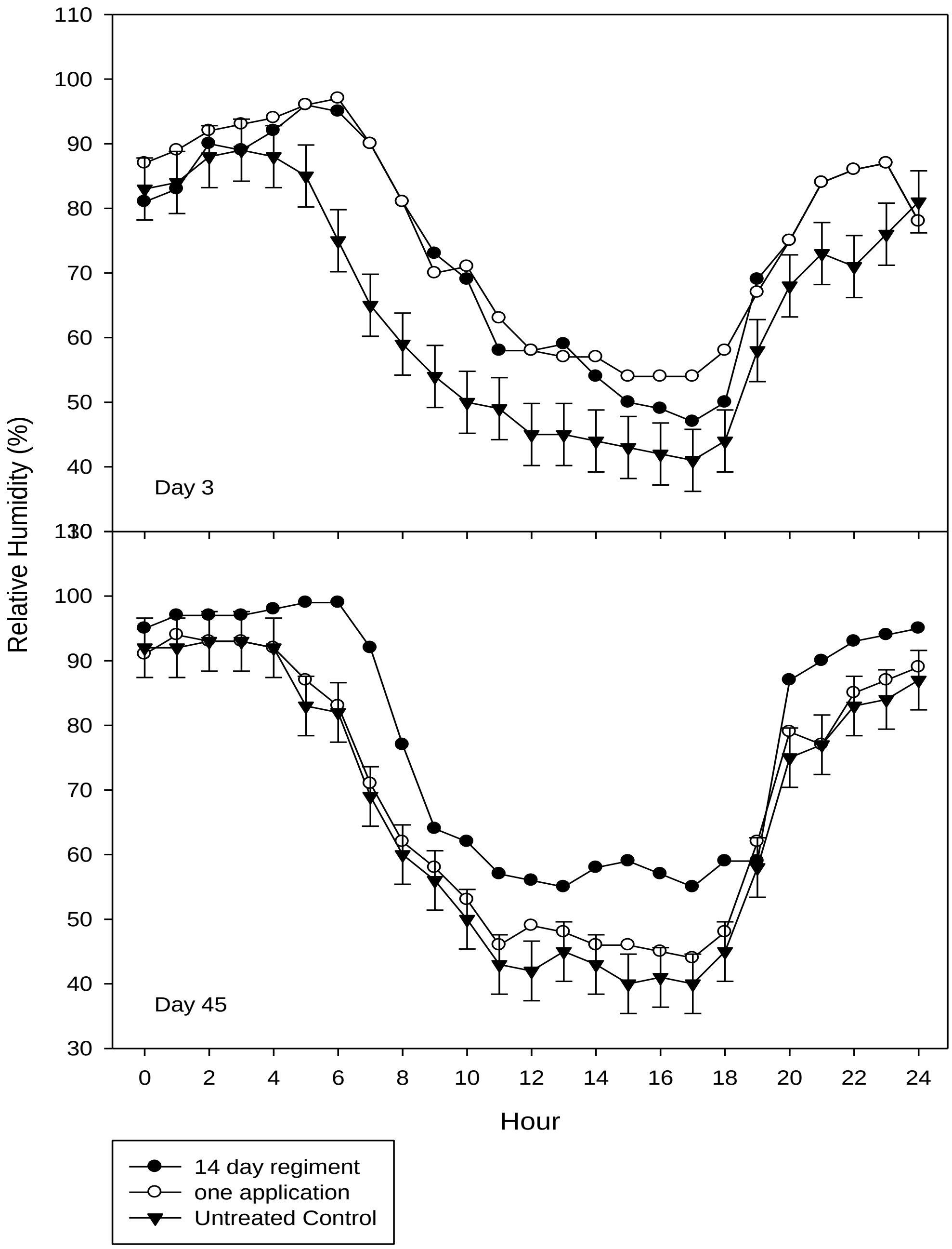

Figure 2.1. Effect of sand topdressing on thatch relative humidity of hybrid-bermudagrass cv 'Celebration' for a 24 hour periods for 15 May 2008 (day 3) and 29 June 2008 (day 45). Sand topdressing treatments included 0.4 cm 14 d^{-1}, a single application at 1.2 cm $year^{-1}$, and an untreated control were initiated 1 May 2008.

