2014

Influence Of Sprigging and Nitrogen Rates On 'Celebration' Bermudagrass Establishment

Matthew Turner
Louisiana State University and Agricultural and Mechanical College

INFLUENCE OF SPRIGGING AND NITROGEN RATES ON ′CELEBRATION′ BERMUDAGRASS ESTABLISHMENT

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in

The School of Plant, Environmental and Soils Sciences

by
Matthew Turner
B.S., Louisiana State University and Agricultural and Mechanical College, 2009
May 2015

ACKNOWLEDGEMENTS

I would like express my sincere gratitude to my major professor, Dr. Jeffrey Beasley, and committee members Dr. Lewis Gaston and Ed Bush. I would also like to thank my fellow graduate students who helped make this project work.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Bermudagrass is grown on many athletic surfaces in the southern United States because of its aesthetics, vigorous growth, and excellent wear and stress tolerances. Establishment of bermudagrass vegetatively from sprigs provides an economical propagation method for large-acreage sites. During sprig establishment, irrigation and N are often applied at high application rates and/or frequencies to accelerate plant growth for faster, denser canopy coverage. Conventional wisdom suggests high rates of N applied more frequently accelerates bermudagrass growth to shorten the establishment duration for playability or susceptibility to erosion. However, during the establishment phase, low initial plant densities, frequent irrigation application, and high nitrogen (N) fertility can lead to increased risks of surface runoff, erosion, and nutrient movement. Therefore, an experiment was conducted to examine the factors of sprig plant rates at 80, 160, 320, and 480 bu ha^{-1} of bermudagrass cv. Celebration fertilized at 0, 12.5, 25, and 50 kg N ha^{-1} wk $^{-1}$ over an 8 week establishment period. Celebration planted at 360 or 480 bu ha^{-1} attained0 ≥85% canopy coverage and greater biomass 6 WAP at N applied at ≥12.5 kg N ha^{-1} wk^{-1}. Higher N application rates were not able to accelerate lower sprig planting rates of 80 and 160 bu ha^{-1}. In the second experiment, the effect of total solid and N losses were examined for sprig planting rates of 160 and 320 bu ha^{-1} fertilized at 12.5 or 50 kg N ha^{-1} wk $^{-1}$. Treatments were subject to three rainfall simulations. Sprigs planted at 320 bu ha^{-1} resulted in faster canopy coverage compared to the lower sprig planting rate regardless of N application rates. However, N losses were 5 times greater for sprigs fertilized at 50 kg N ha^{-1} wk $^{-1}$ regardless of sprig planting rate. The data from the two experiments indicate sprig planting rates >320 bu ha^{-1} fertilized at 12.5 kg N ha^{-1} wk $^{-1}$ accelerate Celebration bermudagrass establish while reducing potential N losses.

CHAPTER 1: LITERATURE REVIEW

1.1 Bermudagrass Origin, Identification, and Characteristics

Bermudagrass (*Cynodon dactylon*) is a perennial grass species that originated under sub-tropical, closely grazed rangelands of Eastern Africa and the East Indies with climates characterized with hot, dry summers (McCarty, 2001). Bermudagrass was first introduced into the United States in 1751 (McCarty, 2001) and can be found growing throughout the southern United States primarily in states with subtropical and tropical climates.

Bermudagrass is a vigorous grass that grows laterally by stolons and rhizomes (Turgeon, 2011). In most *Cynodon* species, long and short internodes alternate with leaves borne on the stem giving the illusion of multiple- leaved nodes (Duble, 2004). Bermudagrass is capable of developing a vigorous, deep-rooted system, making it adaptable to various soil types (McCarty, 2001; Taliafarro, 1995). Optimal growth for bermudagrass occurs in environmental conditions with mild winters, moderate to high rainfall, and soil temperatures ranging from 24 to 29^{o} C. (Christians, 2004; Duble, 2004; Fry and Huang, 2004). At the onset of cooler temperatures, bermudagrass leaves become chlorotic, giving the canopy a tan appearance (Christians, 2004). In climates that have extended periods of cool weather, bermudagrass is less vigorous and more susceptible to winter injury.

