COMPARATIVE MAINTENANCE OF PASPALUM AND BERMUDA GRASSES

By

IVAN M. VARGAS ALTAMIRANO

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To my parents who taught me the importance of intense dedication

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Abstract of Thesis Presented to the Graduate School
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Paspalum grasses have been adopted by golf courses in the southeast U.S. because they appear to have a low nitrogen (N) requirement and a high tolerance to high salinity irrigation water. However, adequate management practices and their economical implications that permit acceptable playability for paspalum grasses are mostly unknown and undocumented compared with the commonly used bermuda grasses. This study (run in 2008 and 2009) evaluated two Paspalum cultivars *Paspalum vaginatum* Swarz (Sea Dwarf and Sea Isle Supreme) and two bermuda cultivars C. *dactylon* (L). Pers. X C. *transvaalensis* Burtt Davy (Jones Dwarf and Mini Verde) grown on putting greens relative to their playability, N nutrition, and maintenance costs. In 2008, two factors such as: three N rates (49, 98 and 196 kg N ha^{-1} yr^{-1}) and two topdressing frequencies (twice and every month) were studied. In 2009, the N rates were reduced for paspalum grasses (12, 24, and 49 kg N ha^{-1} yr^{-1}) and increased for bermuda grasses (122, 244, and 488 kg N ha^{-1} yr^{-1}). Also in 2009, the topdressing frequency was changed to a verticutting frequency factor (every 2 weeks and every 4 weeks). The effect of the treatments was determined for multiple parameters including visual quality, golf ball roll, growth rate, nitrogen uptake, thatch depth, root dry matter, and thatch accumulation (weight loss on ignition). The principal results from (i) turfgrass

cultivar, (ii) N nutrition requirements, and (iii) total maintenance cost are as follow. (i) Jones Dwarf produced the highest growth rate. Paspalum grasses produced more root dry matter than Bermuda grasses, which was reflected in higher N uptake and greater thatch depth. Different topdressing applications did not influence visual quality. However, Jones Dwarf beneficed from monthly topdressing with 1.6 mm of sand. Verticutting every 2 weeks should be included as a management practice for the Paspalum cultivar (Sea Isle Supreme) in order to achieve acceptable golf playability conditions. Maintenance requirements for both bermuda cultivars and one Paspalum cultivar (Sea Dwarf) when grown on push-up native soil greens should include verticutting once a month in order to obtain acceptable ball roll distance. (ii) Paspalum cultivars should be fertilized four times (from May to August) with an N application rate of 49 kg N ha^{-1} yr^{-1} in order to obtain an acceptable visual quality. In comparison bermuda cultivars should be fertilized throughout all the active growth period (from May to September) at the rate of 488 kg N ha^{-1} yr^{-1} to maintain acceptable quality. (iii) Paspalum grass fertilization cost ($138) was lower than bermuda grasses ($806) per year basis growing in putting greens of 125.4 m^2. Paspalum grasses had a higher verticutting cost ($560) than bermuda grasses ($280). Paspalum grasses total maintenance cost was lower ($4811) than bermuda grasses total maintenance ($5199). Therefore, this study found that Paspalum cultivars differed with bermuda grasses in terms of turfgrass cultivar, N nutrition requirements, and total maintenance cost.

CHAPTER 1
INTRODUCTION

Golf Course Economical Impact

In the United States, golf is a popular recreational activity. In 2007, there were 29.5 million golfers in the United States aged 6 and above (National Golf Foundation, 2008). Moreover, in the same year there was an estimated total of 15,970 facilities. Of those, 11,555 were open to the public. A facility is defined as a complex that contains at least one 18 holes golf course. Popular Golfers travel destinations for golf include: Florida, South Carolina, North Carolina, California, and Arizona (National Golf Foundation, 2008).

In 2007, Florida reported the most golf facilities with around 1,060 followed by California, Michigan, Texas, and New York containing 927, 836, 832, and 818, respectively (National Golf Foundation, 2008). In 2000, the economic impact of the Florida golf industry was estimated to have total annual revenue of $4.44 billion. At the same time the golf industry in Florida represented direct employment for 73,000 people. According to Haydu and Hodges (2002), the area owned by Florida golf courses was 82,961 hectares with 56,656 hectares irrigated and 59,489 hectares in maintained turf.

Golf courses represent an important economic component of Florida. For example, the estimated travel expense in Florida is $22.9 billion by golf player visitors. These expenditures had an impact of 226,000 jobs and $9.2 billion in personal and business net income on the Florida economy (Haydu and Hodges, 2002).

The predominant type of turfgrass on typical putting greens and fairways in Florida is some cultivar of bermudagrass representing 93% of maintained turf areas. Accounting for the water used, it was estimated that 173 billion gallons were used for irrigation, of which 49% came for recycled water, with lesser amounts of 29% and 21% from surface waters and wells, respectively (Haydu and Hodges, 2002).

Bermudagrass

Bermudagrass originated in Africa and was introduced into the United States in the mid-1700s (Hanson et al., 1969). It is the primary warm-season turfgrass for golf and is tolerant of low mowing heights; therefore, some cultivars are used on golf course greens. Taliaferro (1995) suggested that there are nine species in the genus *Cynodon*, with *Cynodon dactylon* [l.] Pers. most widely used. This species is known in the United States as common bermudagrass and in other parts of the world by a variety of names including Couch, Doob, and Kweek (Taliaferro, 1995).

In most cases, some variant of hybrid bermudagrass [C. *dactylon* (L). Pers. X C. *transvaalensis* Burtt Davy] has been used in the southern parts of USA for putting greens. Some of the best known of these *C. dactylon x C. transvaalensis* hybrid cultivars are ‘Champion’, ‘FloraDwarf’, ‘Midiron’, ‘Midlawn’, ‘Midfield’, ‘Tiffine’, ‘Tifgreen’, ‘Tifdwarf’, ‘TifEagle’ (TW-72), ‘Tiflawn’, ‘Tifway’, and ‘Tifsport’ (Beard and Sifers, 1996; Taliaferro and McMaugh, 1993).The prefix “Tif” comes from Tifton, GA, home of the Coastal Plain Experiment Station, where these cultivars were developed in the breeding program of Dr. G.W. Burton. The “Mid” cultivars were jointly released from the Kansas and Oklahoma Agriculture Experiment Stations. These hybrids are sterile, and thus no seed is available, so they must be established vegetatively.

Produced from a *C*. *transvaalensis* and *C*. *dactylon* cross, Tifgreen was the first vegetative cultivar to be sprigged on putting greens (Hein, 1961). In 1966, Tifdwarf (a vegetative off-type of Tifgreen) was released because of its smaller leaves, reduced seed head production, and darker green color (Burton, 1966). Since its release for southern putting greens, Tifdwarf has become the standard bermudagrass cultivar. However, selected off-types have been released as cultivars and are commonly grouped together under the term ultradwarfs (Hollingsworth et al., 2005).

Ultradwarfs in the past decade have emerged as a favorite for renovated or newly constructed bermudagrass putting greens. The term “ultradwarf” has come into common usage in recent years to describe bermudagrass that can be maintained at very low mowing height on golf course greens. Some examples of the ultradwarfs are: Champion, FloraDwarf, Mini Verde, Mississippi (MS) Supreme, and TifEagle. Those grasses can be maintained at 3.04 to 3.56 mm if properly managed (Cowan, 2001, Hollingsworth et al., 2005).

TifEagle was produced by γ irradiation of ‘Tifway II’ and it is genetically different from Tifgreen, Tifdwarf, and the previous ultradwarfs (Hanna and Elsner, 1999). Champion is a vegetative selection from Tifdwarf, with genetically different DNA (Beard and Sifers, 1996). MS Supreme is an ecotype selection from Tifgreen and is genetically different from both Tifgreen and Tifdwarf (Krans et al., 1999). FloraDwarf is a vegetative selection from Tifdwarf and it also differs genetically from Tifdwarf (Dudeck and Murdoch, 1998).

In general, ultradwarf bermudagrass have better turf quality, shorter internodes, higher shoot densities, and the ability to withstand lower mowing heights than Tifdwarf; thus, those cultivars have become popular on putting greens. Although they may offer improved turf quality, they present new issues in terms of management (Hollingsworth et al., 2005).

Seashore Paspalum

New Paspalum type grasses such as Seashore Paspalum have been adopted by golf courses in the state as a way to avoid management problems associated with the use of high salinity water. Seashore paspalum is relatively intolerant of cold temperatures and is generally limited to the southern part of the transition zone and south into the tropics (Christians, 2007). This grass usage has increased rapidly in the United States in recent years on areas where salt levels are too high for bermudagrass and other warm-season turf grass species (Christians, 2007).

Seashore Paspalum (*Paspalum vaginatum Swarz.*) is a warm-season native to subtropical and tropical regions around the world. This species has stolons and rhizomes, and its texture varies from coarse to very fine. It has pointed leaves and its blades are narrower than those of bahiagrass. The ligule is a membrane with fine hairs protruding from its upper edge (Christians, 2007). This grass is often found in brackish marsh water or in close proximity to ocean water; it grows naturally in coastal environments. It has been observed that it can grow in areas that receive extended periods of heavy rain and low light intensity. However, the best growth occurs in response to warm temperatures and long day lengths (Trenholm, 2000).

Duncan and Carrow (2000) suggested that Seashore Paspalum (*Paspalum vaginatum Swarz.*) is known by a number of common names other than Seashore Paspalum such as siltgrass, saltwater couch, and sand knotgrass. Some cultivars can be maintained with seawater containing 34,486 mg L^{-1} salt, so that it is known for its high salinity tolerance (Duncan et al. 2000).

The University of Georgia turfgrass breeding program has the largest testing program and collection of paspalum, and has assembled more than 300 ecotypes of this species. The selection of cultivars for sports turf has been limited to the mid and late 1990s, even though the species has been in existence for hundreds of years. Seashore paspalum must be planted as plugs, sods, or springs because it does not produce viable seeds. However once establishment it produce a high-quality, prostrate-growing, dense turf (Trenholm, 2000).

It has been suggested that Seashore Paspalum produces a high-quality turfgrass with minimal fertility requirements. Despite the fact that it will exhibit its best quality and growth under optimal environmental conditions, it can exist under less than optimal conditions for extended periods of time. Some of the advantages of this turfgrass refer to the fact that it can tolerate a wide range of stress. For example, Trenholm (2000) reports that seashore paspalum has excellent tolerance for saline or recycled water, good drought tolerance under proper management, tolerance of low soil fertility, tolerance to a wide range of soil pH (from 4-9), minimal pesticide requirements, excellent wear tolerance, tolerance to extended periods of low light intensity (such as prolonged cloudy or rainy periods), good insect and disease resistance, and tolerance to flooding or extended wet periods. However, there are some disadvantages, such as it produces moderate amounts of thatch during periods of active growth and does not perform well under tree shade (Trenholm, 2000). Some of the cultivars are ‘Sea Isle 1’, ‘Sea Isle 2000’, ‘Sea Isle Supreme Salam’, ‘Seaway’, ‘Sea Dwarf’, and ‘Sea Spray’ (Christians, 2007).

‘Sea Isle 2000’ was developed by plant geneticist Dr. R.R. Duncan at the University of Georgia's Griffin Experiment Station from a sample collected at Alden Pines Country Club in Bokeelia, FL, which is owned and operated by Stewart Bennett. It was suggested that ‘Sea Isle 2000’ is ideal for golf greens and tees, especially in salt-challenged environments. It is similar to the dwarf bermudas in texture and playability when maintained at 3.175 mm mowing height (Phillip Jennings Turf Farms, 2009).

Stimpmeter readings of 3.05 m or more can be seen if regular verti-cutting, light topdressing and periodic rolling are applied. Sea Isle Supreme is a grass that thrives on salt water, using a seawater blend, or even straight ocean water with the right management practices. It also grows well when watered with recycled or effluent sources. The principal characteristics of Sea Isle Supreme 2000 are that it is a very aggressive creeping type of grass (Phillip Jennings Turf Farms, 2009).

The soil reaction range for Sea Isle Supreme 2000 has been suggested at a pH above 6.0. Moreover, it has been observed to perform best on a low level of applied nitrogen, approximately 146 kg N ha^{-1} per year given a balanced N:P:K program according to soil tests (Phillip Jennings Turf Farms, 2009).

Another Seashore Paspalum cultivar that has become popular is Sea Dwarf $_{TM}$ Seashore Paspalum. It was developed and marketed internationally by Environmental Turf. They market this grass as the Premium Seashore Paspalum turf grass, suggesting that Sea Dwarf is suited for use on golf courses tee-to-green and on sports fields such as soccer, baseball, softball and football (Environmental Turf, 2009).

Some of the general characteristics are fine texture, a bright green color, tolerates a wide range of mowing heights, about 2.54 mm to about 10.16 cm, can be irrigated with varied water quality and alternative water sources such as effluent, reclaimed or brackish. Moreover, it also grows well in flow-way applications where the turf will remain wet or even submerged for periods of time and it is fairly shade tolerant, fairly cold tolerant, and can withstand prolonged wet conditions (Environmental Turf, 2009).

In terms of maintenance characteristics, it has been suggested that Sea Dwarf has different maintenance requirements than other turfgrasses such as bermudagrass. For instance, it has been suggested that it takes up to 50% less water and requires up to 75% less nitrogen fertilizer than bermudagrass. Besides that salt can be used as an herbicide (Environmental Turf, 2009).

This variety (Sea Dwarf) has become very popular for golf courses; for example, in the United States it is utilized in Hammock Bay Golf & Country Club, Naples, Florida, Crown Colony Golf & Country Club, Fort Myers, Florida, Olde Palm Golf & Country Club, Palm Beach Gardens, Florida, Galveston Country Club, Galveston, Texas, and Coco Beach Golf & Country Club, Rio Grande, Puerto Rico. In addition, Sea Dwarf is the grass used in Palma de Mallorca, Mallorca, Spain (Environmental Turf, 2009).

There are several studies referring to Seashore Paspalum that can be found in the literature. For example, in 1979 Henry et al. showed N fertilization response for Paspalum, using increasing rates from 8.1 to 33.3 kg ha^{-1}. On a monthly basis, visual quality was improved on Adalayd and Futurf paspalum. However, scalping injury was noticed on both cultivars. Another study Beard et al. (1991) noted that cutting height has a greater effect on visual quality, fall color retention, and spring green- up than did N application. There was a linear response to mowing height, and they noticed a superior visual quality with shorter cut turf, spring green-up, and shoot density (Beard et al., 1991).

In 2001, a study was conducted in Georgia using N application of 196 or 392 kg ha^{-1} in *Paspalum vaginatum* mowed at 4 mm during a 4-month period with two ecotypes (AP10 and AP14). This study showed that application of the higher rate of N did not affect shoot growth, but improved visual quality, color, density and wear tolerance (Trenholm et al., 2001).

Kopec et al. (2007) reported a study with Sea Isle Supreme 2000 Seashore Paspalum (*Paspalum vaginatum* Sw.*)* that was maintained as a putting green surface. They evaluated turf grass response attributes, nutrient content, and ball roll distance (BRD) as affected by three mowing heights (0.3, 0.4 and 0.5 cm) and four monthly N application rates (12, 18, 24, and 36 kg ha^{-1}). They found an acceptable visible turf grass quality of 6.0 (on a scale 1 to 9) or greater for all the treatments. Shoot counts were greatest at the 0.3-cm height and were not significantly influenced by N rates (Kopec et al., 2007).

It was suggested that higher levels of applied N with shorter mowing heights generally increased the clipping dry weight. In terms of leaf tissue, N was found to increase in response to increasing levels of N application. Ball roll distance was largely unaffected by N fertilization, but was affected by mowing height and rolling. The maximum BRD observed was 277 cm; where 234 cm and 214 cm were the mean BRD on rolled and unrolled turf surfaces mowed at 0.3-cm height (Kopec et al., 2007).

Maintenance Practices

Seashore Paspalum has been suggested to have excellent tolerance to the high salt levels found in reclaimed water, effluent, salt spray and seawater after it has been established, and also requires less fertilizer and less irrigation than many other turfgrasses such as bermudagrasses. However, the maintenance requirements for seashore paspalum compared with bermuda grasses are in most cases unknown.

In the case of bermudagrass, McCarty and Miller (2002) suggested that there are cultural practices that need to be taken into the account such as mowing, irrigation/water management, fertilizing, aerification strategies and techniques, topdressing, and overseeding in order to obtain adequate bermudagrass golf greens.

From those maintenance practices, nutritional requirement is one of the most essential and nitrogen use efficiency a very important component in terms of quality and environmental concern. Power and Schepers (1989) suggested that nitrogen placement, nitrogen timing, and nitrogen source are important factors, but when those factors are compared with optimizing the nitrogen rate they usually produce smaller enhancement in terms of nitrogen use efficiency. Moreover, many other authors have shown in several different studies that nitrogen losses increase rapidly when the nitrogen inputs are higher than the crop assimilation capacity, suggesting that the rate of applied nitrogen is the governing factor affecting the nitrogen use efficiency. (e.g., Broadbent and Carlton, 1978; Legg and Meisinger, 1982; Vanotti and Bundy, 1994; Schlegel et al., 1996; Doberman et al., 2006; Meisinger et al., 2008).

Therefore, the present study evaluated the overall maintenance and nutrition requirements of paspalum and bermuda grasses grown on nature soil push-up putting greens in order to determine the best management practices related to their playability and maintenance costs.

Hypothesis and Research Objectives

Previous studies have determinated some of the management practices and nutrition requirements of bermudagrasses growing in putting greens; however, Seashore Paspalum grasses nutritional requirements and management practices for Florida golf courses need to be developed.

- **Hypothesis:** Paspalum grasses and bermuda grasses growing on putting greens will differ overall in terms of maintenance and nutrition requirements.

- **Principal Objective:** To determine overall maintenance and nitrogen nutrition requirements of paspalum and bermuda grasses grown on putting greens.

- **Specific Objectives 1:** Determine the influence of topdressing and verticutting on paspalum and bermuda grasses grown on putting greens relative to their playability and maintenance costs.

- **Specific Objectives 2:** Determine the nitrogen nutrition requirements of paspalum and bermuda grasses grown on putting greens.

CHAPTER 2
MATERIAL AND METHODS

Field Study Design

A field experiment was utilized to evaluate overall maintenance and nitrogen nutrition requirements of paspalum and bermuda grasses grown on push up putting greens. Two cultivars of Seashore Paspalum (*Paspalum vaginatum* Swarz.), Sea Dwarf and Sea Isle Supreme, were evaluated and compared with two cultivars of hybrid bermudagrasses [*C. dactylon* (L). Pers. X *C. transvaalensis* Burtt Davy], Mini Verde and Jones Dwarf. The four grasses were established under putting green conditions on native soil push up greens on the UF/IFAS Turfgrass Research Facilities at the Plant Science Research and Education Unit, near Citra, FL. Research was conducted from April 17th to September 17th, 2008 and repeated in from April 16th to September 17th 2009. The field plots were established in September 2007.

In 2008, three nitrogen rates using urea (46% Nitrogen) were applied at 1.22, 2.44, and 4.88 g m^{-2} every 15 days until acceptable visual quality was achieved. In 2008 the nitrogen rates were 49, 98, and 196 kg N ha^{-1} yr^{-1} and 110, 220, and 440 kg N ha^{-1} yr^{-1} for paspalum and bermuda grasses respectively. The plots were mowed at 0.64 cm three times per week. Two levels of topdressing maintenance were established on all the grasses. Topdressing treatments were applied according to the USGA recommendation (O'Brien and Hartwiger, 2003), rates of 3.2 mm twice at 75-day intervals and 1.6 mm four times at once per month. The field study was established as a split-plot design with three replications. Nitrogen rate treatments were arranged in a randomized complete block design (RCBD), while topdressing was the sub-plot factor.

The study was arranged with 72 experimental units total, organized in 18 experimental units per grass within grass as the main plots; topdressing treatment were arranged as sub-plots and N treatments were replicated three times (Figure 2-1). In 2009 the same four cultivars from 2008 were evaluated, but the nitrogen rates and management practices changed. In 2009 the nitrogen rates were reduced for paspalum grasses (12, 24, and 49 kg N ha^{-1} yr^{-1}) and increased for bermudagrasses (122, 244 and 488 kg N ha^{-1} yr^{-1}) in order to achieve the nitrogen requirements. In 2009 the management practice topdressing was changed to a verticutting frequency factor (every 2 weeks and every 4 weeks). In addition both bermuda grasses plots were relocated due to the immaturity effect which produced a low visual quality in 2008. In 2009, the mowing height was reduced (0.25 cm) and the mowing frequency was increased (four times per week). Each experimental unit consisted of 6.9 m^2 which was 0.91 m wide by 7.62 m long. In 2008 and 2008 clippings were collected every 30 days throughout the 150-day study period.

Data Collection

Data including all management practices such as aerification, mowing frequency, and pest management (insecticides, fungicides, and herbicides) were recorded with their product name and frequency in order to determine the total cost. At termination all maintenance costs were evaluated against the best treatment and compared across turfgrass species. In addition, visual quality, ball roll, clipping yield, N uptake, thatch accumulation, thatch depth, and root dry matter were collected for both years.

Visual quality rating was taken weekly and evaluated from 1 to 9, 1 = brown, dead turfgrass, 5.5 = minimal acceptable turfgrass, 9 = ideal green, healthy turfgrass. Golf ball roll distance (BRD) measurement consisted of three releases, in each of two directions from a standard U.S. Golf Association stimpmeter (U.S. Golf Association, 2000). Measurements were taken on a weekly basis immediately after mowing. Clipping yield (g m^{-2}) was collected once a month (May, June, July, August, and September). Shoot tissue was collected using a Toro walk behind mower following 3 days of growth. Harvested clippings were oven dried at 68° C for 48 hours and weighed to quantify dry matter.