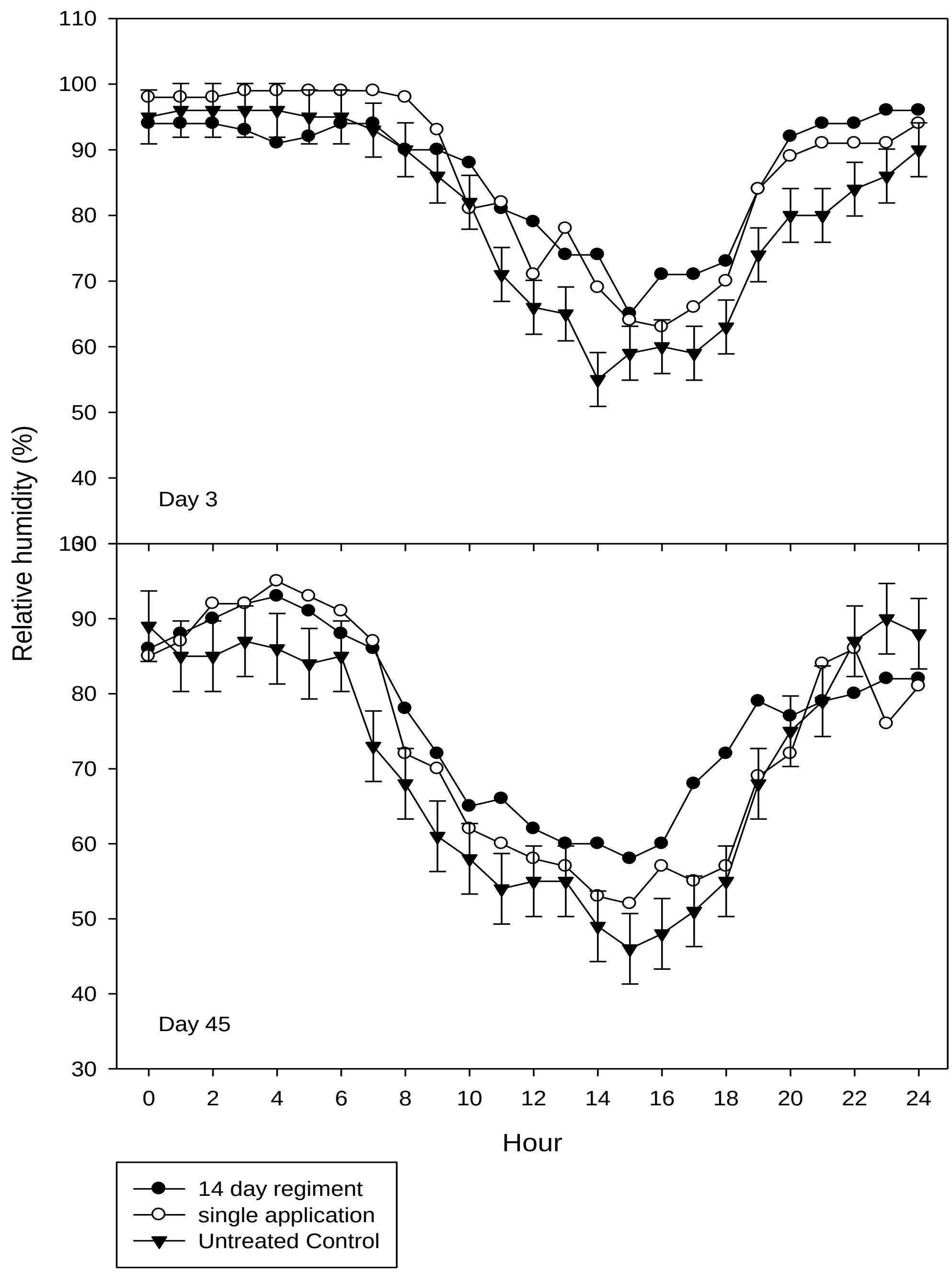

Figure 2.2 Effect of sand topdressing on thatch relative humidity of hybrid-bermudagrass cv 'Celebration' for a 24 hour periods for 15 May 2009 (day 3) and 29 June 2009 (day 45). Sand topdressing treatments included 0.4 cm 14 d^{-1}, a single application at 1.2 cm $year^{-1}$, and an untreated control were initiated 1 May 2009.