Bermudagrass requires high irradiance for optimal growth and development of rhizomes and stolons (Duble, 2004). When bermudagrass is subjected to less than 60% irradiance, the grass develops elongated internodes and leaves, spindly upright stems, and a weak root system (Duble, 2004). Bermudagrass exhibits excellent heat and drought tolerances compared to many other warm-season turfgrass species, although water requirements are cultivar- dependent (Christians, 2004). Under extreme drought conditions, bermudagrass will enter a semi-dormant state with growth resuming once adequate moisture is available. During extreme drought conditions, bermudagrass rhizomes can lose slightly more than 50% of their weight and still recover (Duble, 2004).

Tolerance of bermudagrass cultivars differ with respect to nematodes, insects, and diseases, however, most bermudagrass cultivars exhibit fewer pest problems compared to other highly managed turfgrass species (McCarty, 2001). In addition, bermudagrass has been shown to tolerate saline and low pH soils while providing excellent wear and stress tolerances from considerable amounts of traffic (Duble, 2004; McCarty, 2001).

Most *C. dactylon* cultivars produce viable seed; however, seeded bermudagrass cultivars have typically exhibited poor to average cold hardiness (Fry, 2004). Bermudagrass seeds are available in two forms, hulled or unhulled, with hulled seeds having faster germination rates due to the removal of the physical impediment from the seed coat (McCarty, 2001). Until recently, most seeded bermudagrass cultivars were used for utilitarian purposes because overall turfgrass quality was poor compared to several hybrid-bermudagrasses. However, in recent years improved seeded bermudagrass cultivars have been bred with characteristics suited to highly managed turfgrass sites.

The more popular bermudagrass cultivars used for highly maintained turfgrass sites have been regulated to hybrid-bermudagrasses. Hybrid-bermudagrass is the result of interspecific hybridization between two bermudagrass species such as *C. dactylon* and *C. transvaalensis*. These two species provide traits such as the vigor of *C. dactylon* and finer leaf texture of *C. transvaalensis* (Fry, 2004; Turgeon, 2011; Christians, 2004). Genotypes of these hybrid-bermudagrasses are sterile, necessitating vegetative establishment. The first commercially available hybrid-bermudagrasses, Tifway, Tifgreen and Tifdwarf, were developed in Tifton, Georgia by Dr. Glen Burton (Fry, 2004; Turgeon, 2012; McCarty, 2001; Christians, 2004). Hybrid-bermudagrasses have exceptional recuperative abilities and high tolerance to low mowing heights making it an ideal species for sports fields and other highly maintained turf areas (Fry, 2004).

1.2 Common Practices for Establishment of Bermudagrass

Bermudagrass can be established by seeding or vegetatively by sprigging, plugging, or sodding. Common or improved bermudagrasses are typically established by seed (Christians, 2004; Fry, 2004), whereas hybrid-bermudagrass can only be established vegetatively. Common bermudagrass produces around 3.96 million seeds kg^{-1} (Christians, 2004; McCarty, 2001) with optimal temperatures for germination occurring between 21^{o} and 35^{o} C (McCarty, 2001). This temperature range usually occurs in the southern United States from April to September depending on location. Current recommended seeding rates for bermudagrass are 50-75 kg or 100-150 kg ha^{-1} depending on site characteristics and if hulled or unhulled seeds are applied (Puhalla, 1999). A common practice during bermudagrass establishment is to apply nitrogen frequently to accelerate bermudagrass growth for faster canopy closure.

Vegetative establishment of bermudagrass from sprigs is common and economical for species that exhibit aggressive stoloniferous growth habits (Christians, 2004; McCarty, 2001). A sprig, defined as a vegetative stem, rhizome or stolon, having multiple nodes, will initiate growth and spread under suitable environmental conditions (Puhalla, 1999). Although all bermudagrass species can be established from sprigs, hybrid bermudagrasses can only be established by sprigs or sod because of intraspecific hybridization that renders unviable seed (Christians, 2004; Puhalla, 1999).