All harvested clippings were dried, ground, and analyzed for Total Kjeldahl Nitrogen (TKN). The tissue N concentration was multiplied with the dry matter accumulation to achieve the total nitrogen uptake from each experimental unit. Two root samples were taken from each plot once per month using a rectangular (2 cm by 7 cm) green sampler to a depth of 10 cm in order to measure root dry matter, thatch depth, and thatch organic matter. The top portion of these samples was removed at crown level and thatch depth (cm) was measured using a ruler from three points on the soil cores and averaged. Roots were clipped at the base of the thatch layer and the remaining thatch sample was placed in an 80º C oven for 96 h and weighed. Roots were hand washed in a 1-6mm sieve to remove the roots from soil, dried at 70ºC for 48 h and weighed to determine the root dry matter (g m^{-2}). Thatch samples were placed in a muffle furnace (Benchtop Muffle Furnace LMF-A550, Omega Engineering, Inc., Stamford, CT) at 525 ºC for 3 h to provide ash free weight (Snyder and Cisar, 2000).

Data Analysis

Statistical analysis of data was performed to evaluate the treatment effects using Statistical Analysis System (version 9.1, SAS Institute, Cary, NC). Mean separation was accomplished by using Duncan's multiple range test and single degree of freedom contrast based on the general linear model procedure. A standard analysis of variance (ANOVA) was used to determine statistical differences for the effect of turfgrass cultivar, nitrogen rate, management practices (topdressing or verticutting) and their interactions (SAS Institute Inc, 1999).

CHAPTER 3
RESULTS AND DISCUSSION
COMPARATIVE MAINTENANCE OF PASPALUM AND BERMUDA GRASSES

Study Description

Introduction and Material and Methods

Two Seashore Paspalum (*Paspalum vaginatum* Sw) and two Hybrid bermudagrass [*C*. *dactylon* (L). Pers. X *C*. *transvaalensis* Burtt Davy] cultivars were evaluated in a field study that ran 150 days yr^{-1} (2008 and 2009). The objective was to evaluate the overall maintenance and nitrogen nutrition requirements of paspalum grasses and bermuda grasses grown on push up putting greens. In the 2008 study, three factors were evaluated: three nitrogen rates (49, 98 and 196 kg N ha^{-1} yr^{-1}), two topdressing levels (3.2 mm applied twice and 1.6 mm applied 5 times) and four turfgrasses cultivars (two Seashore Paspalum cultivars Sea Dwarf and Sea Isle Supreme and two Hybrid bermudagrass cultivars Mini Verde and Jones Dwarf) were studied. In the 2009 study, the same four cultivars from 2008 were evaluated, but the nitrogen rates were reduced for paspalum grasses (12, 24, and 49 kg N ha^{-1} yr^{-1}) and increased for bermuda grasses (122, 244, and 488 kg N ha^{-1} yr^{-1}). Also in the 2009 study the topdressing factor was changed to a verticutting frequency factor (every 2 weeks and every 4 weeks) and both bermuda grasses were relocated due to the immaturity of the turfgrass. In both years, the effect of the treatments was determined for multiple parameters such as visual quality, ball roll, growth rate, nitrogen uptake, thatch depth, roots dry matter, and thatch accumulation (weight loss on ignition) in order to make a comparison in term of nitrogen requirement and maintenance between paspalum and bermuda grasses.

In the 2008 study, topdressing (T) only influenced the overall mean ball roll distance of one cultivar (Jones Dwarf). Other than that topdressing and the interaction between topdressing and nitrogen (N) rate did not influence the evaluated parameters. In the 2009 study, verticutting (V) did not influence any parameters other than: (i) the overall growth rate of Sea Dwarf, (ii) the ball roll distance of Sea Isle Supreme during the 2nd treatment cycle, and (iii) the overall ball roll distance of Jones Dwarf. Moreover, N rate and turfgrass cultivars influenced some of the evaluated parameters in both years. Therefore, the main effects of T, N rate, turfgrass, and the V are presented and discussed below.

2008 and 2009 Results and Discussion

Turf Visual Quality

Visual quality ratings were taken weekly on a 1 to 9 scale with 9 representing superior quality turfgrass and 5.5 representing a minimum acceptable turfgrass. Twenty-two (2008) and eighteen (2009) visual quality ratings were averaged and analyzed during the evaluation period. In the 2008 study, visual quality of both paspalum cultivars was impacted at the highest N (196 kg N ha^{-1} yr^{-1}) application rate. Thus, both cultivars were similar in visual quality at the middle (98 kg N ha^{-1} yr^{-1}) and lowest (49 kg N ha^{-1} yr^{-1}) nitrogen application rates (Fig. 3-1a). Trenholm et al. (2001) suggested that an N rate application from 196 to 392 kg ha^{-1} improved visual quality, color, and density in two cultivars of *Paspalum vaginatum.* These results coincide with ours and together suggest that a difference between Paspalum grasses cultivars in visual quality occurs at a high nitrogen rate (above 196 kg N ha^{-1} yr^{-1}).

The mean visual quality response for both paspalum cultivars in 2008 was above 6 for all three nitrogen rates which was higher than the minimum acceptable level of 5.5

(Fig. 3-1a). In order to establish an accurate recommendation of nitrogen application rate it is necessary to obtain values of visual quality below and above the 5.5 acceptable level. The 2008 results suggest that even the lowest nitrogen rate applied (49 kg ha^{-1} yr^{-1}) was too high for Paspalum grasses. Therefore, lower rates were applied in 2009 in order to develop a N response curve. On the other hand, in the 2008 study most of the Bermuda grasses cultivars were below the acceptable minimal value of 5.5 (Fig. 3-1b). Although the N rate applied for bermudagrass (110, 220, and 440 kg N ha^{-1} yr^{-1}) was higher than paspalum grasses only Mini Verde was near acceptable quality at the highest N rate (440 kg N ha^{-1}) during the evaluation period of 2008. This suggests that in terms of N requirements and maintenance bermuda cultivars required more nitrogen compared with the paspalum cultivars in order to obtain an acceptable visual quality. In the 2008 study, it appeared that preexisting growth characteristics such as immaturity of the grasses on the push up greens used may have been responsible for the poor performance of the hybrid bermuda grasses. Therefore, in the 2009 study both bermuda cultivars were relocated and the N rate increased (122, 244, and 488 kg N ha^{-1} yr^{-1}) in order to achieve the desirable visual quality level above 5.5.

This comparative study was divided into five 30 day evaluation periods per year. All four turfgrasses cultivars responded to nitrogen rate in different periods. Paspalum grasses in 2008 responded in visual quality to N rate on Sea Dwarf only during the 2nd 30 day evaluation period and for Sea Isle Supreme a response to N rate was observed during the 2nd, 3rd, 4th, and 5th 30 day evaluation periods. Bermudagrasses showed a visual quality response due to N rate during three evaluation period for both cultivars. Mini Verde and Jones Dwarf responded in visual quality to N rate during the 1st, 2nd, 4th

and the 2^{nd}, 3^{rd}, 4^{th} evaluation period in 2008, respectively. In the 2008 study, a fitted model for paspalum grasses and Mini Verde comparing visual quality and N rate produced a strong relationship from the 2^{nd} evaluation period for Sea Dwarf ($r^2 = 0.83$), Sea Isle Supreme ($r^2 = 0.79$) (Fig. 3-2) and Mini Verde ($r^2 = 0.71$) (Fig 3-3). A fitted model for Jones Dwarf was observed during the 4^{th} evaluation period (r^2=0.63) (Fig. 3-4). Although in 2009 the same tendency was found as that in 2008 for paspalum grasses, the relationship between N rate and visual quality of Sea Dwarf (r^2 =0.42), and Sea Isle Supreme (r^2 =0.37) was much weaker. Henry et al. (1979) demonstrated in Adalayd and Futurf Seashore Paspalum that an increase in N rate from 8.1 to 33 kg ha^{-1} on a monthly basis improved visual quality. This suggested that visual quality could be affected by increases in nitrogen rates. Both evaluated paspalum cultivars in 2008 and the 2009 received four N applications. However, they received three of the four nitrogen applications before the 2^{nd} 30 day evaluation period. Therefore, it appears that the response observed of Paspalum grasses to N rate in 2008 and 2009 was directly due to the actual nitrogen applied.

Although the 2008 and the 2009 paspalum cultivars showed a similar tendency in the 2^{nd} evaluation periods where visual quality was affected by N rate, in 2009 the effect of N rate on the overall mean visual quality of paspalum grasses was not different. In 2009 both Bermuda grasses were influenced by N rate in the same three evaluation periods the (1^{st}, 3^{rd}, and 4^{th}). In the 2009 study a fitted linear and quadratic model for Mini Verde (r^2=0.80) (Fig. 3-5) and Jones Dwarf (r^2 =0.71) (Fig. 3-6) illustrated the overall response for bermuda grasses. Increasing N rate resulted in increased quality.

Bermuda grasses did not reach a plateau therefore it suggest that the nitrogen requirement for bermuda grasses could be even higher.

Environmental conditions of the study could be another factor contributing to the results. Hybrid bermuda grass growth and development are influenced by environmental conditions such as temperature, nitrogen, and light (Stanford et al., 2005). In the 2009 study, the overall mean visual quality for the Bermuda grasses was near acceptable at the higher rate (448 kg N ha^{-1} yr^{-1}) (Fig. 3-1d) and a difference in visual quality response was found between the N rate applied. This complements the 2008 data and together suggested that there is higher nitrogen requirement for Bermuda grasses growing in putting greens compared with Paspalum grasses.

In the 2009 study, the paspalum grasses exhibited a reduction in the overall mean turfgrass visual quality compared to 2008, where it appears that the decreases from 2008 to 2009 in Sea Dwarf and Sea Isle Supreme can be attributed to the reduction in nitrogen rates used in the 2009 study (Fig. 3-1c). Even though the application rates in 2008 (49, 98, and 196 kg ha^{-1} yr^{-1}) were reduced in 2009 (12, 24, and 49 kg ha^{-1} yr^{-1}) the Paspalum grasses still maintained an acceptable (above 5.5) overall mean visual quality. Rates used in 2009 relate with the results obtained by Kopec et al. (2007) where they reported an acceptable visible turfgrass quality of 6.0 (on a scale 1 to 9) or greater for all treatments at four monthly application rates of 12, 18, 24 and 36 kg ha^{-1} to Seashore Paspalum (*Paspalum vaginatum Sw.*). Also, Environmental Turf (2009) supports low N rates for Paspalum grasses. They report that the nitrogen requirement for Seashore Paspalum could be up to 75% less than other turfgrasses such as bermuda grasses. According to Phillip Jennings Turf Farms (2009), the N recommendation for Seashore Paspalum is low at approximately 14.63 g m^{-2} yr^{-1} or 146 kg ha^{-1} yr^{-1}. This comparative study supports those low nitrogen requirements for Seashore Paspalum and high N requirements for bermuda grasses, but according to this study the actual N recommendation should be even lower (approximately 49 kg ha^{-1} yr^{-1}) and bermuda grasses even higher (approximately 488 kg ha^{-1} yr^{-1}).

An accurate N rate is very important in order to obtain high N use efficiency. Power and Schepers (1989) suggested that the effect of N placement, N timing, and N source are important factors, but when those factors are compared with optimizing the N rate they usually produce smaller enhancement in terms of N use efficiency. Moreover, many other authors have shown with several different studies that N losses increase rapidly when the N inputs are higher than the crop assimilation capacity; suggesting that the rate of applied N is the governing factor affecting the N use efficiency (e.g., Broadbent and Carlton, 1978; Legg and Meisinger, 1982; Vanotti and Bundy, 1994; Schlegel et al., 1996; Doberman et al., 2006; Meisinger et al., 2008). Although this study suggested that paspalum requires lower N rates and bermuda requires higher N rates compared with other studies, the environmental conditions of this study could have influenced turfgrass visual quality.

According to Stanford et al. (2005) temperature, nitrogen, and light have an effect on hybrid bermudagrass growth and development. They reported that temperature as well as light levels regulated expressions of dwarfness in Tifdwarf bermudagrass. They suggested that in regions that typically have long periods with daytime temperatures less or equal to 27 °C and photosynthesis photon flux density (PPFD) less or equal to 600 µmol m^{-2} s^{-1} the growth of hybrid bermuda grasses changes considerably producing longer internodes spacing and longer leaves in plants. Also, they reported that an overall trend was seen in which the internodes increased due to an increase in nitrogen. They reported that plants fertilized at the greatest N rate (24.4 kg ha^{-1} wk^{-1}) had longest internode length and more total shoot dry weight compared with those at the lowest N rate (8.1 and 16.3 kg ha^{-1} wk^{-1}). The previous results support this comparative study's results because it was found that bermuda grasses showed a positive response in visual quality to increased N rate applied. Therefore, the recommended N rate for paspalum and bermuda grasses should be adjusted depending on the conditions under which the turfgrass will be grown.

According to Brosnan and Deputy (2008) paspalum evolution has occurred in coastal, brackish ecosystems, and they report the possibility that paspalum grasses only respond to nitrate nitrogen. In this study in Florida, nitrogen form was most likely not a problem for paspalum grasses. This is because the high temperatures and soil conditions in Florida during the 150 day evaluation period were appropriate for urea (46% organic soluble nitrogen) to nitrify and NO_{-3}-N was the predominant nitrogen source available.

A difference in overall mean visual quality was found between paspalum cultivars in 2009. The overall mean visual quality of Sea Isle Supreme was higher (6.06 to 6.13) than Sea Dwarf (5.51 to 5.64) (Fig. 3-1c); therefore, it appears that Sea Dwarf requires a higher nitrogen rate (12 to 24 kg ha^{-1} yr^{-1}) than Sea Isle Supreme (12 kg ha^{-1} yr^{-1}) in order to obtain an acceptable level. In comparison, both hybrid bermuda (Mini Verde and Jones Dwarf) grasses were similar across each N rate and they responded similarly in increasing turf visual quality due to increased N rate applied. Also, a difference in color was noticed between both turfgrasses. The paspalum grasses produced a more persistent green color than the bermuda cultivars.

Finally, this comparative study results demonstrated that there is a clear difference between paspalum cultivars compared with bermuda cultivars in terms of N response and N requirement. Paspalum grasses showed an early response, before the 60 day evaluation period, in visual quality due to N rate; thus, permitting an acceptable visual quality (above 5.5) with only four N applications. Also, it was found that the early response was enough to maintain the paspalum grasses in acceptable visual quality for the entire 150-day evaluation period for both years, which suggests that the N requirement is lower for paspalum cultivars than bermuda cultivars. Contrasting with the low N requirement of paspalum grasses, it was found that bermuda cultivars required higher N rates and a different maintenance plan by applying N throughout the 150-day evaluation period for both years in order to obtain acceptable visual quality. These results show that the actual plateau in term of N requirement for paspalum cultivars is lower than the bermuda cultivars.

Ball Roll

Paspalum grasses have been used in the Caribbean for many reasons such as potential to tolerate high salinity in irrigation water and lower nitrogen requirement. Therefore, in the last few decades some golf courses in United States (US) have adopted new paspalum cultivars for use on golf greens with plans to increase use of salt water while reducing nitrogen application as promising for golf greens that will tolerate saline water and less nitrogen applications. It has been suggested that new paspalum cultivars differ with the hybrid bermuda grasses in terms of golf course playability. Many golfers, primarily in Latin America, the Caribbean, and now in US, have been faced with a problem in terms of golf green playability, principally those golf courses with paspalum cultivars, due to low ball roll speed. However, there is very little information related to the actual management practices in order to alleviate problems produced by paspalum grasses. Therefore, in this study, a comparison of the effect of maintenance practices and N requirement produced information on maintenance practices required to meet to golfer expectations.

In this comparative study, ball roll distance was taken weekly using a Stimpmeter to estimate putting speed, which is considered an accepted measure of golf course playability (Salaiz et al., 1995). As a management practice for paspalum cultivars, Phillip Jennings Turf Farms (2009) suggested that a Stimpmeter reading of 305 cm or more can be obtained if regular verticutting, light topdressing, and periodic rolling are applied. Therefore, in this 2008 study it was expected that topdressing would have an effect on ball roll distance (BRD) in paspalum cultivars; however, topdressing and nitrogen rate did not influence the overall BRD in the 2008 study for paspalum grasses and Mini Verde. Only one bermuda grass cultivar (Jones Dwarf) was influenced in the overall mean ball roll by topdressing. It was found that a light topdressing produced a higher ball roll distance (198 cm) compared with the heavy topdressing application (183 cm) for Jones Dwarf. Because limited topdressing influence on BRD was observed in the 2008 study, topdressing treatments were replaced by two verticutting frequencies in 2009.

An effect due to N rate in mean BRD was found for both paspalum and bermuda cultivars during the first 30-day evaluation period (Table 3-1) in 2008. It appears that lower N rates produced a higher BRD (Fig 3-7b). Also in the 2008 study, Mini Verde produced a higher ball roll distance than Jones Dwarf. Jones Dwarf tends to produce more growth above ground, which was reflected in low BRD. Also, in 2008 the lowest nitrogen rates produced a higher BRD for both Paspalum cultivars. Likewise, increasing nitrogen rate (98 and 196 kg N ha^{-1} yr^{-1}) reduced BRD of both Paspalum cultivars (Fig. 3-7a). In 2008, Sea Dwarf had higher BRD values (154 cm to 163 cm) compared with Sea Isle Supreme (149 cm to 157 cm). The BRD recorded for paspalum grasses in this study would be considered unacceptable for golf playability, because most of the golf courses in America require from 213 to 366 cm in stimpmeter values to be of acceptable playability (Oatis, 1990). Jones Dwarf BRD was not considered acceptable, but Mini Verde which ranged from 214 to 221 cm, did reach the United States Golf Association (USGA) standards. USGA experience shows that trying to keep the speed above 304 cm on a consistent basis usually causes difficult-to-manage turf problems and is not recommended. They recommend maintaining a BRD approximately 244 cm on a daily basis.

In the 2009 study, the same trend in BRD was observed with Sea Dwarf having a higher BRD; however, no difference between Paspalum cultivars was observed (Fig. 3-7c). An effect of verticutting was found in Sea Isle Supreme during the 2nd evaluation period, where a higher BRD of 188.7 cm at the high (every 2 week) verticut frequency was obtained compared with a BRD of 174.7 cm at the low (every 4 week) verticut frequency. Moreover, an increase in BRD was observed from 2008 to 2009 in both Paspalum grasses. Sea Dwarf overall BRD changed in 2008 from 153.6 cm / 163.4 cm to 174.7 cm / 183.2 cm in 2009. However, Sea Isle Supreme increased BRD range in 2009 from 149.4 cm / 157.0 cm to 173.7 cm / 175.9 cm, which represents an increase of approximately 15 percent in BRD for both Paspalum grasses. This can be attributed to the increase in mowing frequency from 3 times wk^{-1} (2008) to 4 times wk^{-1} (2009), the reduction in mowing height 6.34 mm (2008) to 2.54 mm (2009) and the reduction in N rate between both years of the study.

In the 2009 study, bermuda grass differed between cultivars in the same way as in 2008 where Mini Verde BRD was higher than Jones Dwarf. Unexpectedly in 2009, BRD for Jones Dwarf declined (5.2 %) from 190 cm (2008) to 180 cm (2009); This result could be due to the maturity of the Jones Dwarf and the increase in N rate from one year (2008) to the next (2009). On the other hand, Mini Verde BRD increased (2.5 %) from 219 cm to 224 cm (3-7d). This suggests that the change in location for bermuda grasses in 2009 did not consistently increase BRD compared with 2008.

In the 2009 study, N rate only influenced both bermuda grasses in the 4th evaluation period. Results from the 4th period confirmed the reduction in BRD in response to increased N rate applied to bermudagrass. The 2009 study suggested that addition of a higher verticutting frequency could have a positive influence on BRD; therefore, it is suggested that verticutting every 2 weeks should be included as a management practice for seashore paspalum.

In the 2009 study, no difference in the BRD due to nitrogen rate was observed for paspalum grasses. This result could be due to the very healthy condition of the turfgrass and it suggests that the nitrogen rate was not a limiting factor. Similarly, Kopec et al. (2007) reported that BRD on Sea Isle Supreme 2000 was not influenced by nitrogen rates. In comparison, this 2009 study found that verticutting influenced only the overall mean BRD of Jones Dwarf, where high verticutting frequency produced higher BRD values. Therefore, in this comparative study it appears that (i) nitrogen rate did not directly affect BRD at the nitrogen rates applied for paspalum grasses, (ii) verticutting, increased mowing frequency, and decreased mowing height can increase BRD around 15% for paspalum grasses, (iii) the BRD of bermuda grasses tends to be higher than paspalum grasses under the same management practices.

Growth Rate

Crop growth rate (GR) refers to the dry matter accumulation rate per unit of land area, normally it is expressed as g (m of land)$^{-2}$ day^{-1}. Usually crop growth rate is measured by harvesting plants at frequent intervals and calculating the increase in dry weight from one harvest to the next. Normally roots are excluded for GR. For a given interval of GR the following equation is used: GR = (W2-W1) / SA (t2-t1); where W2 and W1 are crop dry weight at beginning and end of interval, t1 and t2 are the corresponding days, and SA is the soil area occupied by the plants at each sampling. Usually the most accurate GR is obtained when the crop is sampled at frequent intervals.