Chamber Experiments

Influence of Temperature and Relative Humidity on Thatch Decomposition

Thatch decomposition was affected by changes in RH and temperature but not bermudagrass cultivar (table 2.1). This lack of difference in thatch decomposition between cultivars may be due impart to tissue composition similarities with ranges of 38% to 41% hemicelluloses, 21% to 23% cellulose and 11% to 12% lignin across cultivars (table 2.5). However, as RH increased at each temperature regiment, cultivars exhibited a pattern of increasing thatch decomposition. Increasing RH from 80% to >99% at 30 C, resulted in 189% to 397% increase in C-CO_2 production or 34.2 to 98.9 µg C-CO_2 g biomass^{-1}and 19.7 to 98.0 µg C-CO_2 g biomass^{-1} for 'Tifway' and 'Celebration', respectively. 'Tifway' and 'Celebration' thatch at 20 C resulted in 241% to 312% or 14.8 to 60.34 µg C-CO_2 g biomass^{-1}and 15.2 to 51.8 µg C-CO_2 g biomass^{-1} for 'Tifway' and 'Celebration', respectively. (figure 2.3)

Table 2.5. Thatch tissue composition of hybrid-bermudagrass cultivars in 2008 and 2009

	May-08		May-09	
	Celebration	Tifway	Celebration	Tifway
	% Composition	% Composition	% Composition	% Composition
Hemicellulose	38.34	38.27 NS*	37.89	41.17 NS*
Cellulose	23.21	22.65 NS*	22.02	21.15 NS*
Lignin	11.64	12.52 NS*	12.47	12.86 NS*