In this comparative study, clippings were collected on a monthly basis in order to obtain growth rate estimates to determine how growth rate is influenced by the study factors nitrogen rate, topdressing or verticutting, and turfgrass cultivars. In the 2008 study, both paspalum cultivars and Jones Dwarf Bermuda grass showed similar growth rates across the N rates applied. However, it was found that increases in N rate produced an increased in growth rate only for Mini Verde bermuda grass. Mini Verde responded to N rates in three of the four evaluation periods (2nd, 3rd, and 4th) (Table 3-2). A linear regression model (r^2 =0.87) shows a strong relationship between increases in nitrogen rate and increases in growth rate in Mini Verde for 2008 (Fig. 3-9). These results are supported by Stanford et al. (2005) was reported at day/night temperatures ranging from 19/11ºC to 35/27ºC and increasing N rate from 8.1 to 24.4 kg ha^{-1} wk^{-1}

resulted in increased dry matter production. Alternatively, an N rate effect on Jones Dwarf was observed only in the 3rd evaluation period in 2008. It was found in 2008 that the Bermuda grass cultivars differed in GR with higher growth rate values in Jones Dwarf across all the N rates than Mini Verde (Fig 3-8b).

Each cultivar of paspalum produced a different growth rate, which was demonstrated in the higher growth rate values (3.1 to 3.7 g m^{-2} day^{-1}) in Sea Dwarf compared with Sea Isle Supreme (2.8 to 3.0 g m^{-2} day^{-1}). However, no difference in growth rate by turfgrass was found across the nitrogen rates (Fig. 3-8a). The usual expectation is that dry matter should increase as the rate of applied N increases; for example, Kopec et al. (2007) suggested that higher levels of applied N with shorter mowing heights generally increased clipping dry weight. However, this study suggests that the growth rate for paspalum grasses was similar for both cultivars at all N rates applied in 2008. Therefore, this implies that nitrogen requirement could be even lower for Paspalum grasses.

It appears from this study that Paspalum grasses could produce considerable growth rate at the lowest nitrogen applied for both years. Trenholm (2000) supports this studys' results because she reported that paspalum grasses have been observed growing in areas that receive extended periods of heavy rains and low light intensity. Also, she reported that the best growth occurred in response to warm temperatures and long day lengths, conditions very similar to where this study was evaluated. This evidence could explain the similar effect of nitrogen rate on growth rate for paspalum in this study.

In this comparative study in 2009, growth rate was not influenced by N rates for paspalum grasses. In this case, growth rate was similar between both Paspalum cultivars (Fig 3-8c) which is ultimately the same result found in 2008. Thus, a shift in overall growth rate relative to cultivars was observed during the 2 years and, it appears that the reduction in the nitrogen rates in 2009 enhanced Sea Isle Supreme Paspalum visual quality more than Sea Dwarf.

The same tendency for bermuda grasses was found in 2009 (Fig 3-8d) which suggested that Jones Dwarf tends to have a higher growth rate at all the N rates applied compared with Mini Verde. Also in 2009, an increase in Mini Verde growth rate was due to the change in location and the incorporation of verticutting as a management practice in 2009.

Verticutting in 2009 influenced the overall growth rate of Sea Dwarf. Verticutting promoted a lower growth rate (2.69 g m^{-2} day^{-1}) at the higher frequency (every 2 weeks) compared with a higher growth rate (3.14 g m^{-2} day^{-1}) from the lower frequency (every 4 weeks) in Sea Dwarf Paspalum. This suggests that verticutting reduced growth rate. One possible explanation could be that the Sea Dwarf did not recuperate from the stresses created by the higher verticutting frequency. Ultimately, this study suggests that both paspalum cultivars and Jones Dwarf grew similarly at the applied nitrogen rates in 2008 and 2009, and Mini Verde tended to have a lower growth rate compared with the rest of the cultivars evaluated.

Nitrogen Uptake

In the 2008 and the 2009 paspalum study, five and four harvests, respectively were collected and analyzed for N concentration. Clippings from each harvest were dried in a forced-air oven at 60°C for 48h, weighed, and ground. Then each subsample was prepared for total Kjeldahl N analysis. Yield-weighed tissue N concentrations were calculated using equation 3-1 to determine the Paspalum grasses' mean nitrogen uptake.

For any nitrogen rate:

Gi= growth rate at i^{th} harvest from each paspalum cultivar (g m^{-2} day^{-1})

Ni=tissue N concentration at i^{th} harvest (%)

ny= number of harvest.

$$\frac{((G1*N1)+(G2*N2)...(G5*N5))*10}{ny} = \text{Mean Nitrogen Uptake (mg } m^{-2}\ day^{-1}) \qquad (3\text{-}1)$$

In the 2008 study, both paspalum and bermuda grass cultivars overall mean N uptake was influenced by N rate. For paspalum grasses as the rate of applied N increased from 49 to 196 kg ha^{-1} yr^{-1} the N uptake also increased from 75 to 93 mg m^{-2} $d^{-1}$and 71 to 83 mg m^{-2} d^{-1} for Sea Dwarf and Sea Isle Supreme, respectively (Fig. 3-10a). It was found that both paspalum cultivars were similar in terms of overall N uptake. However, nitrogen uptake for Sea Isle Supreme was influenced in three of the four evaluation periods and for Sea Dwarf was influenced by N rate only during the 2^{nd} 30-day evaluation period (Table 3-2) in 2008. Also N uptake was different between bermuda grasses cultivars, as Jones Dwarf had a higher nitrogen uptake than Mini Verde (Fig.3-10b). In the 2008 study, N rate affected N uptake of Mini Verde which increased as N rate increased. Mini Verde N uptake was influenced by N rate primarily in the 2^{nd} and 3^{rd} evaluation periods (Table 3-4). A fitted model from the 2^{nd} evaluation period of Mini Verde (r^2= 0. 86) showed a positive relationship between an increase in nitrogen rate and an increase in nitrogen uptake (Fig. 3-11). Jones Dwarf showed a response during three of the four evaluation periods: 1st, 2nd, and 3rd (Table 3-3).

In the 2009 study, increasing N rate did not increase mean N uptake but the Paspalum cultivars did differ in N uptake. Sea Dwarf N uptake in 2009 was lower than Sea Isle Supreme (Fig. 3-10c). Although in the 2009 study N rate did not influence N uptake, it appears that a trend existed for higher N uptake by both Paspalum cultivars in response to N application rate compared with bermuda cultivars.

In the 2009 study, Jones Dwarf accumulated more N than Mini Verde (Fig.3-10d). Nevertheless, in 2009 there was evidence that an increase in nitrogen application produced an increase in nitrogen uptake. Nitrogen rate did influence the overall mean nitrogen uptake by both Bermuda grasses in 2009. Jones Dwarf was affected by nitrogen rate only in the 4th evaluation period. However, Mini Verde was affected by nitrogen rate in the 1st and the 4th evaluation periods. A linear regression model (r^2=0.69) showed increased nitrogen uptake as a result of increased nitrogen application in 2009 for Mini Verde (Fig.3-12). A reduction in N rate applied to the paspalum in 2009 resulted in a reduction of N uptake for paspalum grasses from 2008 to 2009. An increase N rate applied to hybrid bermuda grasses produced an increase in N uptake in 2009 compared with 2008. Therefore it is suggested that there is a strong positive relationship between N rate and N uptake for turfgrasses.

Thatch Depth

Thatch is a layer of partially decomposed organic matter between green shoot tissue and the soil surface (McCarty et al., 2007). Five measurements of thatch depth were made for each year (2008 and 2009). In 2008, paspalum and bermuda grasses thatch depth fluctuated from 2.4 to 2.5 cm (Fig. 3-13a) and from 1.5 to 1.8 cm respectively. Only Mini Verde was influenced by N rate. During this time period, higher values of thatch depth were found at the highest nitrogen rate in Mini Verde Bermuda grass. However, paspalum grasses did not differ in thatch depth and they were not influenced by N rate in 2008. Paspalum grasses showed a higher thatch depth than the hybrid bermuda grasses cultivars. In 2009, the same trend was found as in 2008 where N rate did not influence thatch depth, nor did either paspalum cultivar influence the overall thatch depth. The thatch depth in 2009 was higher for both paspalum grasses and bermuda grasses compared with the results in 2008. An increase of around 115% in the thatch depth was noticed from 2008 to 2009 for bermuda grasses. This increased thatch depth is possibly due to turf maturity and relocation. The 2008 evaluation was taken during the first year after establishment and the 2009 evaluation was taken on established grasses. According to Trenholm (2000), one of the disadvantages of Seashore Paspalum is that it produces moderate amounts of thatch during periods of active growth. Therefore, higher thatch depths recorded for paspalum grasses in 2009 were expected. In general, this comparative study suggests for bermuda grasses that Mini Verde tends to produce more thatch compared to Jones Dwarf. These data agree with other studies such as Hollingsworth et al. (2005) where they found that thatch depth can be affected by cultivar. Also, they evaluated the cultural management and nitrogen source effects on ultradwarf bermuda grass cultivars and reported that other research showed that the ultradwarfs may produce excess thatch (Hollingsworth et al., 2005).

In terms of management, it appears that paspalum grasses will require a new set of practices compared with bermuda grasses primarily because higher thatch depth produces serious problems for golf course playability in the long term. The chemical components of thatch are cellulose, hemicellullose, and lignin, but the main problem is lignin. Lignin is highly resistant to microbial degradation, so that only 80% of the organic component present in thatch is readily decomposable. According to McCarty (2001) thatch decompositions rely upon the activity of soil microorganisms, whose activity is greatly affected by: pH, aeration, temperature, moisture, and carbon-nitrogen ratio. From those factors, mechanical aerification is a commonly used maintenance practice. Some of the available options that can be used by golf course superintendents to reduce thatch accumulation in paspalum cultivars are practices that focus on aeration. According to Christians (1998), there are available practices that favor aeration such as: core aerification, solid tine aerification, deep-drill aerification, water injection cultivation, and vertical mowing. The challenge is to use combination of those maintenance practices to increase microbial activity and reduce the thatch accumulation rate.

From this comparative study, the required maintenance for paspalum grasses appears to be different from bermuda grasses because the higher production of thatch depth. Light and frequent topdressing applications, the optimal nitrogen rate and verticutting appeared to produce the best paspalum quality in this study. However, further evaluation of other maintenance practices such as rolling frequency and aerification intervals are highly recommended.

Root Dry Matter

Root dry matter sampling was taken five times per year. In the 2008 study, N rate did not influence Sea Dwarf root dry matter at any of the evaluated dates, but it did influence the overall root dry matter for Sea Isle Supreme during the 3rd evaluation period. Sea Dwarf root dry matter was higher (1329 to 1059 g m^{-2}) compared with Sea

Isle Supreme root dry matter (847 to 844 g m^{-2}) (Fig. 3-14a) in 2008. Root dry matter for bemuda grasses in 2008 was not influenced by N rates. However, a difference was found between cultivars: Jones Dwarf root dry matter was higher (648 to 668 g m^{-2}) compared with Mini Verde (446 to 476 g m^{-2}) (Fig. 3-14b).

In the 2009 study, the same tendency was found where root dry matter was not influenced by N rates for paspalum cultivars. However, a reduction in overall mean root dry matter was found in 2009 for paspalum (Fig 3-14c). This result suggested that even though the grass was of acceptable quality in 2009, the decrease in N rate produced a reduction in root dry matter between the 2 years. In the 2009 study, paspalum grasses showed the same response to N application as in 2008 for both cultivars in root dry matter, ranging from 857 to 1083 g m^{-2}. In 2009, similar results were found compared with bermuda grasses of 2008 because nitrogen rate did not produce a difference in root dry matter (Fig. 3-14d).

In 2009, verticutting did influence the overall mean root dry matter in Jones Dwarf. The high verticutting frequency produced more roots dry matter (692 g m^{-2}) compared with the low verticutting frequency (556.6 g m^{-2}) for Jones Dwarf in 2009. This result suggests that paspalum cultivars produced similar root dry matter, and they produce more root dry matter than hybrid bermudagrass. Although paspalum grasses received lower nitrogen application than hybrid bermuda grasses, they produced more root dry matter and it could explain the higher turfgrass visual quality. Also a positive effect in the Jones Dwarf roots dry matter was observed due to the higher verticutting frequency.

Loss on Ignition

Weight loss on ignition is a measurement of the amount of organic matter or thatch in the sample. Percentage weight loss on ignition is commonly used to quantify the amount of organic matter accumulated in the thatch layer of turfgrass (Kruse and Sartain 2001, Sartain, 1985; Sartain and Volk, 1984; Smiley and Craven,1978).

In 2008, the overall mean percentage loss on ignition of Paspalum grasses was influenced by nitrogen rate. Unexpectedly it appeared that paspalum grasses percentage loss on ignition values decreased from 13.8% to 12.1% as the nitrogen rate increased from 49 to 196 kg N ha^{-1} yr^{-1} (Fig. 3-15a). On the other hand, Bermuda grasses loss on ignition was not influenced by N rate in 2008 (Table 3-8).

In the 2009 study, an increase in the overall percentage loss on ignition was observed for paspalum and bermuda grasses compared with 2008, with values from 30.35% to 32.58% (3-15c) and 35.92% to 37.34% (Fig 3-15d) for paspalum and bermuda grasses, respectively. The increases in amount of oxidizable organic matter were expected in the second year because a higher increase in thatch depth was found. In 2009, paspalum grasses did not produce more weight loss on ignition in response to applied N.

In 2009 study, all turfgrasses were very similar in weight loss on ignition across the three nitrogen rates. This comparative study differs with other studies because they have shown linear and quadratic effects in percentage loss on ignition with increases in N rate (Guertal and Evans; 2006, and Trenholm et al., 1998). It appears that the percentage loss on ignition results obtained for both years in this study can be attributed to the similar growth rate and thatch depth responses of both cultivars to the nitrogen rates applied.

Economic Analysis

Golf courses represent an important component of the Florida economy. According to Haydu and Hodges (2002) the area owned by Florida golf courses was 82,961 hectares with 56,656 hectares irrigated and 59,489 hectares in maintained turf. The predominant type of turfgrass on typical putting greens and fairways in Florida is some cultivar of Bermudagrass representing 93% of maintained turf areas. However, paspalum grasses have been adopted by golf courses in the southeast US because they appear to have low N requirements and tolerance to high salinity irrigation water. Accounting for the water used, it was estimated that 173 billion gallons were used for irrigation of golf courses in Florida (Haydu and Hodges, 2002), of which 49% came from recycled water, and with lesser amounts of 29% and 21% from surface waters and wells, respectively (Haydu and Hodges, 2002). Therefore, introduction of new paspalum cultivars that require less N fertilization can have a positive impact for golf courses in Florida, but at the same time they require a new set of management practices.

Golf course superintendents have used many cultural practices in order to produce a healthy turf that fulfills golfers' expectations. It has been suggested that maintenance costs for paspalum cultivars are lower when compared with bermuda cultivars, but the actual cost of maintaining an acceptable paspalum green is unknown. A comparative maintenance study of paspalum and bermuda grasses was conducted and an economic analysis was accomplished.

The cost of each of the cultural practices such as mowing (frequency and height), aerification, irrigation, topdressing (frequency and rate), verticutting (frequency), nitrogen fertilization (rate and frequency), pest management practices (product and doses), labor, and equipment depreciation were recorded for both years (2008 and 2009) to calculate and compare the total cost.

Paspalum grasses fertilization cost ($137.5) was lower than bermuda grasses ($805.5) because during this study paspalum grasses required a lower N rate (12.25 kg N $ha^{-1}yr^{-1}$) and fewer applications (four) compared with bermuda grasses, which required higher N rate (49kg N $ha^{-1}yr^{-1}$) and more applications (nine). However, paspalum grasses had a higher verticutting cost ($560) than bermudagrasses ($280) because paspalum grasses required higher verticutting frequency (twice/month) compared with bermuda grasses (once/month). The other cost component such as: mowing ($2064), Aerification ($92), irrigation ($300), topdressing ($640), and pest management practices ($1017) were similar between cultivars. Finally, paspalum grasses total maintenance cost was lower ($4811) (Table 3-5) than Bermuda grasses total maintenance ($5199) (Table 3-6).

CHAPTER 4
SUMMARY AND CONCLUSSIONS

In order to maintain an acceptable quality turfgrass throughout the year it is necessary to understand the nitrogen requirement and management practices of the turfgrass cultivars used. Paspalum grasses have been adopted by golf courses in the southeast US because they appear to have a low N requirement and a high tolerance to high salinity irrigation water. However, necessary management practices that permit acceptable playability for paspalum grasses are mostly unknown and undocumented in the US compared with the commonly used bermuda grasses.

This study (2008 and 2009) was conducted to determine and compare the overall maintenance and nitrogen nutrition requirements for two Paspalum cultivars (Sea Dwarf and Sea Isle Supreme) and two Bermuda cultivars (Jones Dwarf and Mini Verde) grown on native soil push-up putting greens. In both years, the effect of the treatments (three N rates and two management practices) was determined for multiple parameters such as visual quality, ball roll, growth rate, nitrogen uptake, thatch depth, roots dry matter, and thatch accumulation (weight loss on ignition). The effects of N rates and management practices (topdressing in 2008 and verticutting in 2009) were discussed. The following results were obtained:

1. Paspalum cultivars (Sea Dwarf and Sea Isle Supreme) differed compared with bermuda grasses (Mini Verde and Jones Dwarf) in terms of maintenance and nitrogen nutrition requirements.

2. Topdressing applications did not influence visual quality. However, topdressing at least once a month with 1.6 mm of sand should be applied on bermuda grasses primarily in Jones Dwarf because it increased the ball roll distance.

3. Paspalum cultivars should be fertilized four times (from May to August) with an N application rate of 49 kg N ha^{-1} yr^{-1} in order to obtain an acceptable visual quality grown in push up greens.

4. To obtain acceptable visual quality for bermuda cultivars they should be fertilized throughout the active growth period (from May to September) at the rate of 488 kg N ha^{-1} yr^{-1}.

5. Jones Dwarf produced the highest growth rate. Paspalum grasses produced more root dry matter than Bermuda grasses, which was reflected in higher N uptake and greater thatch depth.

6. Verticutting every 2 weeks should be included as a management practice for Sea Isle Supreme in order to achieve acceptable golf course playability.

7. Maintenance requirements for both Bermuda cultivars (Mini Verde and Jones dwarf) and Sea Dwarf Seashore Paspalum should include verticutting once a month to obtain acceptable BRD.

8. Paspalum grasses fertilization cost ($137.5) was lower than bermuda grasses ($805.5) due to a lower N rate (49 kg N $ha^{-1}yr^{-1}$) and fewer applications (four) required compared with bermuda grasses, which required a higher N rate (488 kg N $ha^{-1}yr^{-1}$) and more applications (ten).

9. Paspalum grasses had higher verticutting cost ($560) than bermuda grasses ($280) because paspalum grasses required higher verticutting frequency (twice/month) compared with bermuda grasses (once/month).

10. Paspalum grasses total maintenance cost was lower ($4811) than Bermuda grasses total maintenance ($5199).

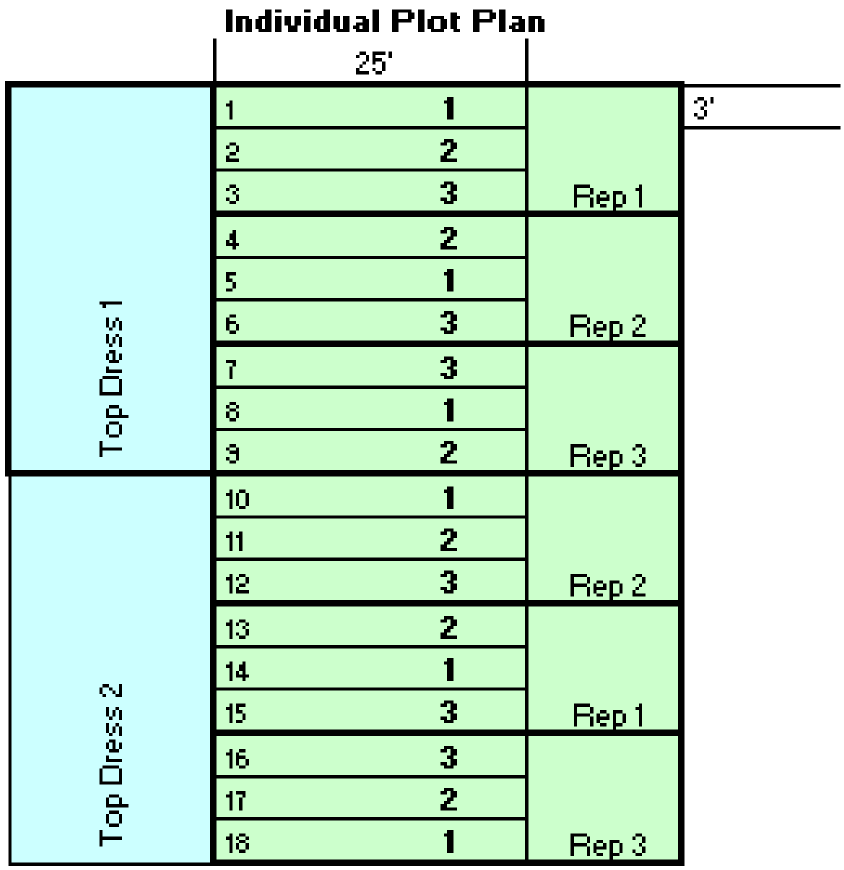
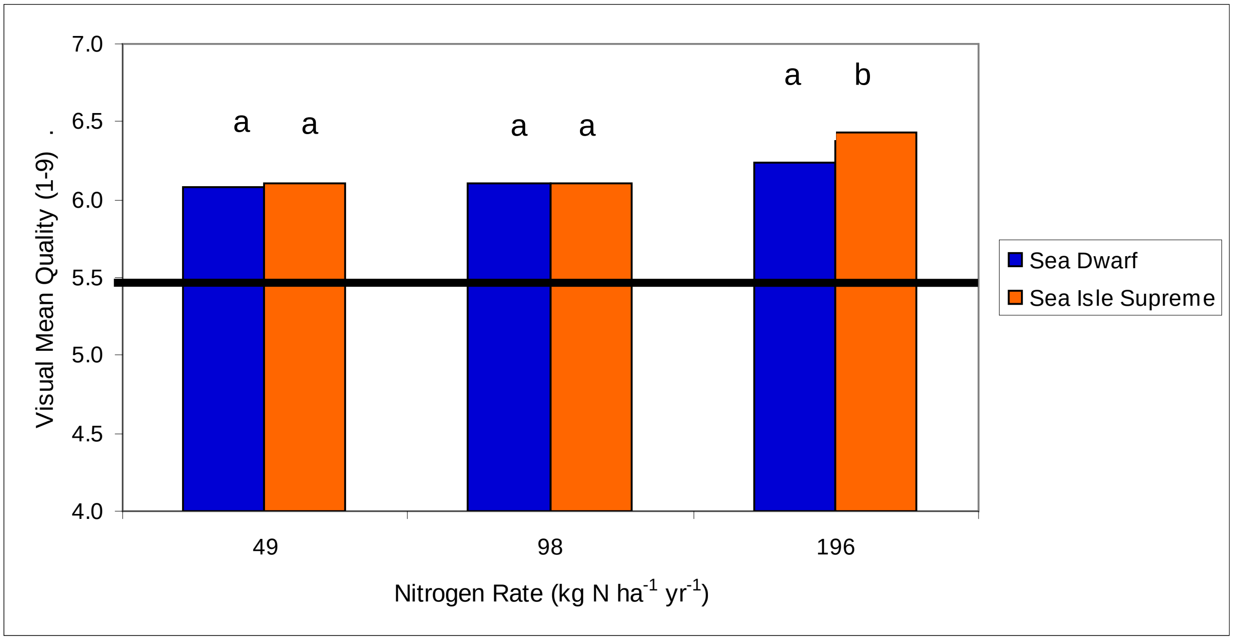
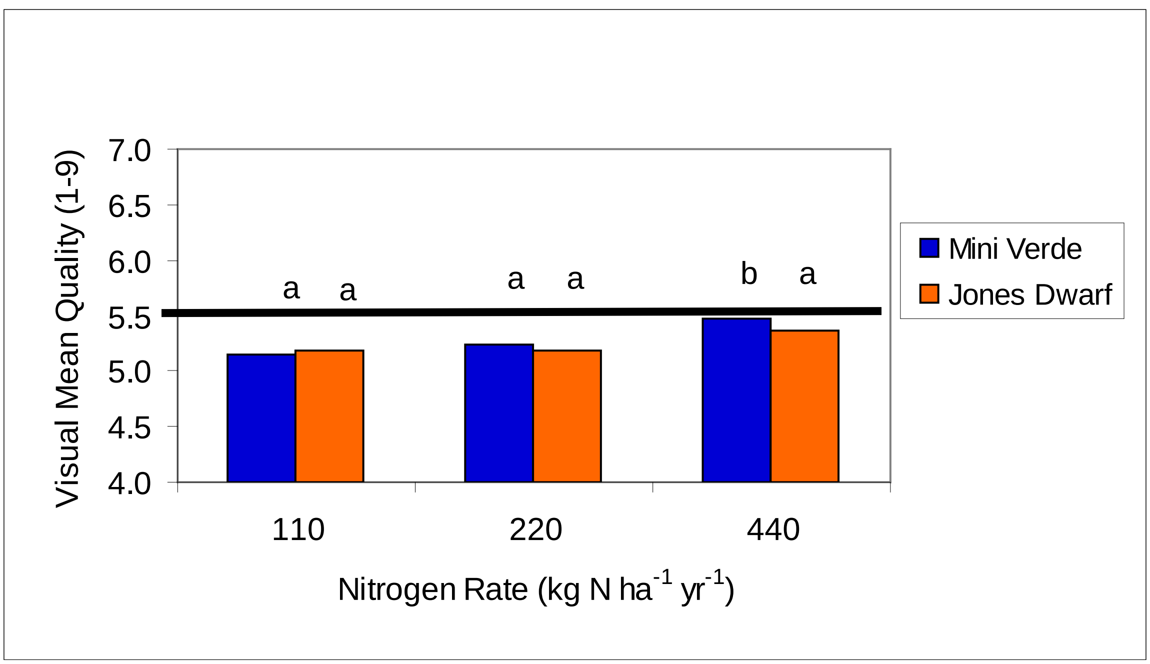


Figure 2-1. Individual plot plan split-block design with three nitrogen rates and three replications arranged in a randomized complete block design (RCBD) with two topdressing as the sub-plot factor.

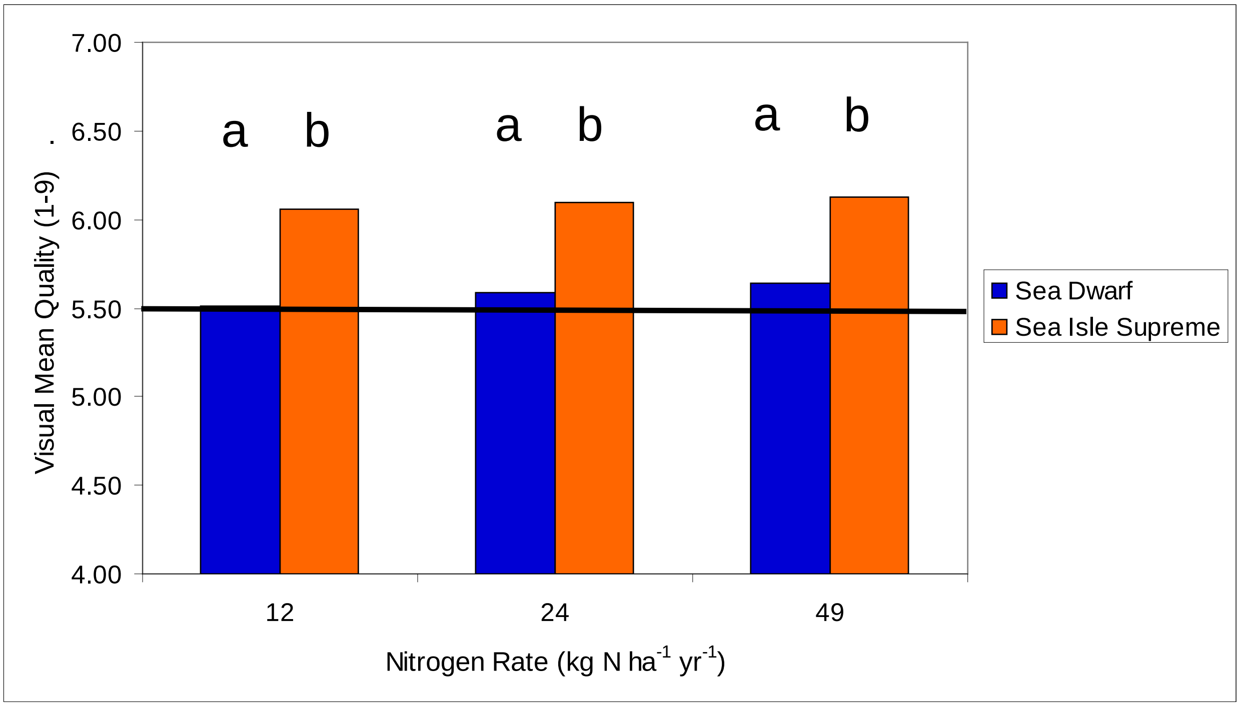


A)

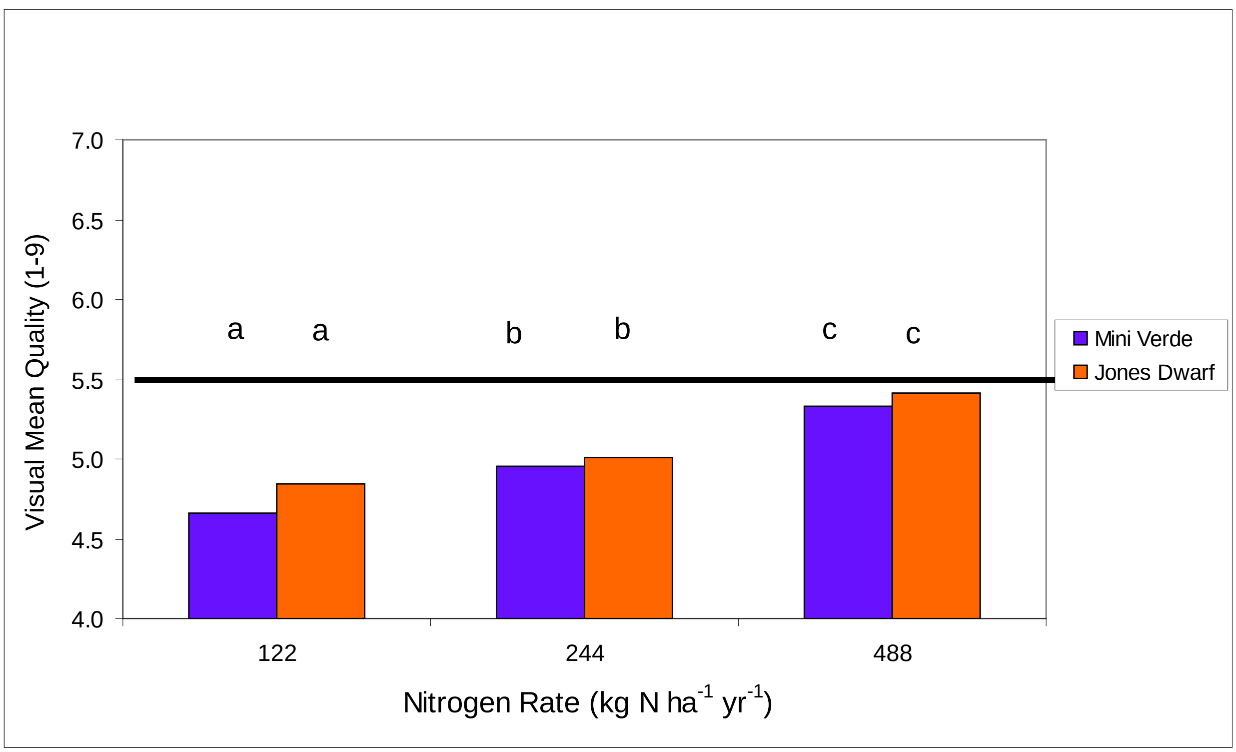


B)

Figure 3-1. Effect of nitrogen rate on the overall mean visual quality in 2008 for A) Paspalum cultivars, B) Bermuda cultivars, and in 2009 for C) Paspalum cultivars, D) Bermuda cultivars. Letters indicate statistical differences across nitrogen rates as determined by Duncan mean square separation at α = 0.05. The horizontal line represents a critical 5.5 visual quality minimal acceptable level.



C)



D)

Figure 3-1. Continued

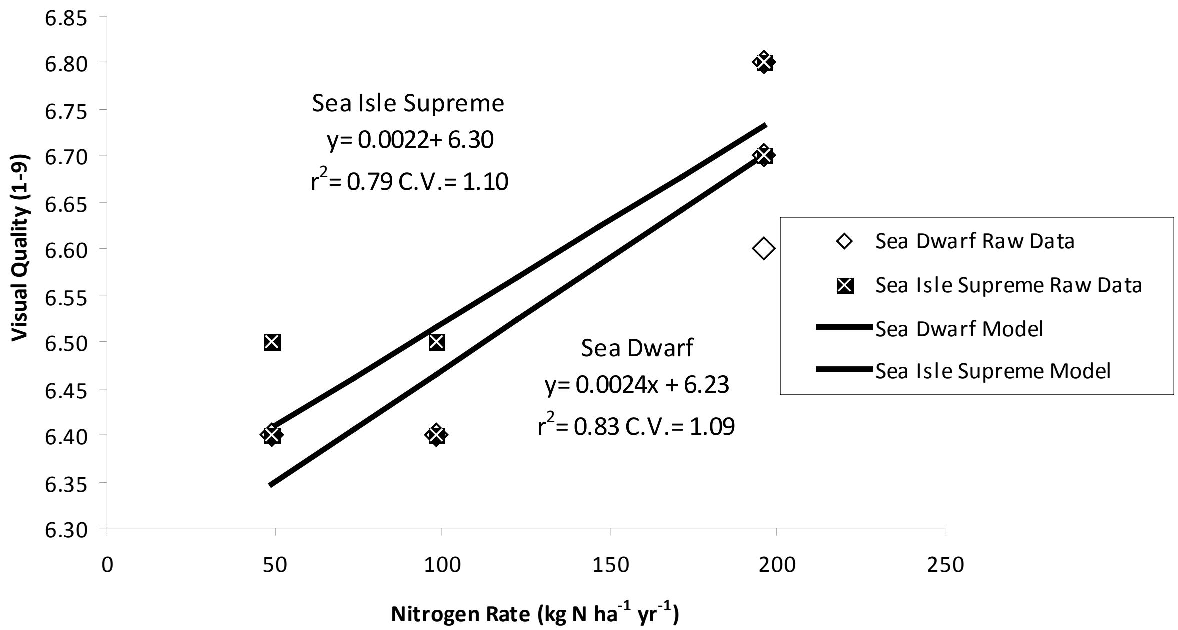


Figure 3-2. Effect of nitrogen rate on visual quality in the 2nd evaluation period for paspalum grasses in 2008.

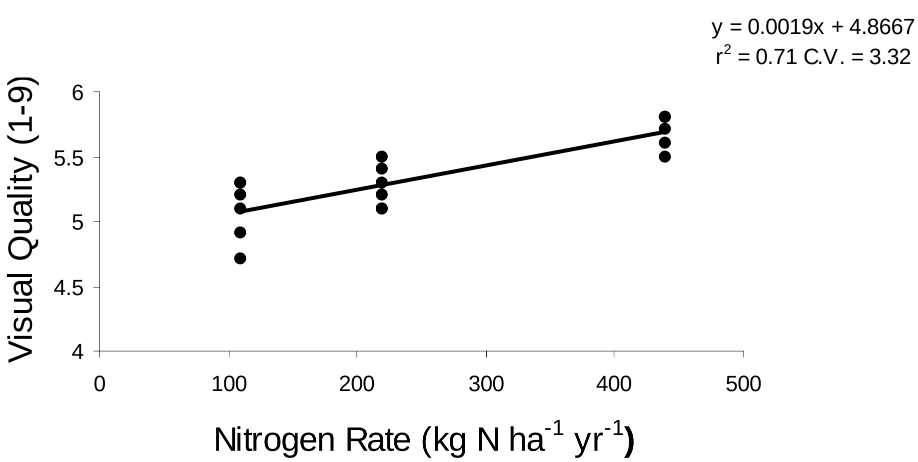


Figure 3-3. Effect of nitrogen rate on Mini Verde bermuda grass visual quality 2nd evaluation period in 2008.

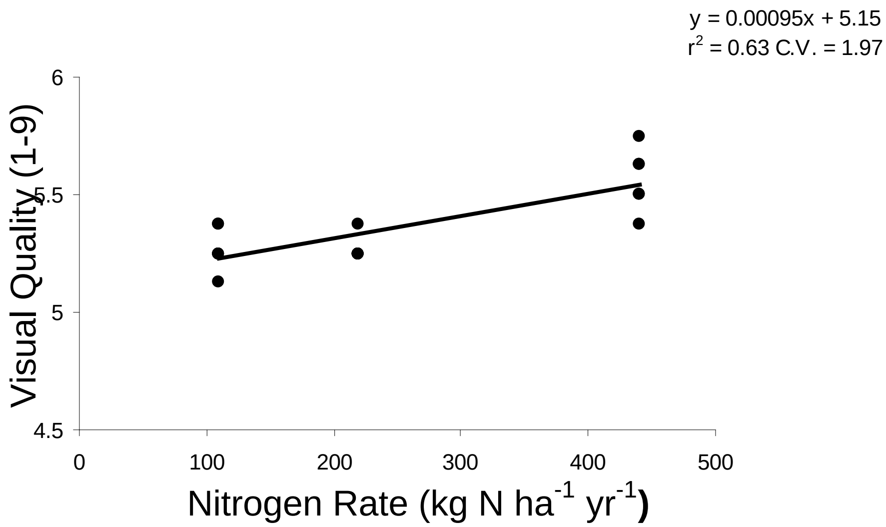


Figure 3-4. Effect of nitrogen rate on Jones Dwarf bermuda grass visual quality 4th evaluation period in 2008.

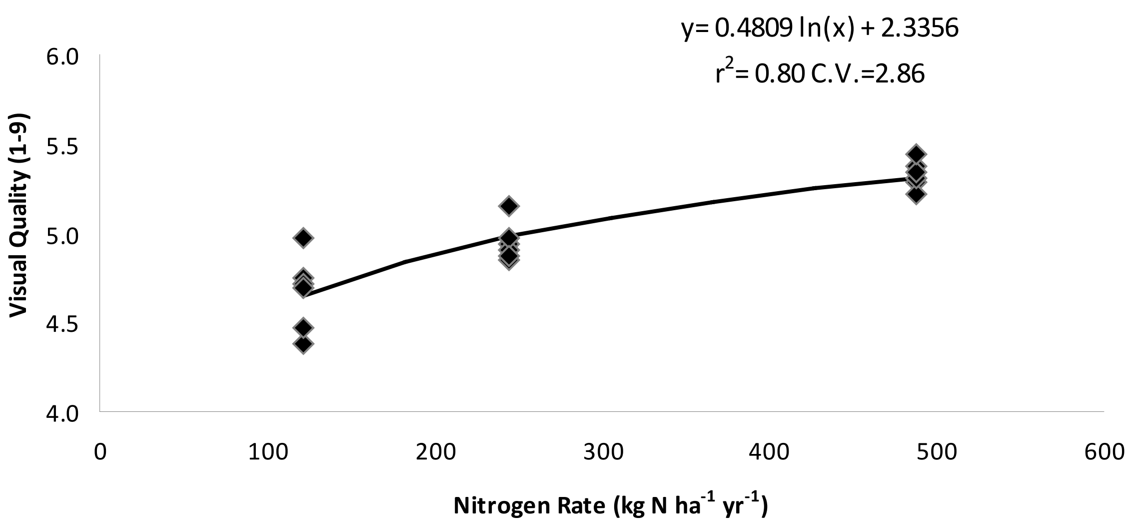


Figure 3-5. Effect of nitrogen rate on the overall mean Mini Verde bermuda grass visual quality in 2009.