*Not Significant

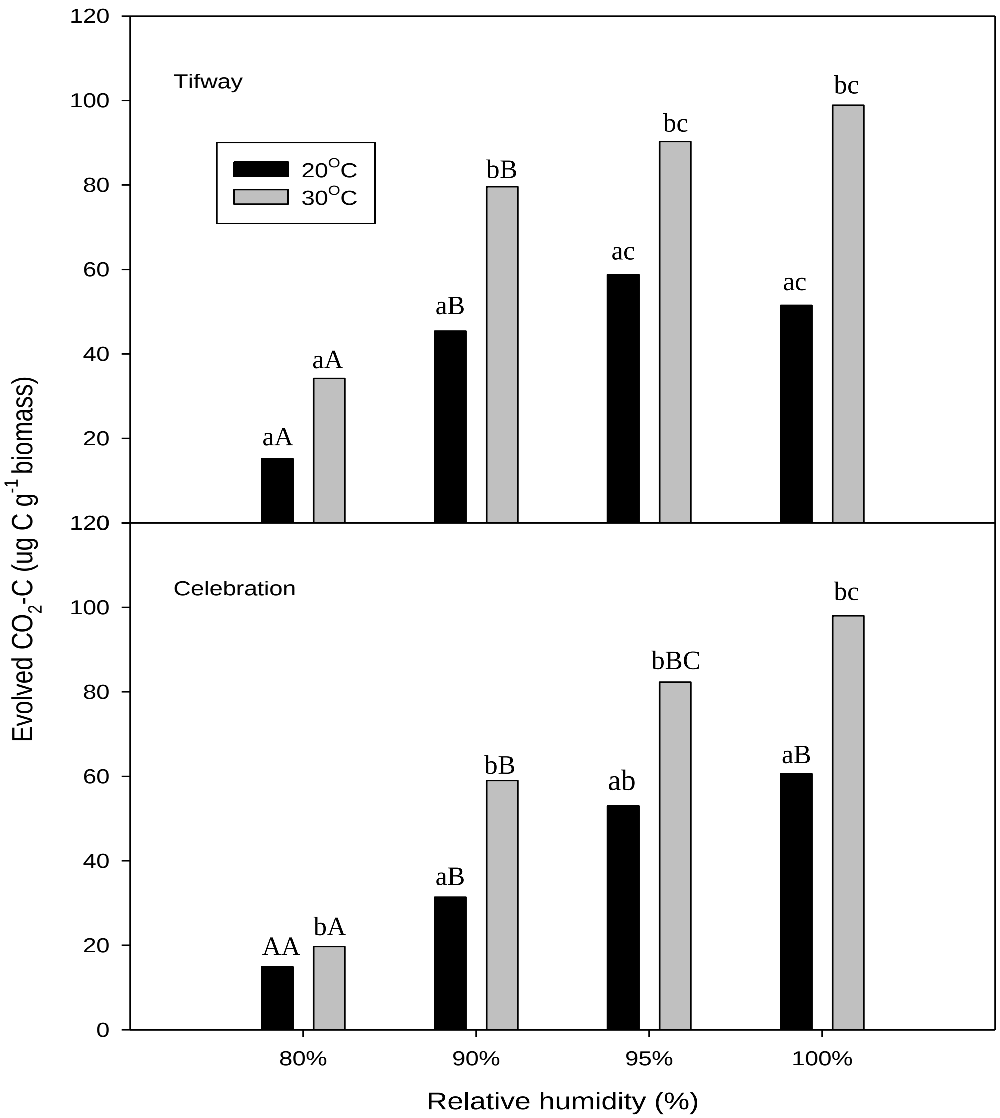

Figure 2.3. Effect of two temperatures. 20 and 30 C, and relative humidity (80%, 90%, 95%, 100%) on CO_2 evolved during hybrid-bermudagrass decomposition for 21 days in enclosed chambers.

Higher water tensions from less humid environments reduced tissue water contents as exhibited in table 2.6. As tissue water content was reduced, microbial activity was negatively affected as measured through CO_2 production.

Table 2.6. Percent Moisture of hybrid-bermudagrass thatch at four relative humidities at 20 C

Relative Humidity	Celebration			Tifway		
	Wet	Dry	Moisture	Wet	Dry	Moisture
	----------g-------		-------%-------	--------g--------		-------%-------
80%	1	0.74	26.00	1	0.71	29.00
90%	1	0.66	34.00	1	0.66	34.00
95%	1	0.60	40.00	1	0.63	37.00
>99%	1	0.49	51.00	1	0.54	46.00

Increasing temperature from 20 to 30 C affected thatch decomposition. Thatch decomposition at 30 C exhibited a pattern of greater C-CO_2 production compared to 20 C. However, the mass of C-CO_2 evolved at each RH combination at 30 C compared to 20 C were significantly higher; with the exception at 80% RH of 14.8 and 19.7 mg C-CO_2 at 20 and 30 C, respectively, for each cultivar. In general, warmer temperatures coupled with higher RH resulted in higher thatch decomposition compared to the cooler temperature and corresponding RHs.

Effects of Wetting and Drying Cycles on Thatch Decomposition

Because micro-environmental conditions fluctuate within a thatch layer, as demonstrated in the field experiments, the effect of wetting and dry cycles were examined. Hybrid-bermudagrass cultivar had no effect on thatch decomposition, but decomposition was highly influenced by interplay between tissue water content and water tension (table 2.7). Thatch maintained at a continuously high RH environment resulted in higher microbial activity (figure 2.4). Thatch tissue placed in growth chambers controlled at 30 C exhibited increases of 170% and 243% C-CO_2 evolved across hybrid-bermudagrasses compared to thatch tissues wetted every 3d and subjected to higher water tension.

Table 2.7. ANOVA table for the wet/dry cyclic experiments.

Treatment	Degrees of Freedom	F Value	Pr > F
Experiment	1	1.95	0.2349
Cultivar	1	0.72	0.4139
Cultivar*exp	1	0.01	0.9228
Wet/Dry cycle	1	18.27	0.0011
Cycle*exp	1	0.02	0.8841
Cultivar*cycle	1	1.58	0.2332
Cultivar*cycle*exp	1	0	0.8318