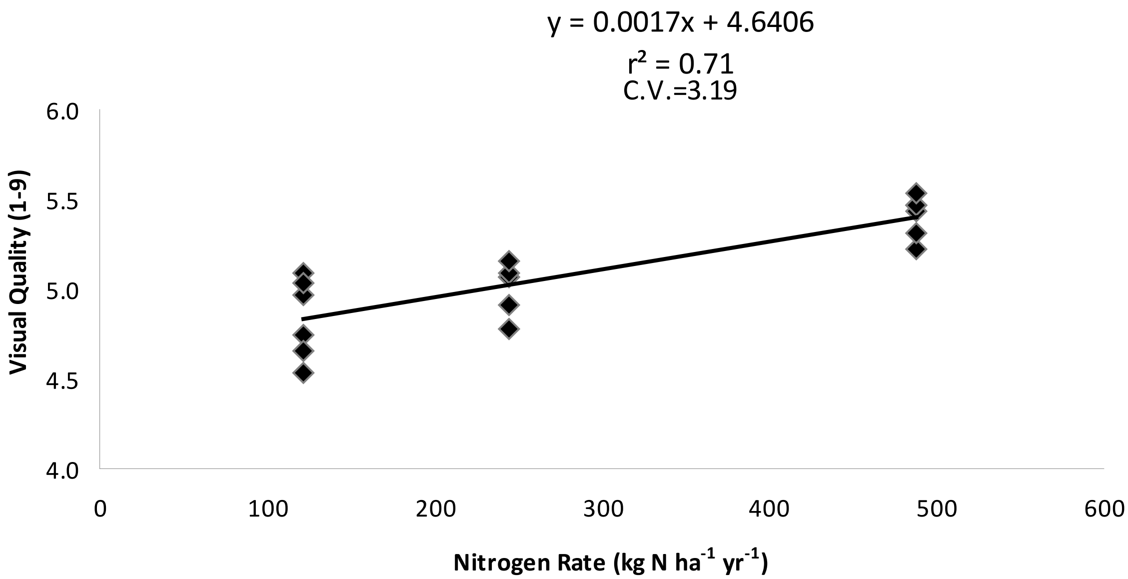
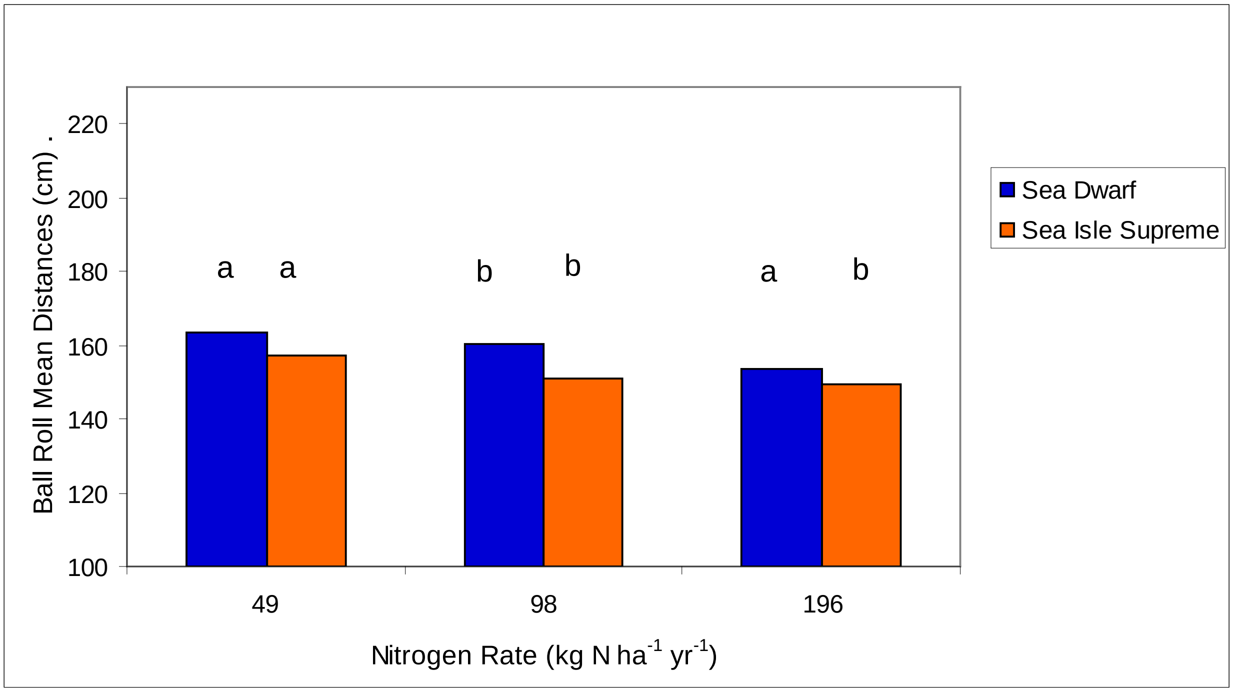
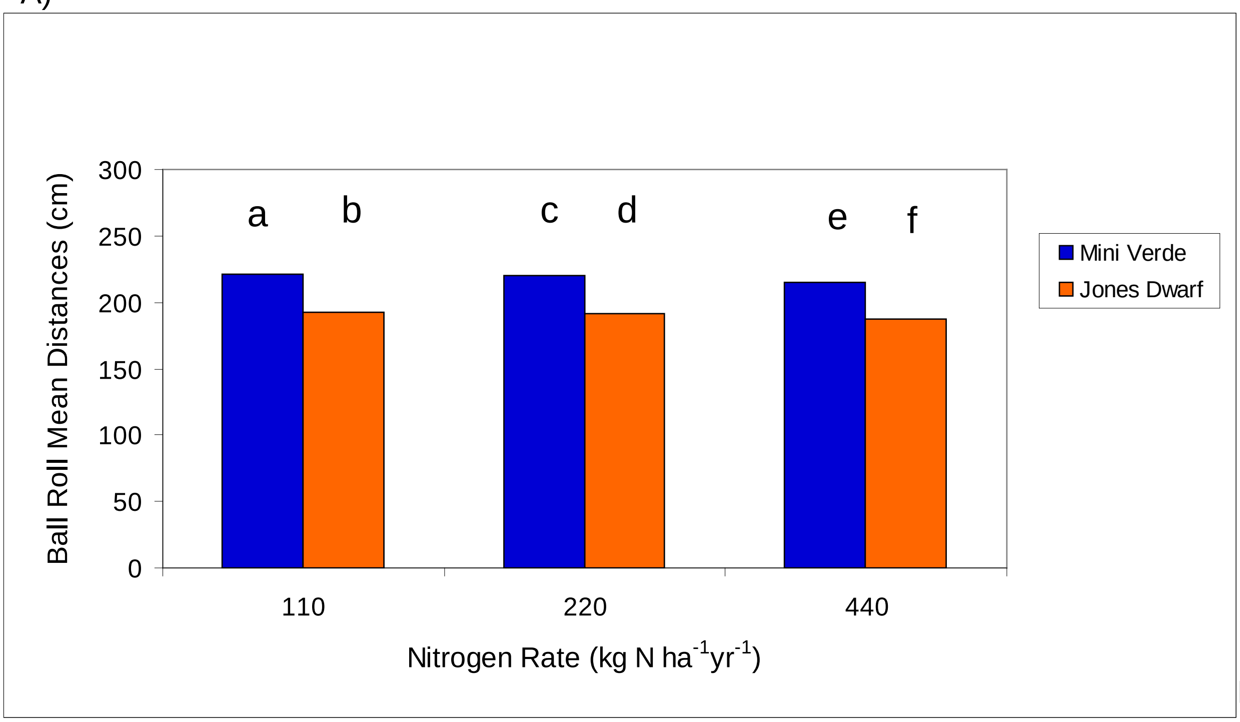


Figure 3-6. Effect of nitrogen rate on the overall mean Jones Dwarf Bermuda grass visual quality evaluation period in 2009.

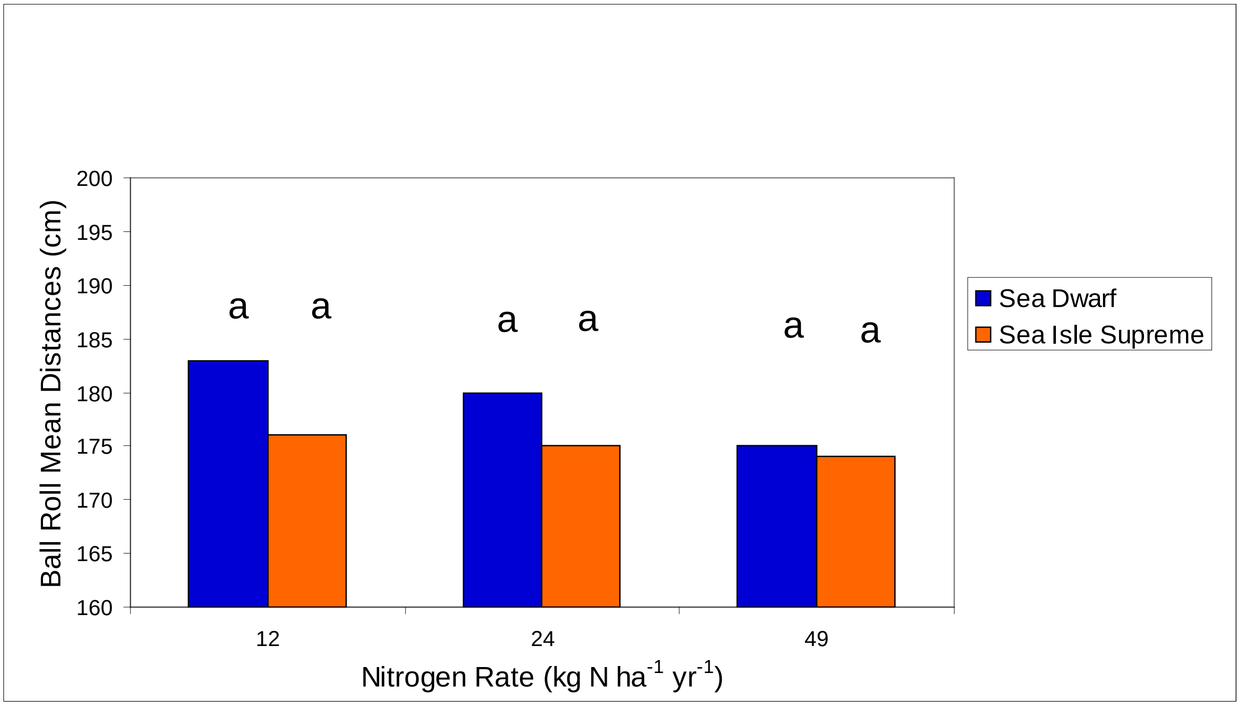


A)

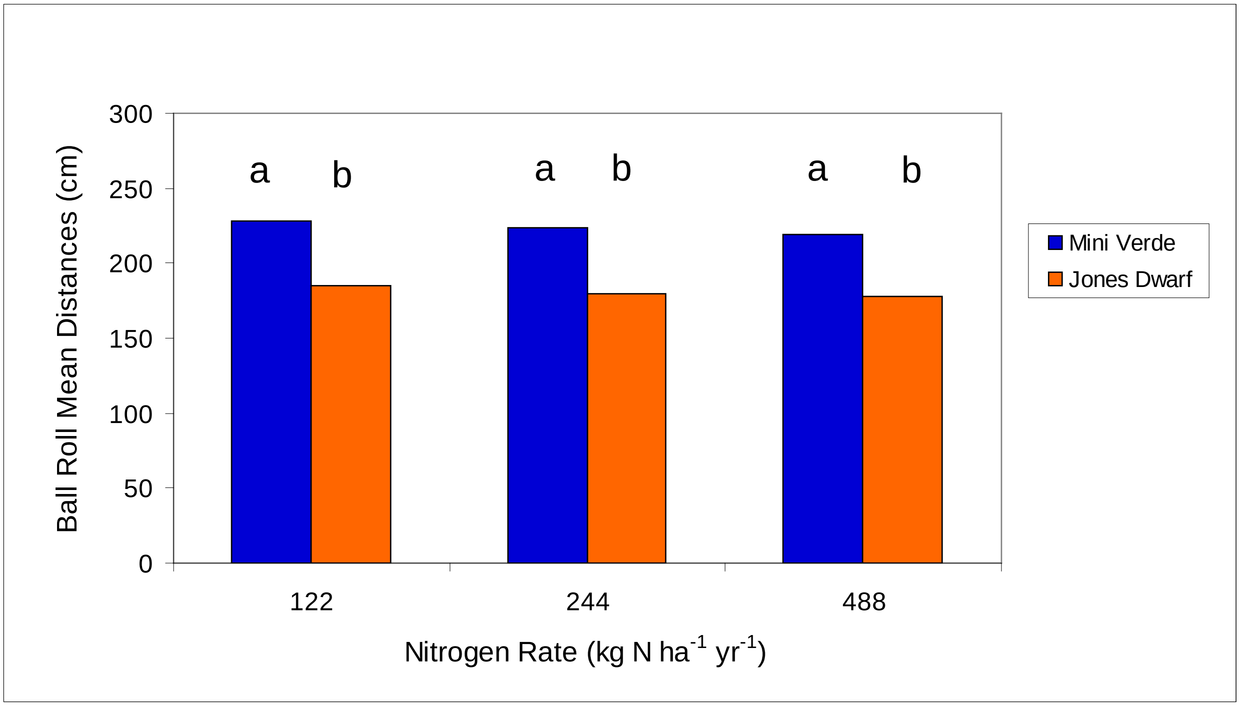


B)

Figure 3-7. Effect of nitrogen rate on the overall mean ball roll distance in 2008 for A) Paspalum cultivars, B) Bermuda cultivars, and in 2009 for C) Paspalum cultivars, D) Bermuda cultivars. Letters indicate statistical differences across nitrogen rates as determined by Duncan mean square separation at α = 0.05.



C)



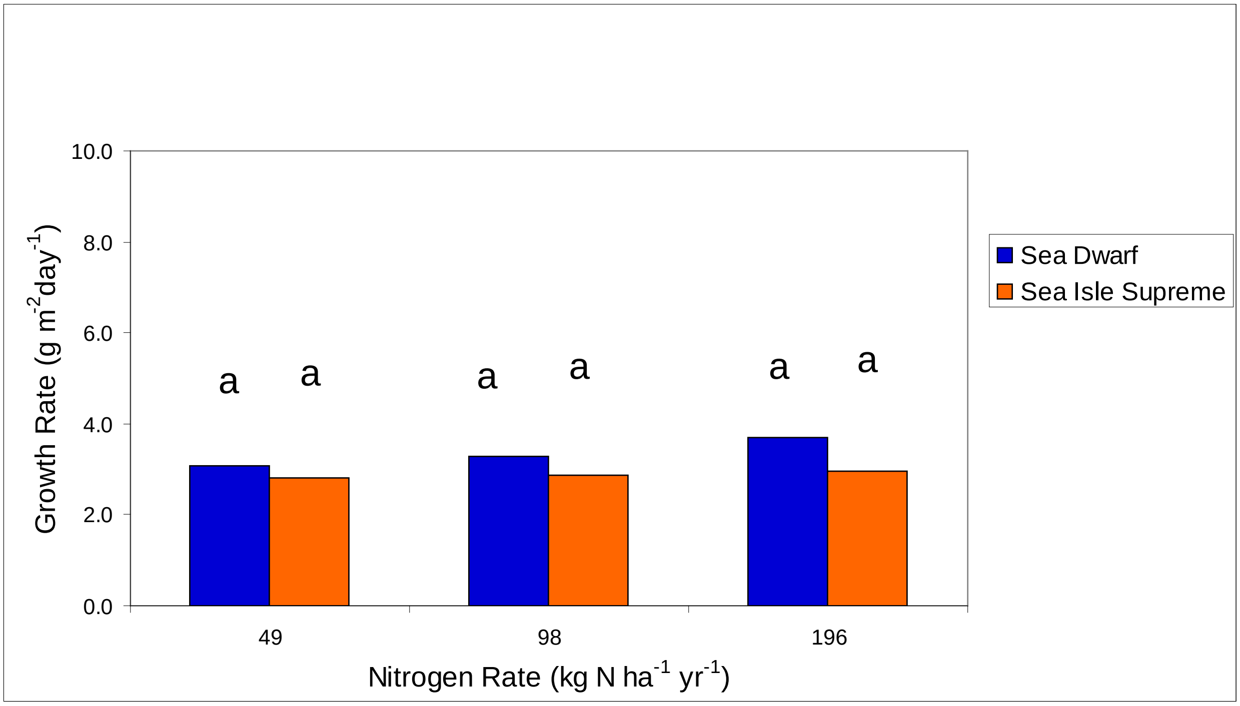
D)

Figure 3-7. Continued

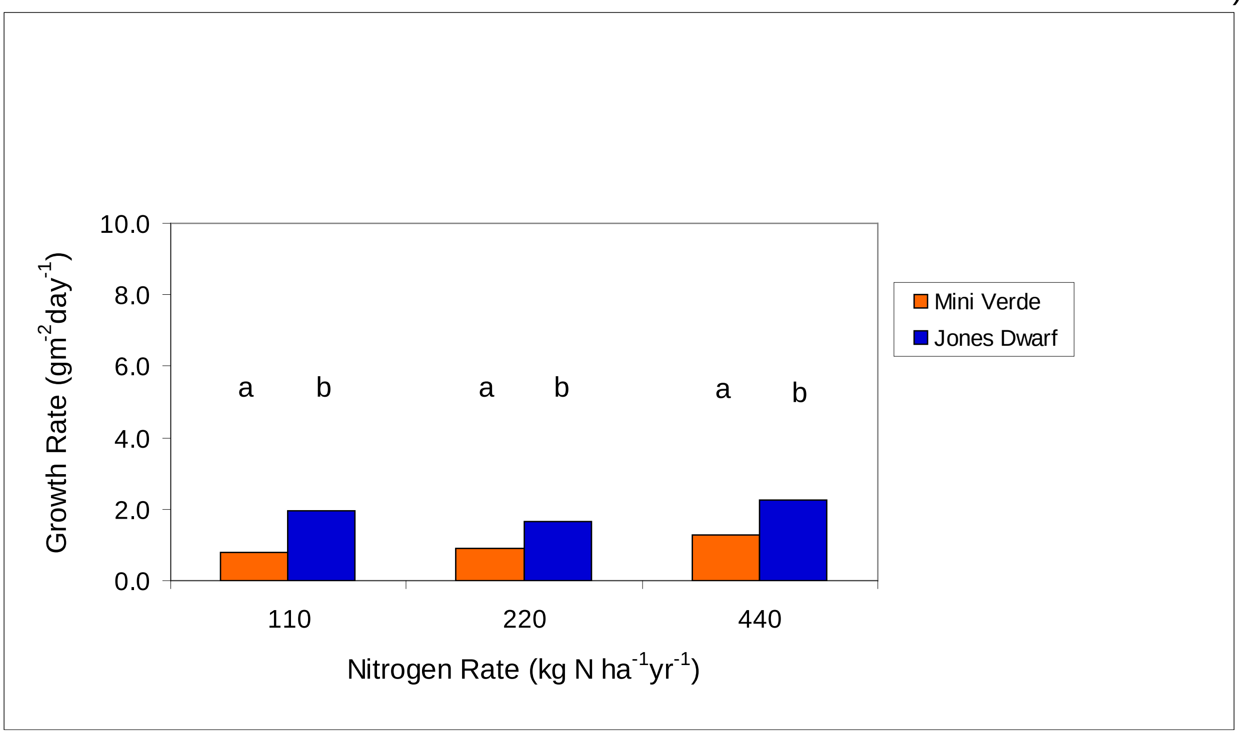
Table 3-1. Ball roll distance of paspalum cultivars in response to management practices and N rate 2008 and 2009.

2008			30 Days Evaluation Period 1st	2nd	3rd	4th	5th
Treatments	T	N	------------Ball Roll distance (cm) ------------				
	mm	Kg ha^{-1}yr^{-1}					
Sea Dwarf		49	148	152	197	177	151
		98	145	152	193	173	145
		196	135	145	184	173	136
	3.2		144	155	195	175	147
	1.6		142	145	188	174	141
			P Value				
Top (T)			ns	ns	ns	ns	ns
TxN			ns	ns	ns	ns	ns
Nitrogen rate (N)			0.0291*	ns	ns	ns	ns
Sea Isle Supreme		49	150	153	179	164	142
		98	144	144	175	159	137
		196	138	147	169	163	132
	3.2		147	154	177	167	142
	1.6		141	142	171	157	131
			P Value				
Top (T)			ns	ns	ns	ns	ns
TxN			ns	ns	ns	ns	ns
Nitrogen rate (N)			0.028*	ns	ns	ns	ns

2009			30 Days Evaluation Period 1st	2nd	3rd	4th
Treatments	V	N	------------Ball Roll distance (cm) ------------			
	freq	kg ha-1 yr-1				
Sea Dwarf		12	152	208	219	173
		24	151	204	214	168
		49	146	195	210	165
	High		154	208	223	171
	Low		145	197	206	166
			P Value			
Sea Dwarf						
Verticutting (V)			n.s	n.s	n.s	n.s
VxN			n.s	n.s	n.s	n.s
Nitrogen rate (N)			n.s	n.s	n.s	n.s
Sea Isle Supreme		12	153	183	208	178
		24	154	182	203	179
		49	155	179	199	176
	High		159	189	213	180
	Low		149	175	194	176
			P Value			
Sea Isle Supreme						
Verticut (V)			n.s	0.0442*	n.s	n.s
VxN			n.s	n.s	n.s	n.s
Nitrogen rate (N)			n.s	n.s	n.s	n.s

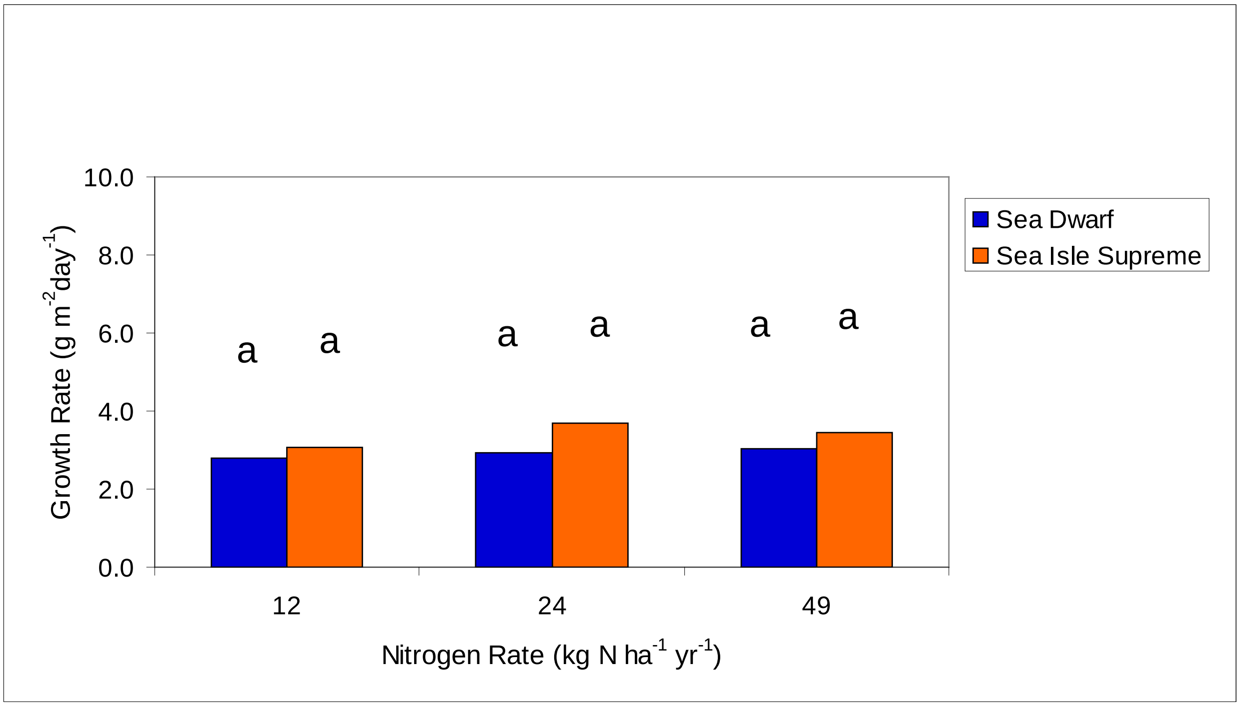


A)

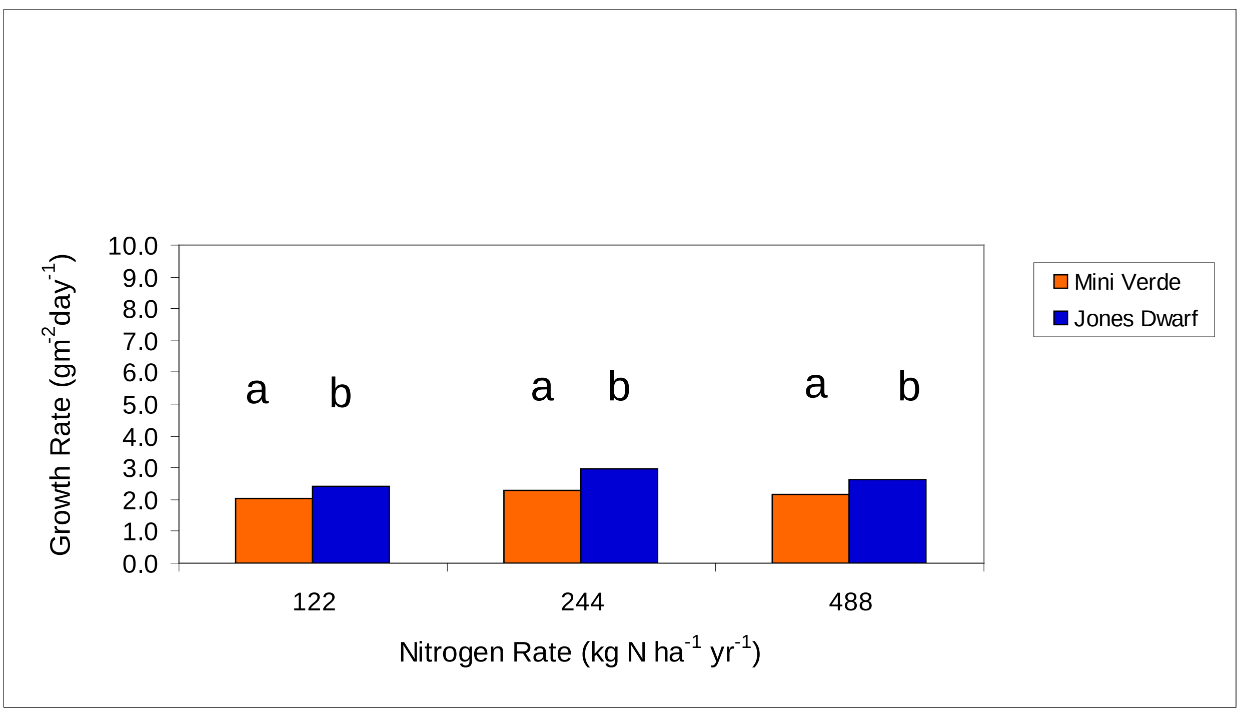


B)

Figure 3-8. Effect of nitrogen rate on the overall mean growth rate in 2008 for A) Paspalum cultivars, B) Bermuda cultivars, and in 2009 for C) Paspalum cultivars, D) Bermuda cultivars Paspalum cultivars. Letters indicate statistical differences across nitrogen rates as determined by Duncan mean square separation at α = 0.05.



C)



D)

Figure 3-8 Continued

Table 3-2. Growth rate of bermuda cultivars in response to management practices and N rate in 2009.

			30 Days Evaluation Period			
			1st	2nd	3rd	4th
Treatments	T	N	Growth Rate			
	mm	kg ha-1 yr-1	(g/m2/day)			
Mini Verde		110	0.28	0.39	1.08	1.42
		220	0.29	0.52	1.30	1.55
		440	0.25	0.91	1.88	2.10
	3.2		0.27	0.60	1.29	1.71
	1.6		0.27	0.62	1.55	1.67
			P Value			
Top (T)			ns	ns	0.042	ns
TxN			ns	ns	ns	ns
Nitrogen rate (N)			ns	0.0001*	0.0005*	0.0385*
Jones Dwarf		110	0.56	1.58	2.07	3.69
		220	0.62	1.28	2.27	2.42
		440	0.62	1.76	3.42	3.30
	3.2		0.70	1.47	2.26	3.91
	1.6		0.49	1.61	2.92	2.38
			P Value			
Top (T)			ns	ns	ns	ns
TxN			ns	ns	ns	ns
Nitrogen rate (N)			ns	ns	0.0077*	ns

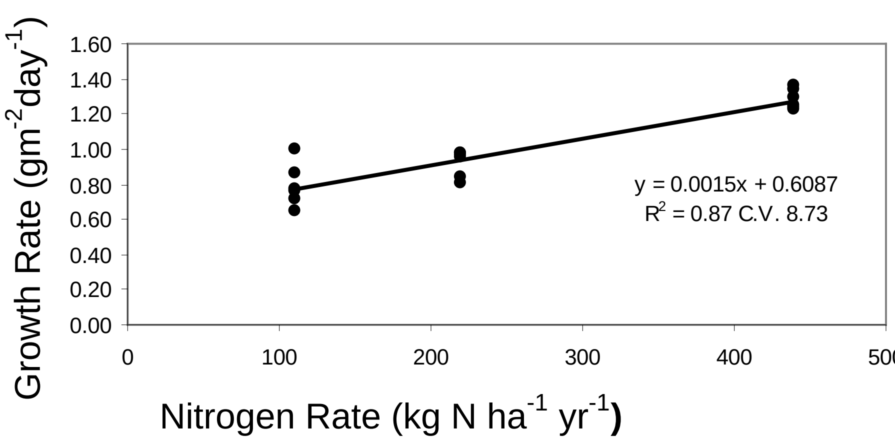
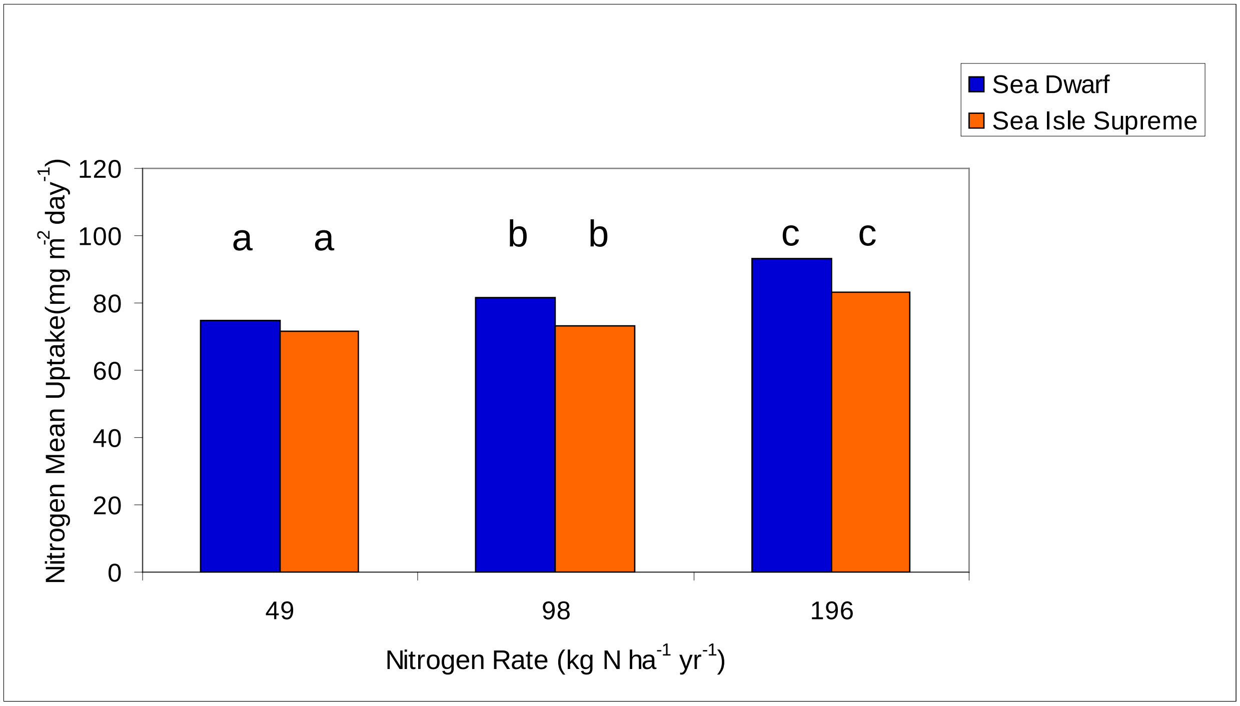
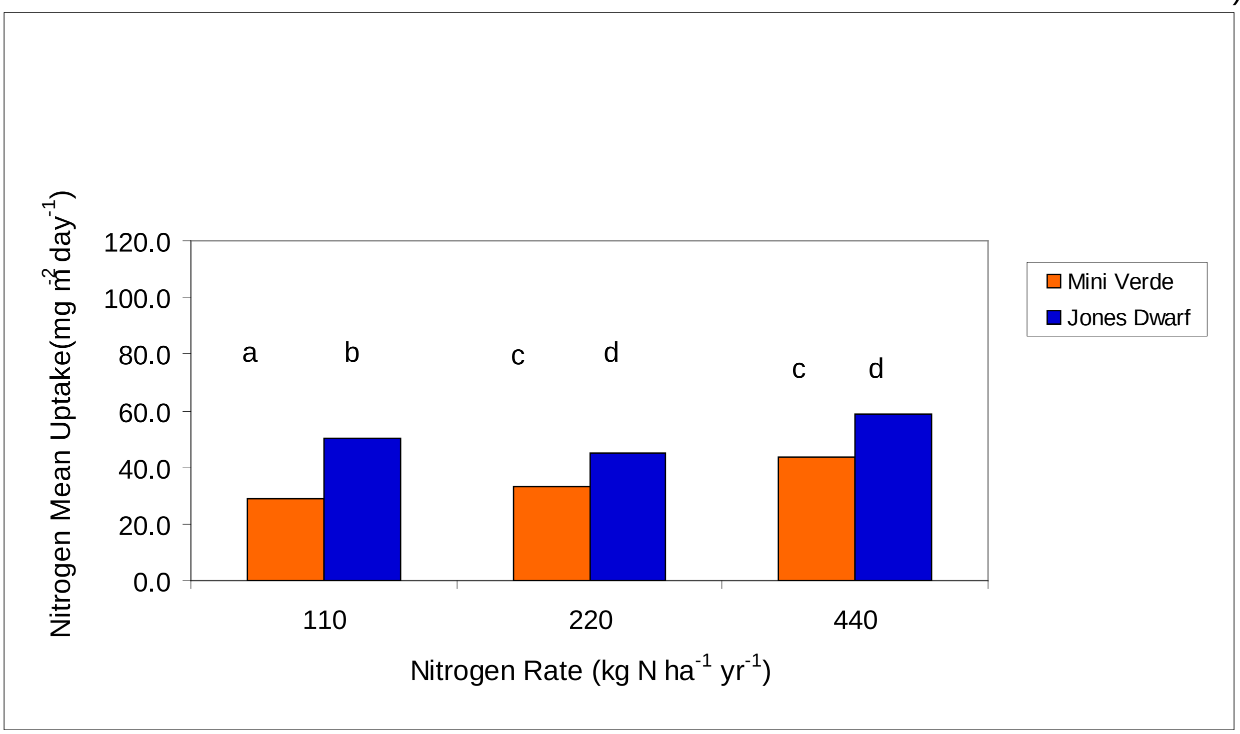


Figure 3-9. Effect of nitrogen rate on Mini Verde overall mean growth rate in 2008.

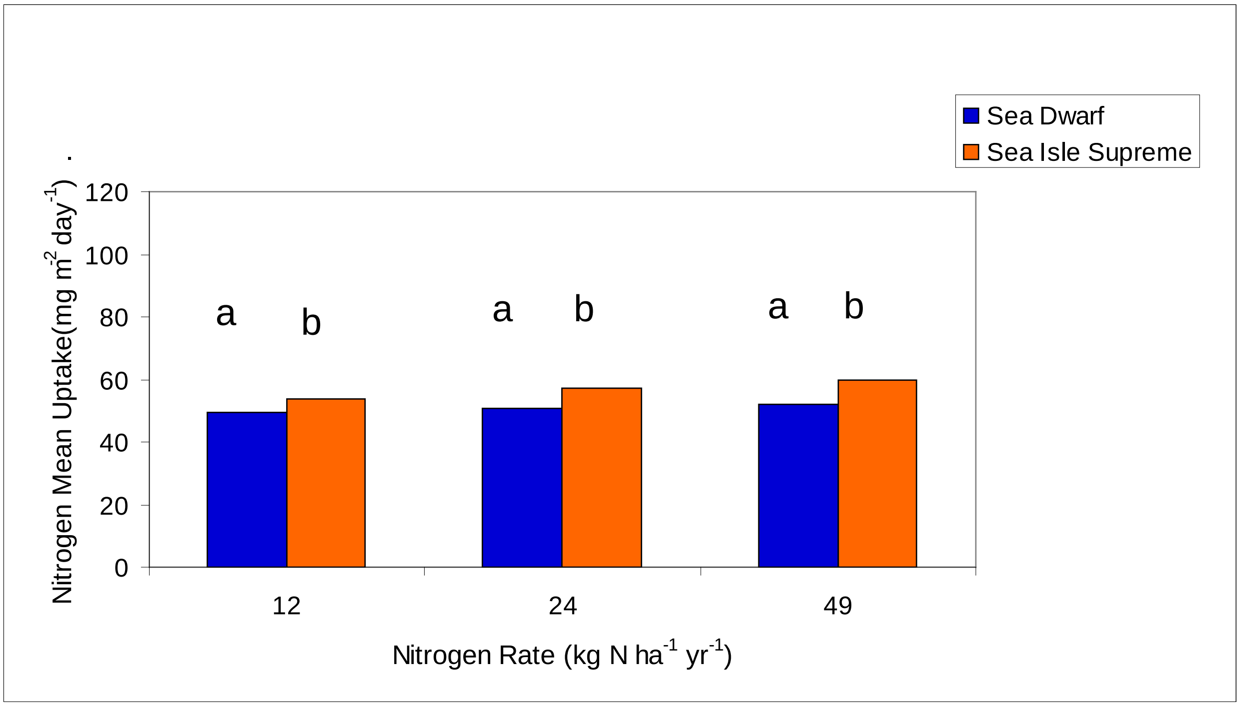


A)

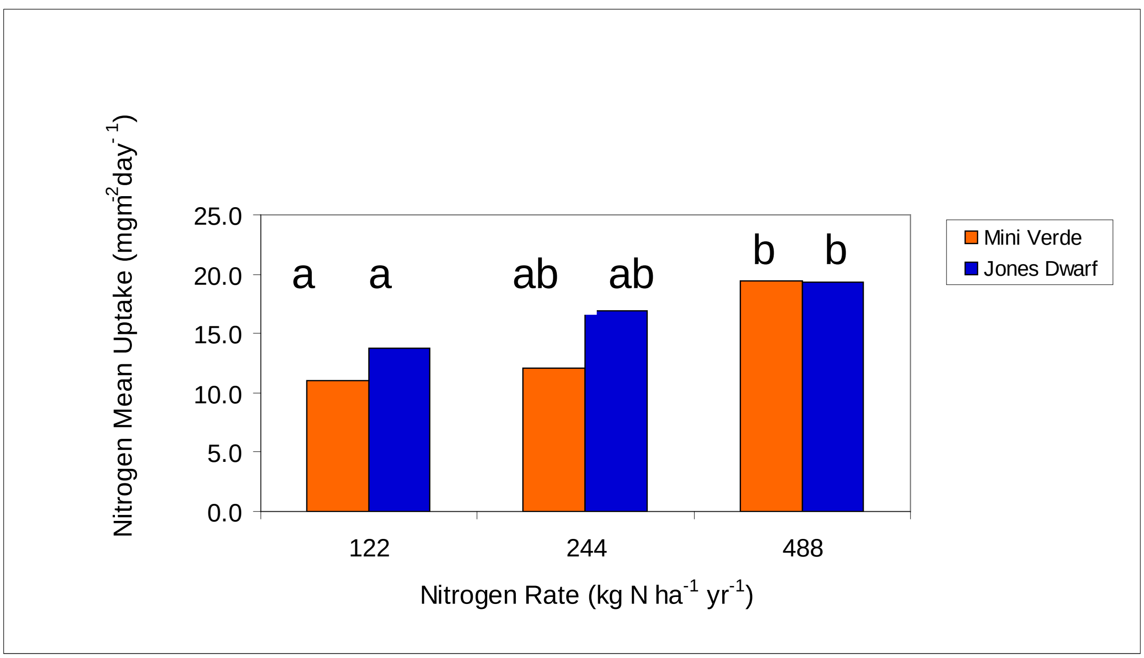


B)

Figure 3-10. Effect of nitrogen rate on the overall nitrogen uptake in 2008 for A) Paspalum cultivars, B) Bermuda cultivars, and in 2009 for C) Paspalum cultivars, D) Bermuda cultivars. Letters indicate statistical differences across nitrogen rate as determined by Duncan mean square separation at $\alpha = 0.05$.



C)



D)

Figure 3-10 Continued

Table 3-3. Nitrogen uptake of paspalum cultivars and bermuda cultivars in respond to management practices and N rate in 2008.

			30 Days Evaluation Period				
			1st	2nd	3rd	4th	5th
Treatments	T	N	Nitrogen Uptake				
	mm	kg ha^{-1}yr^{-1}	(mg m^{-2} day^{-1})				
Sea Dwarf		48.8	73.8	63.3	78.4	82.3	76.7
		97.6	78.0	69.8	80.9	96.5	82.2
		196	90.9	82.0	99.7	113.2	81.2
	3.2		88.2	72.4	84.6	116.2	84.7
	1.6		73.5	71.0	88.1	78.4	75.4
			P Value				
Top (T)			ns	ns	ns	ns	ns
TxN			ns	ns	ns	ns	ns
Nitrogen rate (N)			ns	0.0346*	ns	ns	ns
Sea Isle Supreme		48.8	22.7	77.0	63.6	90.2	103.9
		97.6	26.6	81.3	63.1	102.5	93.1
		196	36.1	98.4	74.0	126.6	81.6
	3.2		28.3	85.6	72.6	97.4	80.1
	1.6		28.6	85.5	61.3	115.4	105.6
			P Value				
Top (T)			ns	ns	ns	ns	ns
TxN			ns	ns	ns	ns	ns
Nitrogen rate (N)			0.0149*	0.0363*	ns	0.004*	ns

			30 Days Evaluation Period			
			1st	2nd	3rd	4th
Treatments	T	N	Nitrogen Uptake			
	mm	kg ha^{-1} yr^{-1}	(mg m^{-2} day^{-1})			
Mini Verde		110	5.7	15.0	41.4	26.1
		220	6.3	20.9	49.3	26.7
		440	6.6	37.2	76.8	45.9
	3.20		6.4	23.1	51.6	28.7
	1.60		5.9	25.6	60.1	37.1
			P Value			
Top (T)			ns	ns	ns	ns
TxN			ns	ns	ns	ns
Nitrogen rate (N)			ns	0.0001*	0.0002**	ns
Jones Dwarf		110	7.9	40.2	62.8	89.86
		220	11.1	40.3	68.0	59.91
		440	14.9	55.7	94.9	69.93
	3.20		12.9	45.0	70.6	90.38
	1.60		9.7	45.8	79.9	56.09
			P Value			
Top (T)			ns	ns	ns	0.0493
TxN			ns	ns	ns	ns
Nitrogen rate (N)			0.0285*	0.0168**	0.0007***	ns

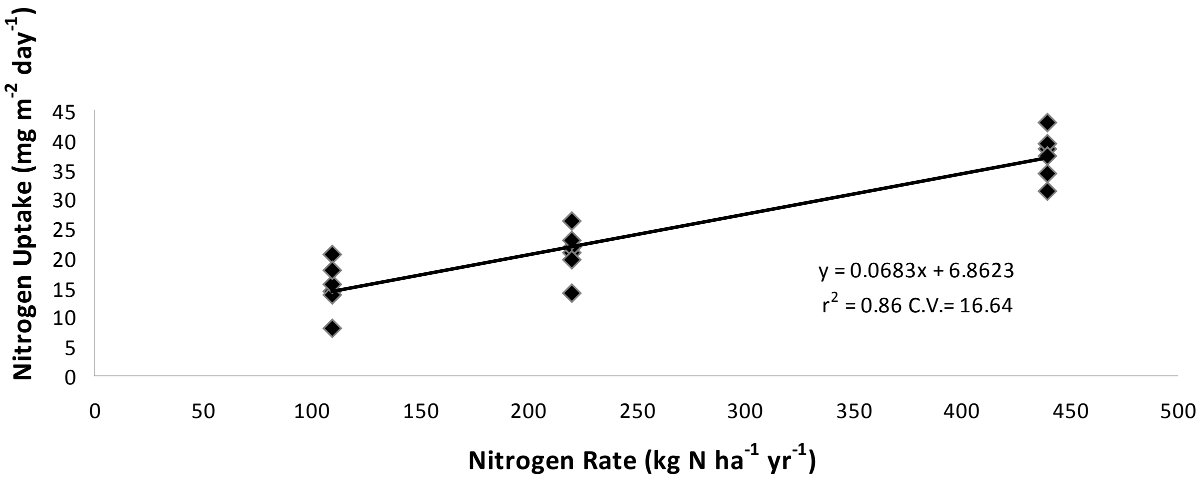


Figure 3-11. Effect of nitrogen rate on Mini Verde bermudagrass nitrogen uptake 2nd evaluation period in 2008.