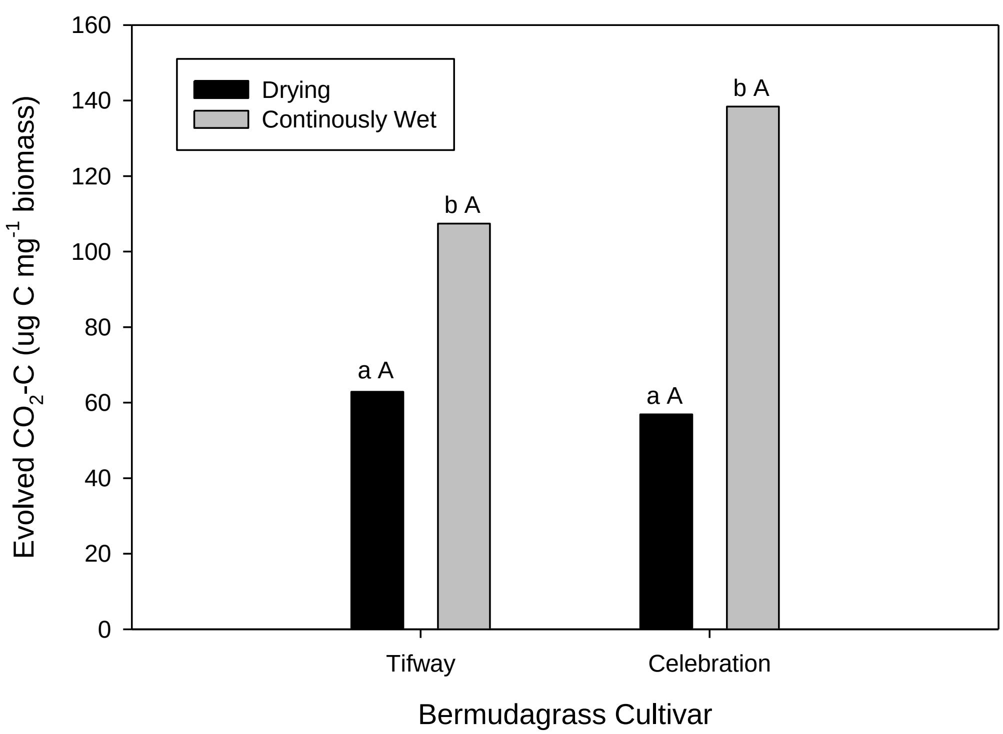

Figure 2.4. Effect of wet/dry cycle on CO_2 evolved from hybrid-bermudagrass thatch decomposition for 21 days. Drying thatch was wetted to 200% moisture content every 3 day and the continuously wet tissue was subject to >99% relative humidity.

Discussion

Concurring with previous studies evaluating sand topdressing effects on thatch decomposition, we also found sand topdressing enhanced thatch decomposition. In field trials, routine sand topdressing reduced or limited each hybrid-bermudagrass cultivars' thatch layer without compromising turf quality. White et al (1984) reported sand topdressing as the most effective method to reduce large amounts of thatch in bermudagrass for this extremely vigorous growing stoloniferious and rhizotamous turfgrass species. Several other studies have supported these findings that topdressing with sand is an extremely effective cultural practice for thatch control for various species (Murrary et al. 1977, Turgeon 1986, McCarty 2005, Carrow et al. 1987). Even though 'Celebration' had a deeper thatch layer compared to 'Tifway' at the initiation of the study, each cultivar had greater thatch decomposition occur with the more frequent sand topdressing applications compared to control or single sand applications per year. The practice of ultradwarf hybrid-bermudagrass being topdressed more frequently with light sand applications compared to heavier infrequent sand topdressings is highly recommended (McCarty and Canegallo 2005). The unsustained effects of single sand top-dressing applications to enhance microbial thatch decomposition may be due to sand particles leaching through the thatch thereby lessening sands affect on the micro-environment.

Based on thatch microenvironmental measurement of RH, more frequent applications of sand provided a more humid environment compared to the single heavier sand topdressing application and untreated control. Relative humidities were consistently higher for sand topdressing treatments compared to controls soon after application. The re-application of sand every 14 d helped to restore higher thatch RHs compared to the single sand topdressing application. Based on empirical calculations, RH of soil air at the permanent wilting point at -10

MPa at 20 C remains at 92% (Brady and Heil, 2007). Therefore, application of sand provides a mechanism in which the thatch microenvironment maintains higher RH that is more conducive for microorganism growth and higher thatch tissue water contents for greater thatch decomposition.

To examine the effects of temperature and RH on microbial thatch decomposition and tissue water content of hybrid-bermudagrass cultivars, laboratory showed higher water tensions from less humid environments reduced tissue water contents, a factor that decreased microbial activity as measured through CO_2 production. The effect of water tension was more pronounced at 30 C compared to 20 C. The positive effects of increasing temperatures and moisture on microbial decomposition have been well-documented in other biological studies especially when evaluating decomposition of leaf litter or compost (Ibrahim et al., 2010; Cisneros-Dozal et al., 2007; Howard and Howard, 1979). Microorganism populations and thus activity have been shown to be highly subject to environmental conditions (Howard and Howard, 1979). In fact, differences in temperature and RH may partially explain why stimulation of thatch decomposition by commercial available inoculums has not consistently resulted in reducing thatch.