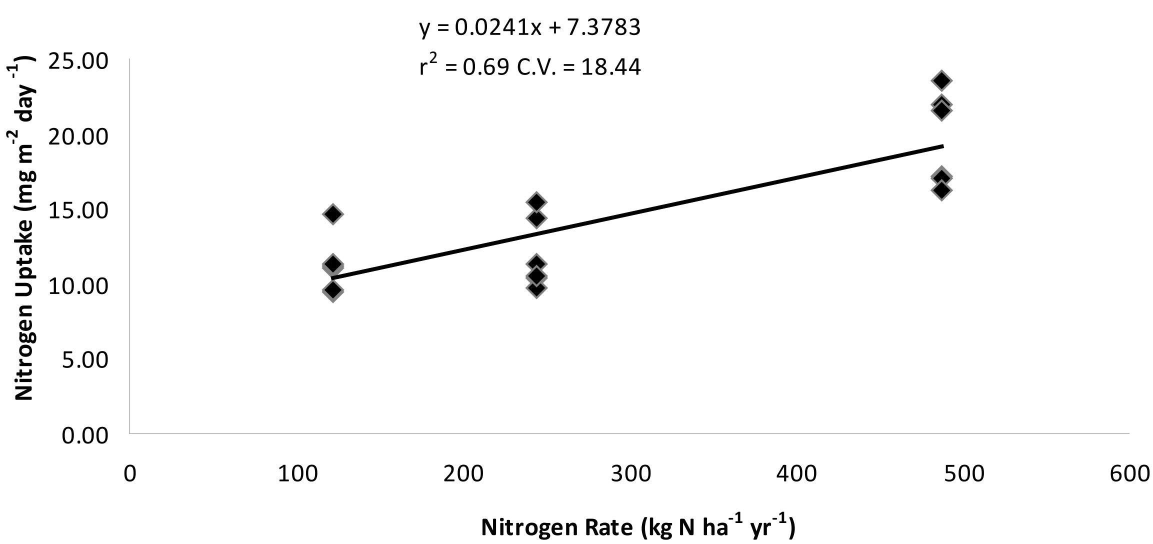
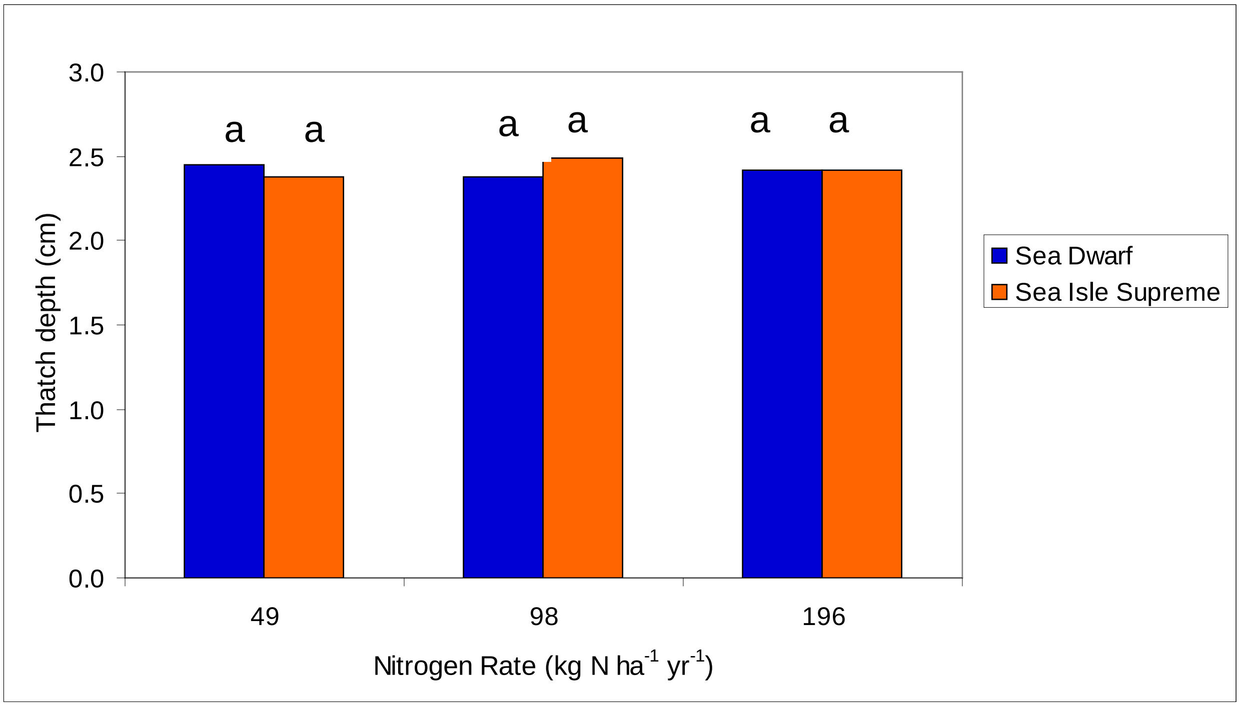
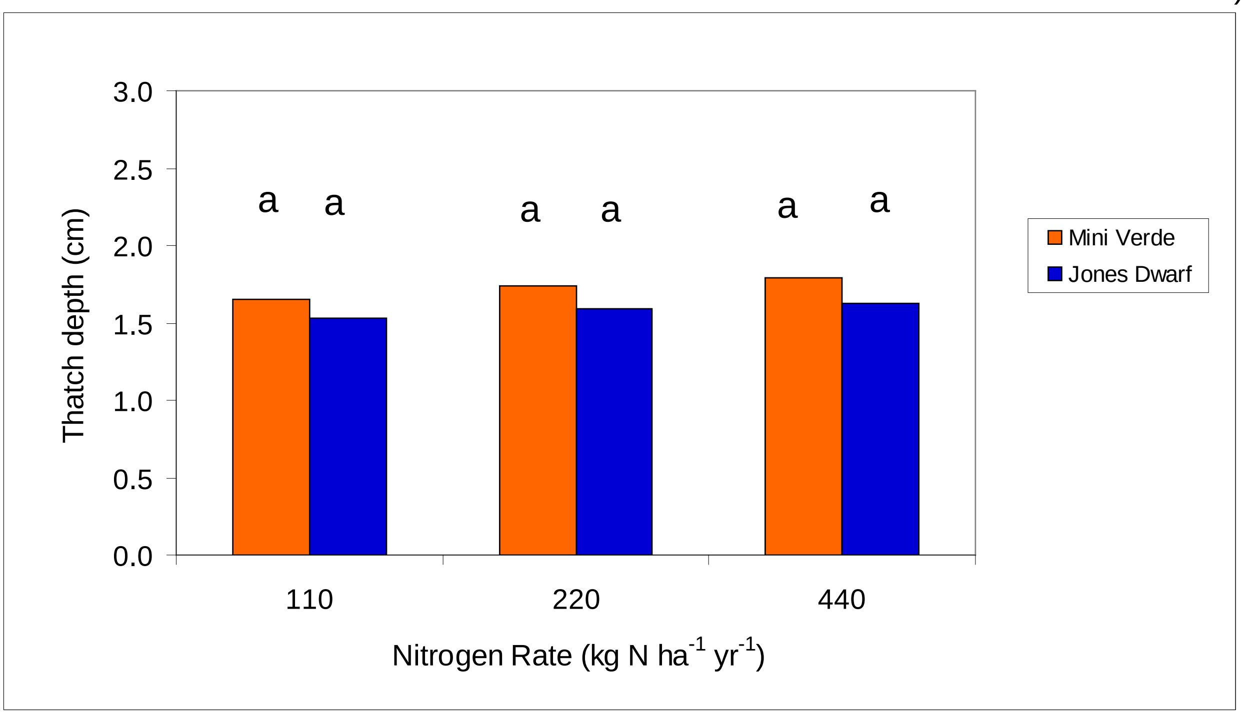


Figure 3-12. Effect of nitrogen rate on the overall nitrogen uptake for Mini Verde in 2009

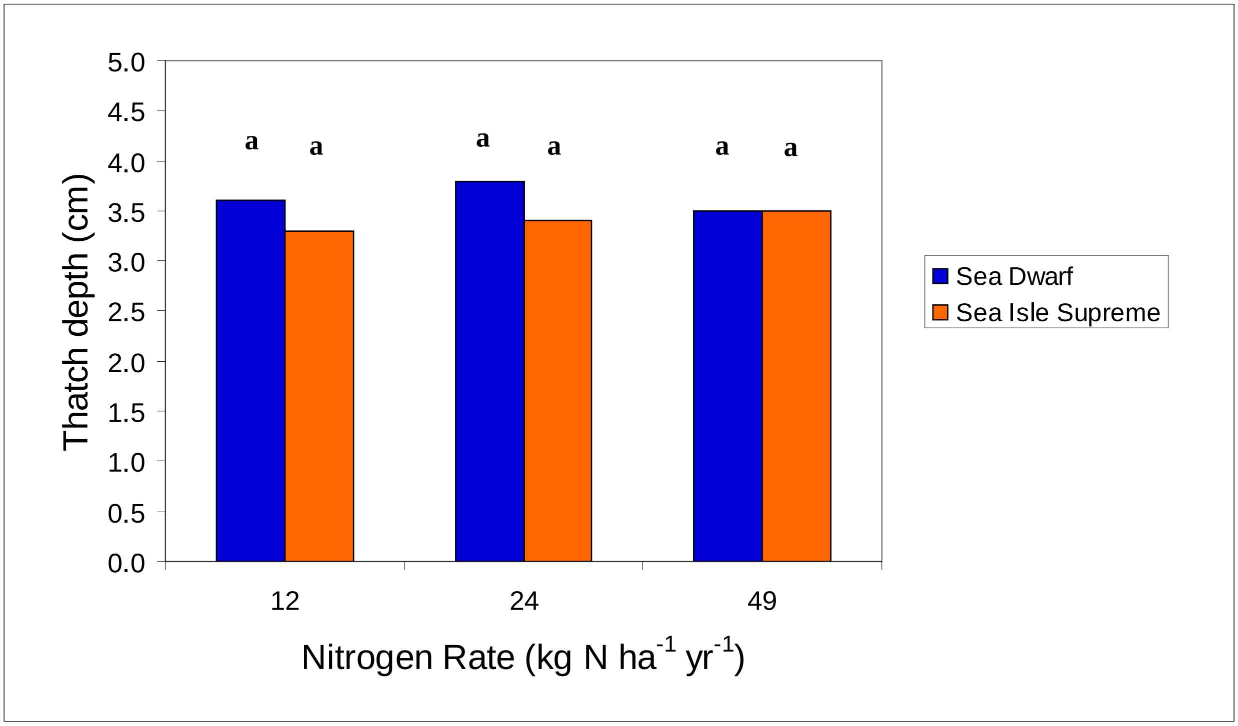


A)

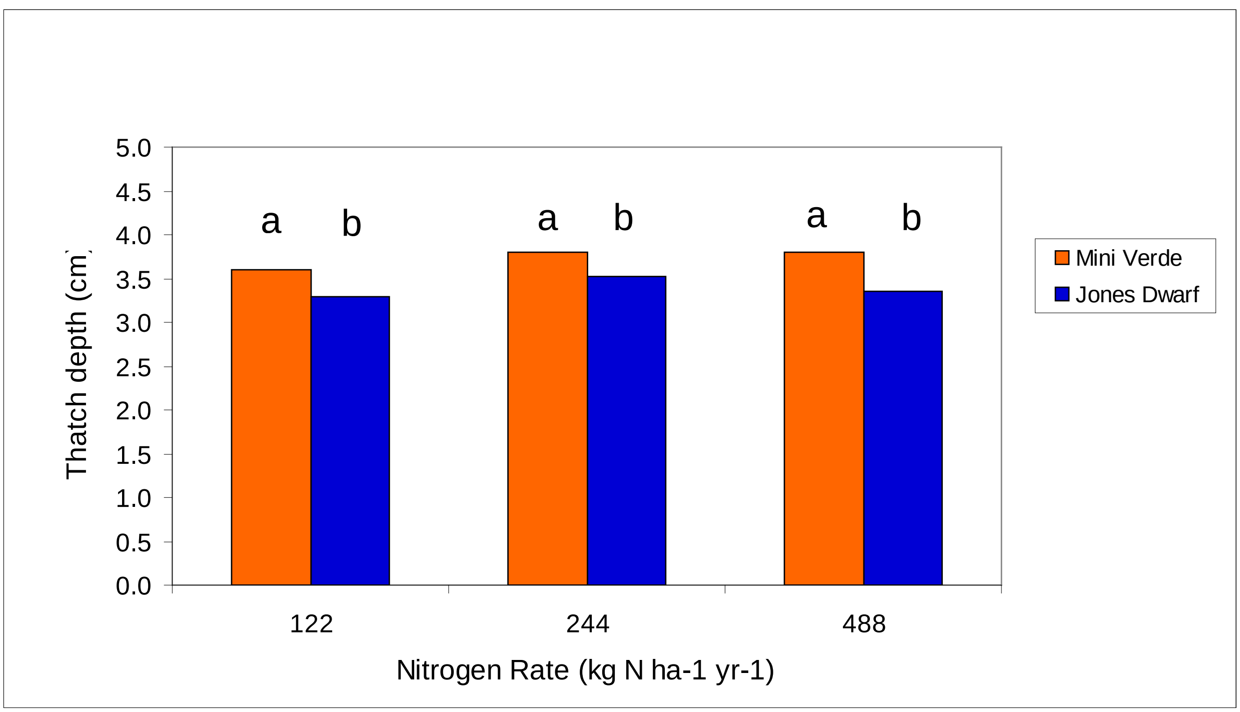


B)

Figure 3-13. Effect of nitrogen rate on the overall thatch depth in 2008 for A) Paspalum cultivars, B) Bermuda cultivars, and in 2009 for C) Paspalum cultivars, D) Bermuda cultivars Letters indicate statistical differences across nitrogen rate as determined by Duncan mean square separation at α = 0.05

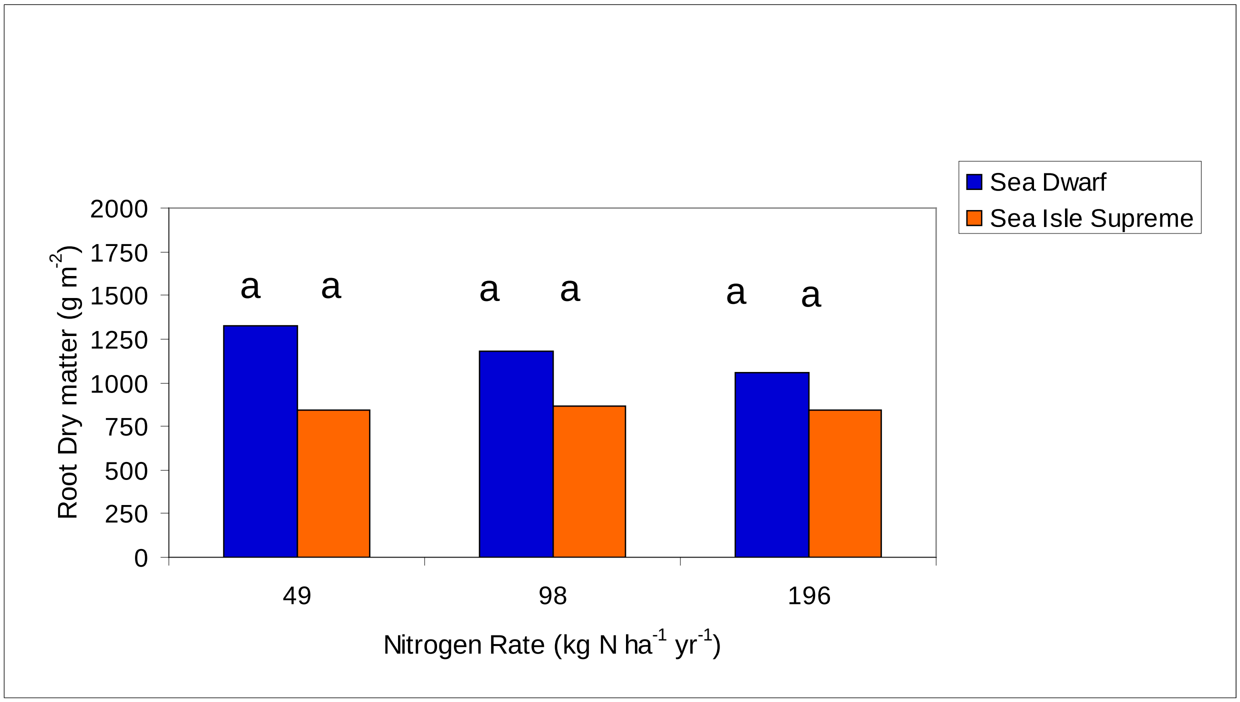


C)

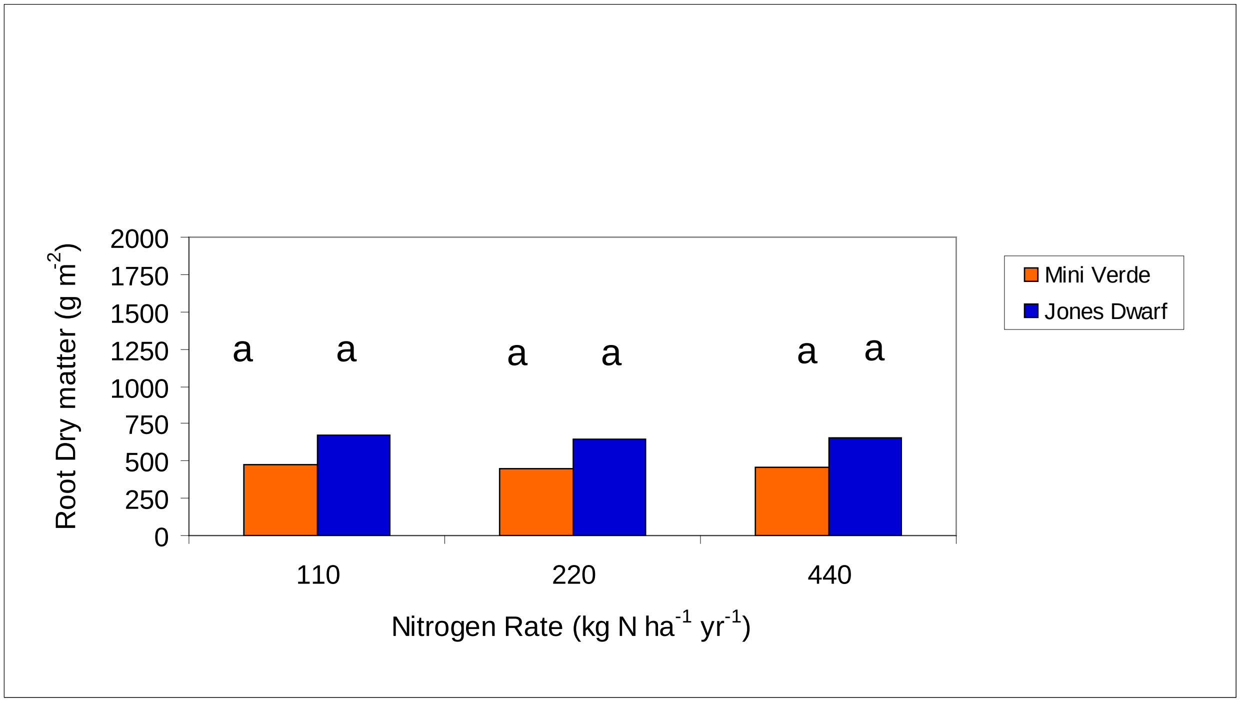


D)

Figure 3-13. Continued

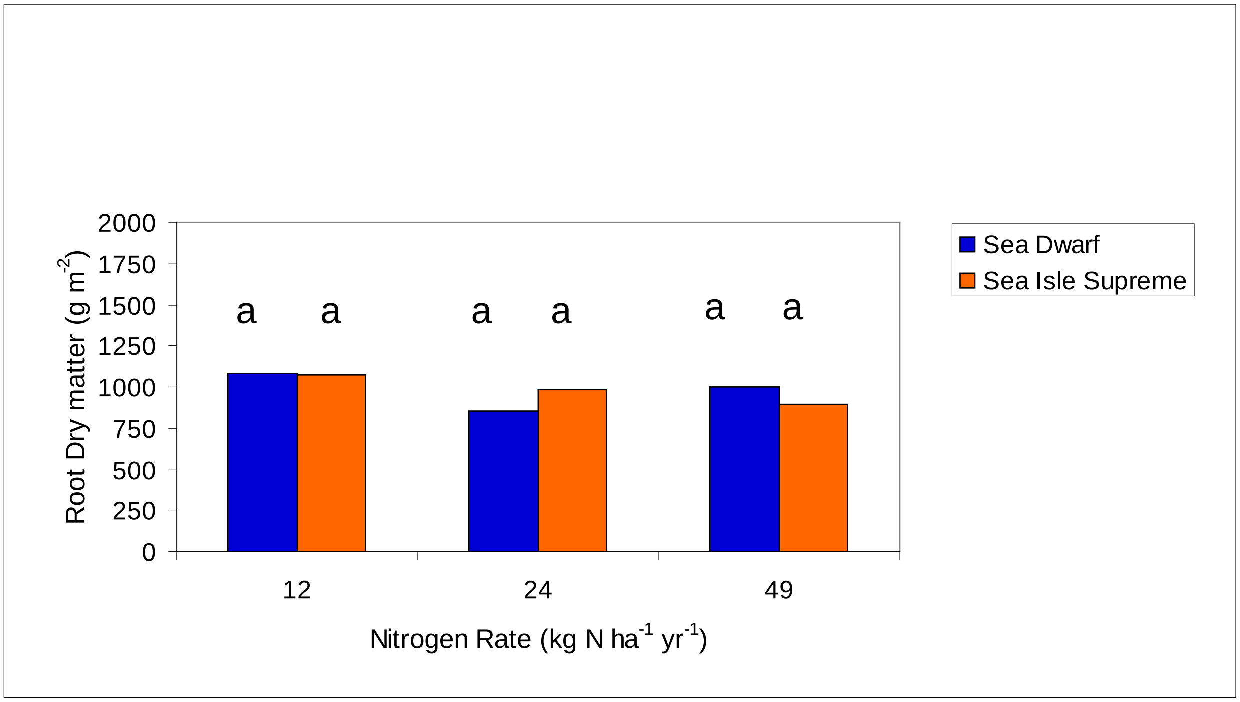


A)

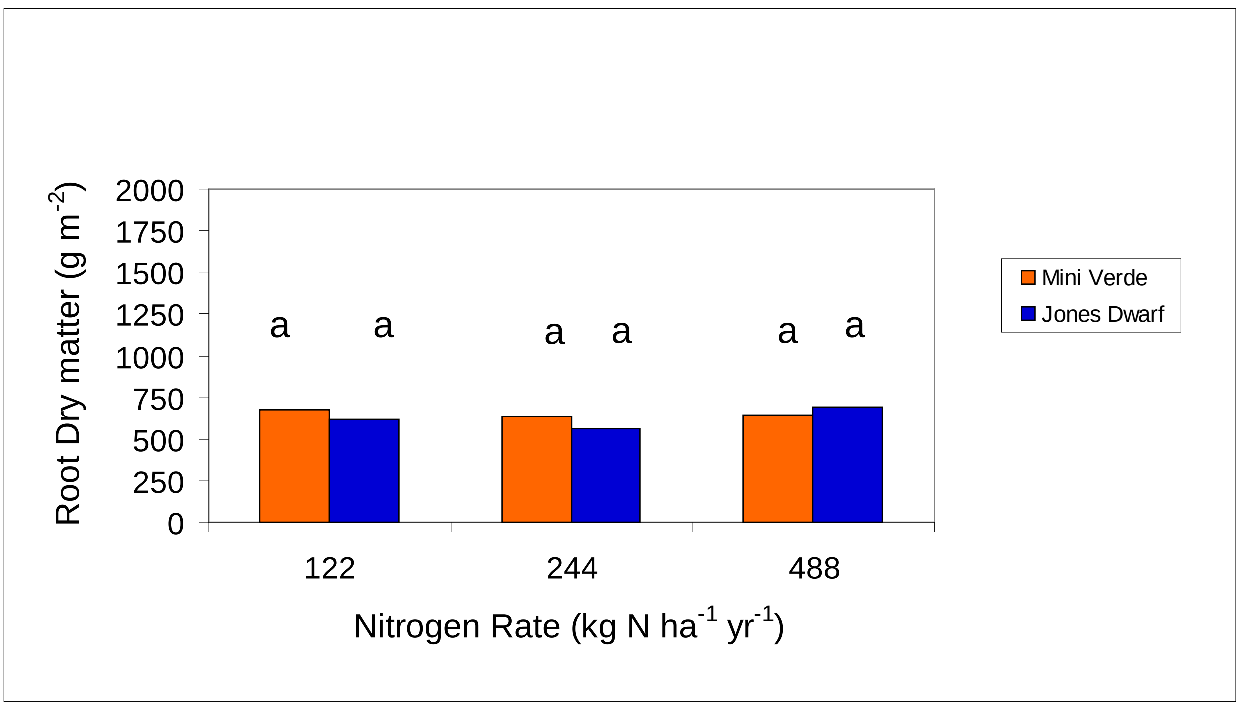


B)

Figure 3-14. Effect of nitrogen rate on the overall roots dry matter in 2008 for A) Paspalum cultivars, B) Bermuda cultivars, and in 2009 for C) Paspalum cultivars, D) Bermuda cultivars Paspalum cultivars. Letters indicate statistical differences across nitrogen rate as determined by Duncan mean square separation at α = 0.05.

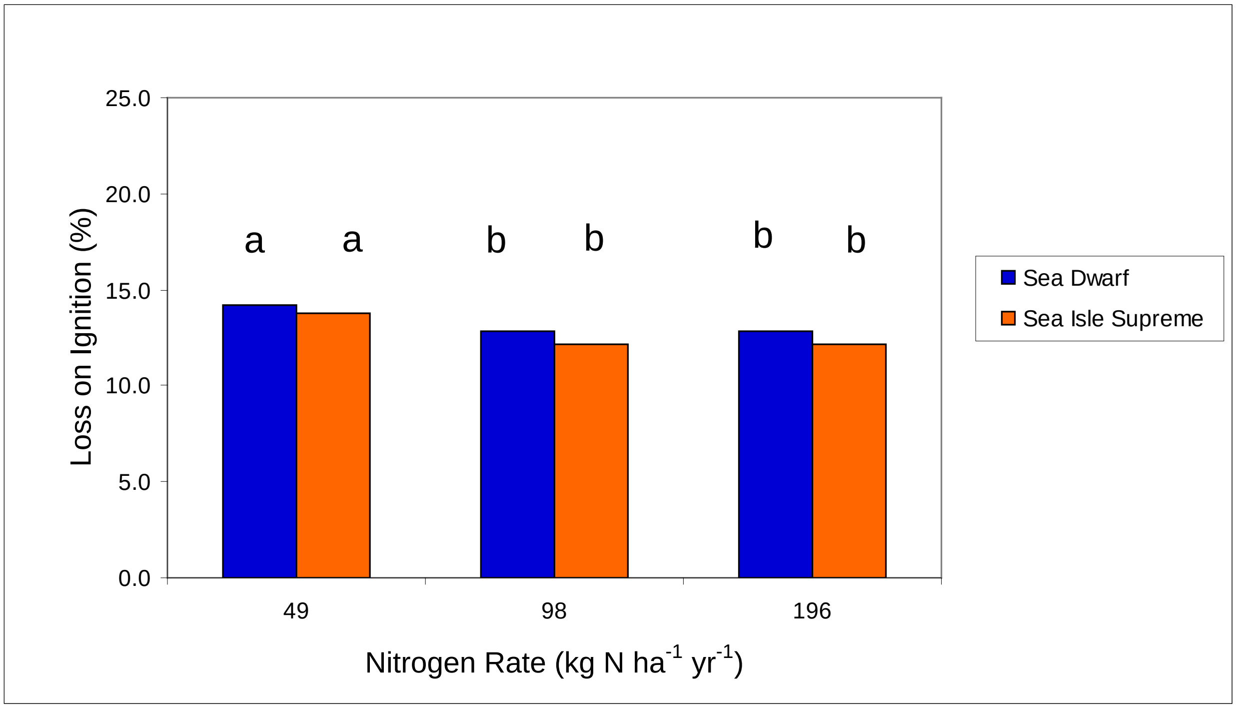


C)

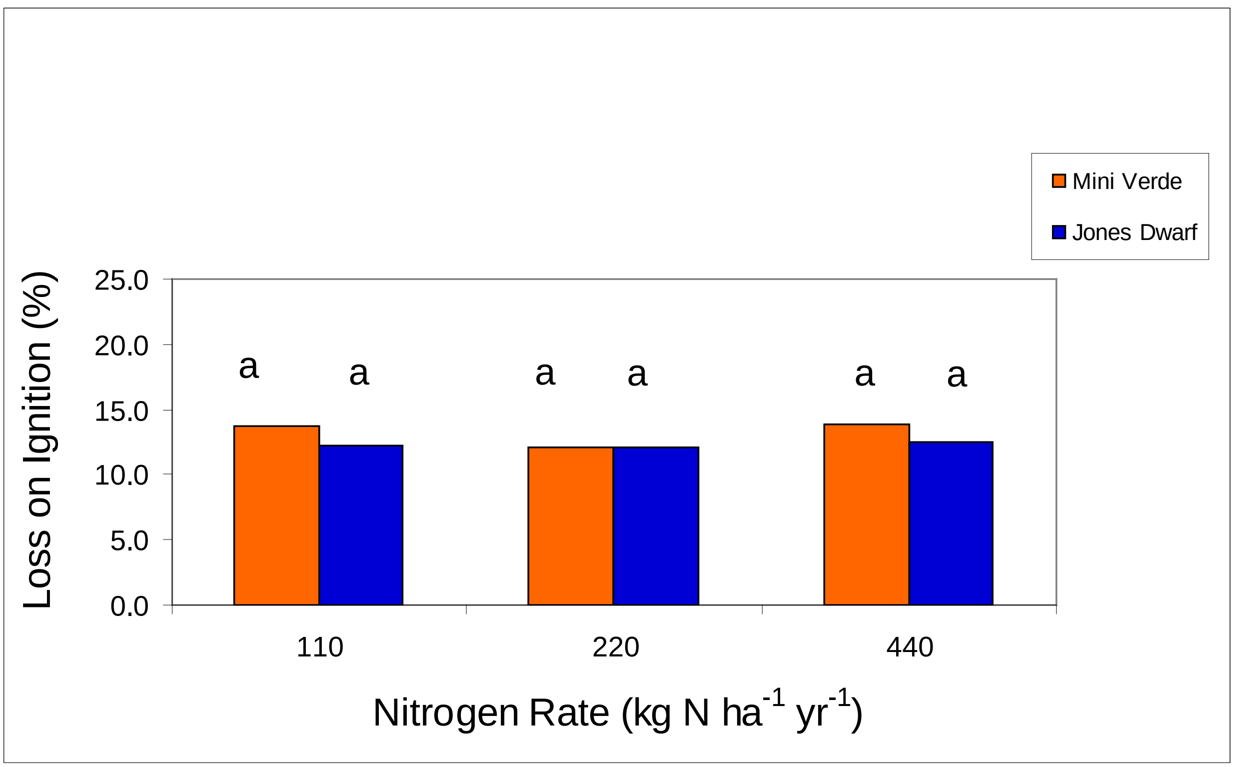


D)

Figure 3-14. Continued

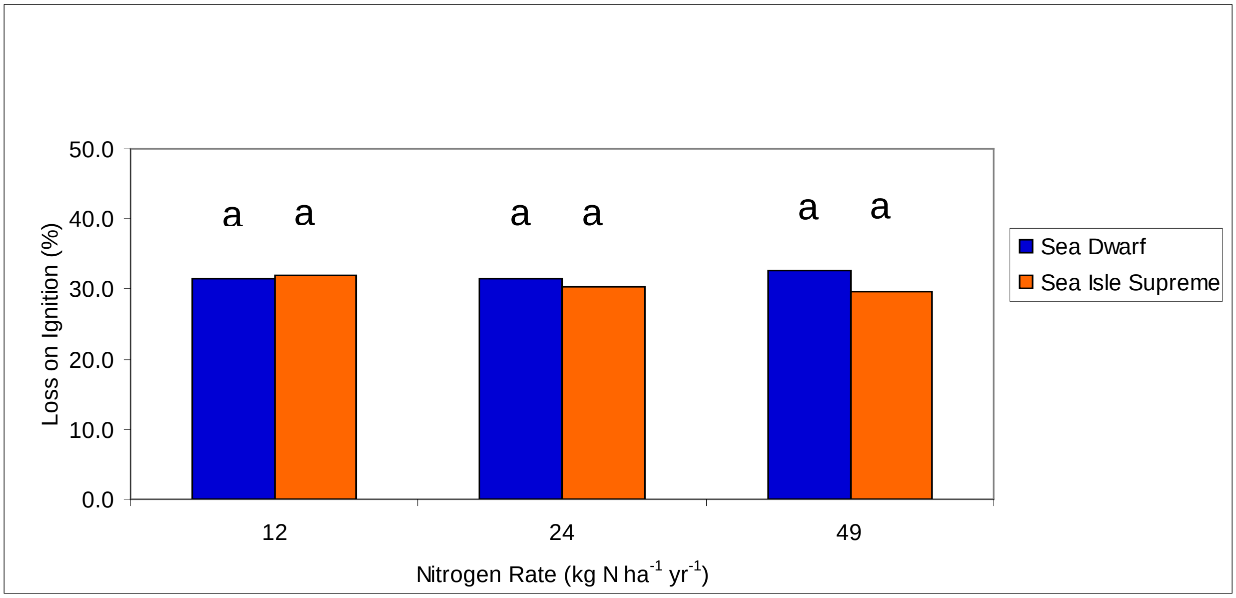


A)

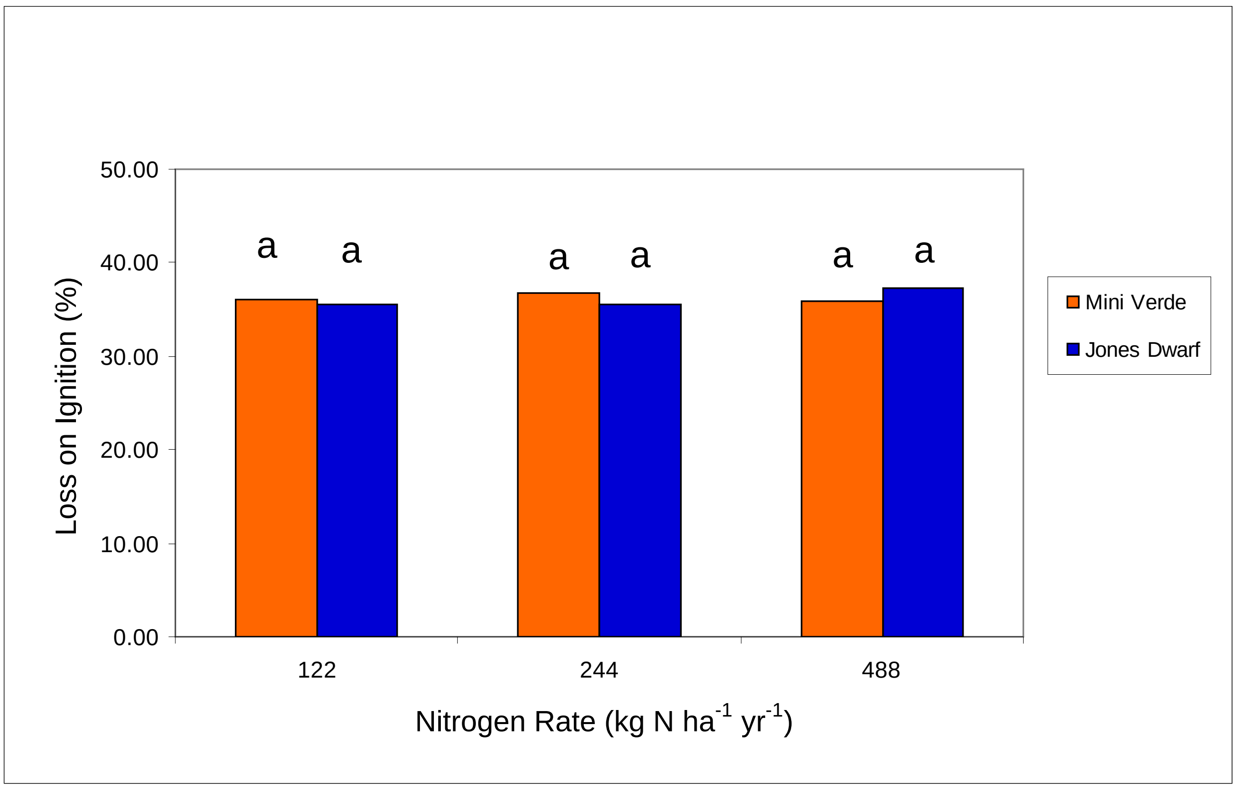


B)

Figure 3-15. Effect of nitrogen rate on the overall loss on ignition in 2008 for A) Paspalum cultivars, B) Bermuda cultivars, and in 2009 for C) Paspalum cultivars, D) Bermuda cultivars. Letters indicate statistical differences across nitrogen rate as determined by Duncan mean square separation at $\alpha = 0.05$.



C)



D)

Figure 3-15. Continued

Table 3-4. Percent weight loss on ignition of bermuda cultivars in respond to management practices and N rate in 2008.

			30 Days Evaluation Period				
			1st	2nd	3rd	4th	5th
Treatments	T	N	--------Loss on ignition (%)---				
	mm	kg ha-1 yr-1					
Mini Verde		110	3.6	4.3	6.5	26.2	28.2
		220	3.6	5.3	6.3	24.1	21.4
		440	3.8	4.8	5.8	26.5	28.3
	3.2		3.7	4.6	6.4	28.0	24.4
	1.6		3.7	5.0	6.1	23.3	27.5
			P Value				
Topdressing (T)			ns	ns	ns	ns	ns
TxN			ns	ns	ns	ns	ns
Nitrogen rate (N)			ns	ns	ns	ns	0.045*
Jones Dwarf		110	3.7	4.5	5.0	19.3	28.5
		220	3.9	4.4	4.8	20.5	27.0
		440	4.0	4.9	4.6	19.1	31.0
	3.2		3.6	3.9	5.0	21.0	30.0
	1.6		4.1	4.6	4.7	18.2	27.8
			P Value				
Top (T)			ns	ns	ns	ns	ns
TxN			ns	ns	ns	ns	ns
Nitrogen rate (N)			ns	ns	ns	ns	ns

Table 3-5. Cultural practices and total maintenance cost of two paspalum cultivars (Sea Dwarf and Sea Isle Supreme) grown in putting greens of 125.4 m^2.

Cultural Practice	Amount	Units	Total Times	Frequency	Price	Units	Total
Mowing							2064
Equipment	1.5	hr	86	4 times/week	8.0	hour	1032
Labor	1.5	hr	86	4 times/week	8.0	hour	1032
Aerification							92
Equipment	2	hr	2	twice/year	15.0	hour	60
Labor	2	hr	2	twice/year	8.0	hour	32
Irrigation							300
Equipment	1	days	150	every day	1.0	day	150
Water	1	days	150	every day	1.0	day	150
Topdressing							640
Equipment	2	hr	4	once/month	25.0	hour	200
Sand	1.6	mm	4	once/month	50.0	mm sand	320
Labor	2	hr	4	once/month	15.0	hour	120
Fertilization							137.5
Nitrogen Fertilization	12.25	kgN ha^{-1} yr^{-1}	4	four/year	1.5	kg N	73.5
Labor	2	hr	4	four/year	8.0	hour	64
Verticutting							560
Equipment	2.5	hr	8	twice/month	20.0	hour	400
Labor	2.5	hr	8	twice/month	8.0	hour	160
Pest Management Practices							1017
Fungicides	2.9	kg ha^{-1}	6	six/year	10.3	lbs	160
Equipment	2.5	hr	6	six/year	20.0	hour	300
Herbicides	910	g ha^{-1}	1	once/year	1.3	oz	17
Equipment	2.5	hr	1	once/year	20.0	hour	50
Insectides	3.1	kg ha^{-1}	4	four/year	3.2	lbs	36
Equipment	2.5	hr	4	four/year	20.0	hour	200
Wetting Agent	98.1	g ha^{-1}	5	five/year	0.6	oz	4
Equipment	2.5	hr	5	five/year	20.0	hour	250
		Total Cost					4811

Table 3-6. Cultural practices and total maintenance cost of two bermuda cultivars (Mini Verde and Jones Dwarf) grown in putting greens of 125.4 m^2.

Cultural Practice	Amount	Units	Total Times	Frequency	Price	Units	Total
Mowing							2064
Equipment	1.5	hr	86	4 times/week	8.0	hour	1032
Labor	1.5	hr	86	4 times/week	8.0	hour	1032
Aerification							92
Equipment	2	hr	2	twice/year	15.0	hour	60
Labor	2	hr	2	twice/year	8.0	hour	32
Irrigation							300
Equipment	1	days	150	every day	1.0	day	150
Water	1	days	150	every day	1.0	day	150
Topdressing							640
Equipment	2	hr	4	once/month	25.0	hour	200
Sand	1.6	mm	4	once/month	50.0	mm sand	320
Labor	2	hr	4	once/month	15.0	hour	120
Fertilization							805.5
Nitrogen Fertilization	49	kgN ha^{-1} yr^{-1}	9	nine/year	1.5	kg N	661.5
Labor	2	hr	9	nine/year	8.0	hour	144
Verticutting							280
Equipment	2.5	hr	4	once/month	20.0	hour	200
Labor	2.5	hr	4	once/month	8.0	hour	80
Pest Management Practices							1017
Fungicides	2.9	kg ha^{-1}	6	six/year	10.3	lbs	160
Equipment	2.5	hr	6	six/year	20.0	hour	300
Herbicides	910	g ha^{-1}	1	once/year	1.3	oz	17
Equipment	2.5	hr	1	once/year	20.0	hour	50
Insectides	3.1	kg ha^{-1}	4	four/year	3.2	lbs	36
Equipment	2.5	hr	4	four/year	20.0	hour	200
Wetting Agent	98.1	g ha^{-1}	5	five/year	0.6	oz	4
Equipment	2.5	hr	5	five/year	20.0	hour	250
		Total Cost					5199

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BIOGRAPHICAL SKETCH

Ivan Mauricio Vargas Altamirano was born in Perez Zeledon, San Jose Costa Rica, in 1985. He grew up next to his family's animal production farm and coffee operation in the General Valley of the South Pacific of Costa Rica. After graduating from EARTH University with a "Licenciatura" degree as an Agronomic Engineer in 2006, Ivan soon moved to Gainesville, Florida, where he was admitted to the University of Florida to pursue a Master of Science degree in the Soil and Water Science Department with a specialization in soil fertility and turfgrass science. He received his Master of Science from University of Florida in the spring of 2010. Upon graduation in May 2010, Ivan plans to begin studying towards a Master in Business Administration (MBA) so that he may pursue a business/research career that involves collaboration between Latin America and the USA.