In field studies, the effect of sand sterilization treatments indicate changes in micro-environment are sufficient to support increased activity and population increases of existing thatch microbes, and that sand applications do not appear to be a major source for microorganism introduction. Mancino et al. (1993) showed continual changes in microorganism populations and species over seasons in creeping bentgrass (Agrostis Palustrus L.) thatch and soil of a USGA built putting green. However, other factors such as pH and nutrient availability have also been reported to affect grass tissue decomposition (Beard, 1983). Potter et al (1990) reported use of nitrogen fertilizers and certain pesticides had a negative impact on earthworm activity. Therefore, failure to provide a suitable environment for degrading microorganisms and fauna not only leads to decreased microbial populations but decreased activity that equates to slower thatch decomposition.

Unlike chamber experiments that simulate constant temperature and RH environments, micro-environments within the thatch are continually changing as a result of weather and cultural practices. Therefore, the application of sand topdressing alone may not be sufficient to achieve desired thatch control. Griffin (1981) stated moisture was often the most limiting factor for microbial decomposition of organic matter. Irrigation management may have an integral role in determining the efficacy of sand to degrade thatch. Based on the wet/dry cycle chamber experiments, thatch subjected to a constant high RH environment resulted in greater decomposition compared to thatch tissue subjected to cyclic wet/dry. This suggests thatch decomposition of highly managed turfgrass is most limited by water availability. Data from the dry/wet cyclic experiments emphasize thatch environments with lower water tensions result in tissues with higher water contents and accelerated microbial degradation of thatch. In studies evaluating composting, Richard et al (2002) demonstrated how moisture could affect decomposition of various organic substrates.

Therefore, if one chooses to use sand topdressing as a means to accelerate thatch decomposition, water management will be important to maintaining thatch RH and enhancing thatch decomposition. As demonstrated in the field, RH measurements of thatch with sand demonstrates that sand only provides a media to prolong higher moisture within the thatch. Higher RH associated with applications of sand can contribute to sands ability to absorb moisture from soils. Sands finer particle size decreases pore spacing allowing for more moisture to be absorbed hence leading to a spike in RH within the thatch layer. Breitenbeck and Wells (1986) reported a 3 d lag period before microbial decomposition resumed if dry cycles were introduced during microbial decomposition. However, experiments that have attempted to provide high moisture environments in the field have not always lead to results of decreased thatch layers. Fu and Dernoeden (2008) reported thatch increased for creeping bentgrass greens maintained under a light frequent irrigation regiment compared to deep infrequent irrigation most likely due to better plant growth and higher tissue deposition.

Although we have shown the complexity of moisture and temperature have on thatch decomposition within the field and laboratory, Berndt (2008) demonstrated the ability to described hybrid-bermudagrass thatch decomposition using a double exponential model for chamber experiments held under mesophilic conditions (22-23 C). He attributed differences in decay between the two hybrid-bermudagrass cultivars, ‘Tifeagle’ and ‘Tifdwarf’, to be a result of C:N ratios and possibly tissue composition. Breitenbeck and Wells (1986) also reported differences in tissue composition to be a factor when describing decomposition of several warm-season turfgrass species thatch in chamber experiments. Although, no differences in thatch decomposition were evident between the hybrid-bermduagrass cultivars for the chamber experiments, which may be partially explained by the similarities in tissue composition of more degradable and recalcitrant constituents; field studies showed a greater cultivar difference in thatch layers. Given the similarities of ‘Celebration’ and ‘Tifway’ tissue composition and decomposition to changes in temperature and RH in chamber experiments, one may conclude ‘Celebration’’s deeper initial thatch layer and less magnitude in thatch depth from sand topdressing is the result of ‘Celebration’’s more aggressive growth and thatch deposition rate. A similar type of thatching tendencies between cultivars has been reported for creeping bentgrass (Carrow, 2004).

Other considerations such as nutrients, pH and soil aeration must be accounted for when developing a thatch management program. Thatch management of more aggressive hybrid-bermudagrass cultivars may require more frequent sand topdressing regiments in addition to more frequent mechanical removal. Further studies are needed to evaluate the interaction of various management practices such nitrogen source and rate, irrigation management, and inoculums effects on thatch decomposition.

Conclusion

The rate at which thatch accumulates can be calculated as directly proportional to the imbalance of plant tissue production and organic matter decomposition. However, the interactions of various factors that affect thatch decomposition have been shown to be complex. Factors such as cultivar, environment and sand topdressing frequency will affect the decomposition process and thus thatch accumulation. This study focused only on understanding the influence sand topdressing regiments have in accelerating thatch decomposition of two hybrid-bermudagrasses by relating changes in microenvironment from sand topdressing application frequency. The more frequent sand topdressing is applied, the greater and more prolonged affect sand has on thatch RH for greater decomposition. Increasing temperature significantly enhances the decomposition as RH and tissue water content are increased. However, the cultural practice of sand topdressing application may not be sufficient to control newer hybrid-bermudagrass cultivars. Combinations of sand topdressing and mechanical removal will be necessary to achieve suitable thatch layers.

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APPENDIX

ENVIORMENTAL DATA

May 2008 – September 2008 Environmental Data in Baton Rouge, LA

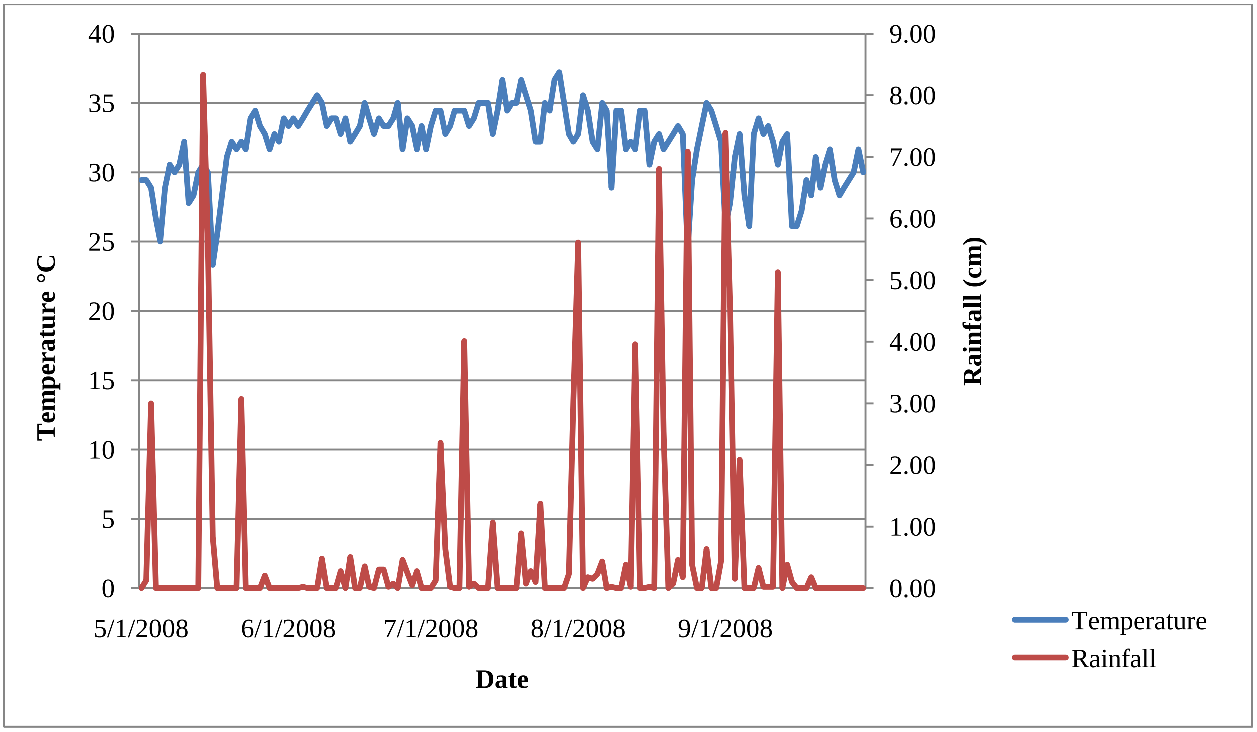

Figure A.1. Environmental data consisting of monthly precipitation and monthly temperature for Baton Rouge, LA from May, 2008 through September, 2008

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May 2009-September 2009 Environmental Data for Baton Rouge, LA

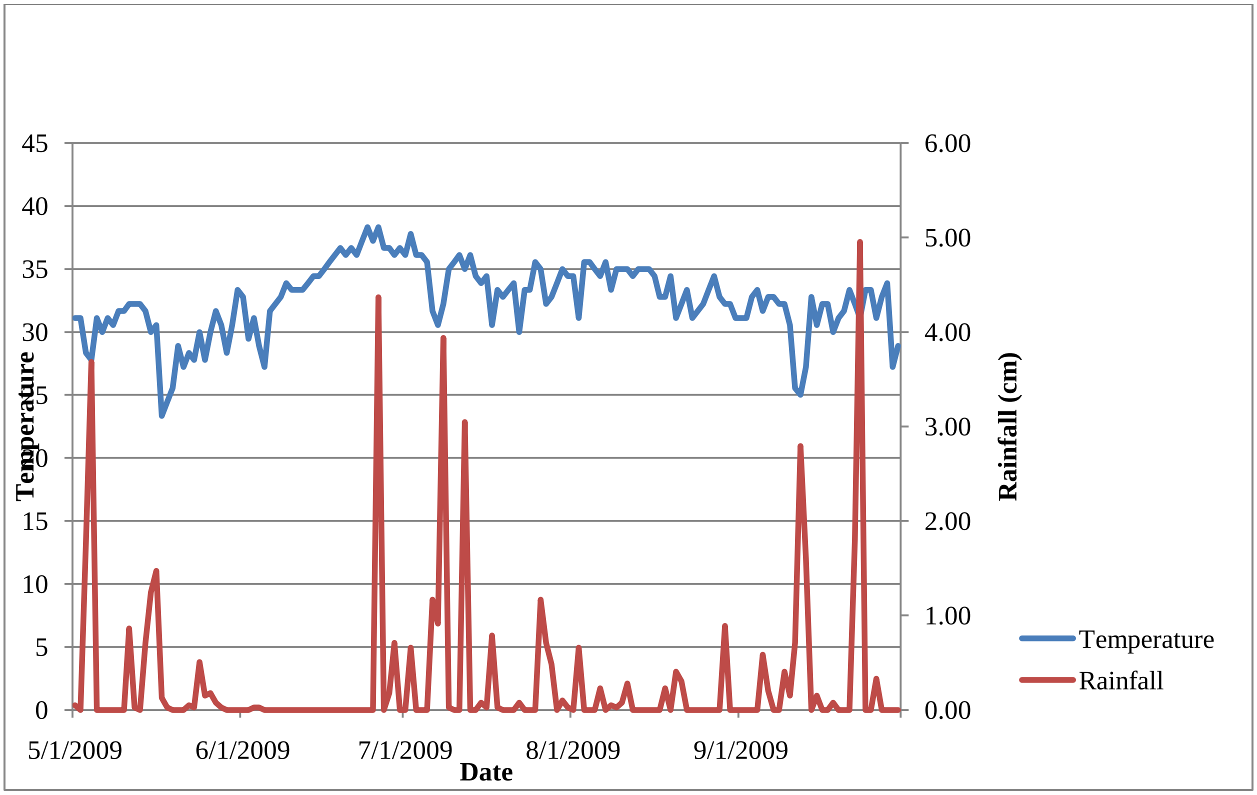

Figure A.2. Environmental data consisting of monthly precipitation and monthly temperature for Baton Rouge, LA from May, 2009 through September, 2009.

VITA

Dustin Scott Parker was born December 1983, as the oldest child of Robin and Paige Parker. Raised in Sikes, Louisiana, Dustin graduated from Dodson High School in 2002 and enrolled at the University of Louisiana Monroe that fall. Graduating with a Bachelor of Science in agriculture business in 2006, Dustin became a fertilizer applicator for Jimmy Sander Inc. Dustin was then accepted by The Graduate School at Louisiana State University, Baton Rouge, Louisiana, to the Department of Plant, Environmental, and Soil Sciences under the supervision of Dr. Jeff Beasley. Dustin is presently a candidate for a Master of Science degree in agronomy with a research emphasis in turfgrass science.