Sprigs are extremely perishable due to heat damage and desiccation, especially during the first 48 hrs post harvesting (McCarty, 2001). Establishment rates for sprigging vary from 81 bu ha^{-1} to as high as 323.75 bu ha^{-1} (Puhalla, 1999; Christians, 2004). In a study evaluating sprigging rates and N applications of ‘Tifway’, Johnson (1973) showed increasing sprigging rates accelerated the rate of establishment. During establishment, N rates as high as 50 kg ha^{-1} and irrigation are frequently applied to prevent sprig desiccation (Rodriguez et al., 2002). Currently, N applications vary greatly, depending on the region or turfgrass manager. Nitrogen rates as high as 48 kg N ha^{-1} wk^{-1} has been applied during bermudagrass establishment from sprigs. However, Geurtal and Evans (2006) reported N applications above 48 kg N ha^{-1} wk^{-1} did not result in faster sprig establishment of ‘Tifeagle’ hybrid-bermudgrass nor did N applications above 24 kg N ha^{-1} wk^{-1} accelerate ‘Tifway’ or ‘Tifsport’. Excess N would have the potential for offsite movement.

Plugging, another vegetative establishment practice for bermudagrass, is less common for high acreage sites. However, plugging can be useful in smaller areas when time and labor are limiting factors. Plugs are small pieces of sod, ranging from 5-15 cm, of plant and soil media that are transplanted to bare areas (Christians, 2004; Puhalla, 1999; Turgeon, 2011). Because bermudagrass is a vigorous species, bermudagrass plugs spread laterally through rhizomes and stolons. Additions of N and irrigation can accelerate establishment. There has been no pre-determined rate, diameter, or plug spacing specified for bermudagrass. However, Puhalla (1999) showed 10 cm diameter plugs at 30cm spacing will effectively cover an area within two months. Therefore, plug spacing and size required will depend on the area to be established, time period for establishment and environmental conditions.

Sodding, the fastest establishment practice, provides an instant ground cover, but is typically the most expensive method for turfgrass propagation (Turgeon, 2011). Bermudagrass sod can establish within 30 days compared to 60 days for bermudagrass established by sprigs (Puhalla, 1999). During establishment adequate soil moisture should be maintained to prevent desiccation until sufficient rooting occurs (Puhalla, 1999). Because soil is attached to the turf plant, choosing sod that is chemically and physically compatible to existing soil is imperative. Soil harvested with the sod may not be similar to the planting area resulting in poor rooting and decreased water infiltration and percolation (Puhalla, 1999; Turgeon, 2011; Christians, 2004). Establishment by sod generally requires fewer expenses such as machinery, and labor than by seed, sprig, or plug.

1.3 Nitrogen and Phosphorus Losses in Grasses

Increased concentrations of N and P in surface water bodies can result in eutrophication, a process where algal blooms increase before dying, decomposing, and decreasing dissolved oxygen concentrations. Ultimately this results in poor environmental condition for many aquatic fauna. Nutrient concentrations of N and P as low as 0.035 and 0.01 mg L^{-1}, respectively, have been found to result in eutrophication (Mallin and Wheeler, 2000).

One practice to reduce surface runoff is the use of plants in riparian areas to reduce the incidence of runoff as well as pollutant offsite movement (Gross et al., 1990; Morton et al., 1988). Scientist such as Krenitsky et al. (1998) have reported vegetation can reduce impact erosion and sediment attached pollutants from running off during precipitation events. Other scientists have also suggest proper application of inputs such as fertilizer may not lead to excessive pollutant transfer (Easton and Petrovic, 2004). Gross et al. (1990) and Miltner et al. (1996) reported losses of nitrogen in grasses in runoff or leachate to be reduced compared to unvegetated soils. More specific to warm-season grasses, Bowman et al. (2002) and Hay et al . (2007) reported losses from fertilized bermudagrass were highest for the runoff or leaching event immediately post application with nitrogen losses declining with subsequent runoff or leaching events.

Other factors beyond fertilization practices affect nutrient losses. Factors such as antecedent soil moisture and post-application irrigation practices have been shown to influence nitrogen and phosphorus runoff losses. Both Shuman (2002) and Cole et al. (1997) reported high soil moisture and failure to irrigation nutrients post-application led to higher nutrient losses. Shuman (2002) reported irrigating phosphorus post-application could reduce losses nearly five-fold. The majority of nutrient losses, such as phosphorus, are believed to be the result of surface runoff (Fleming and Cox, 2001). Differences in phosphorus losses between annual agronomic commodity production practices and perennial grass systems have been reported. It is believed the majority of phosphorus losses in annual agronomica commodity production is the result of sediment movement (Hay et al., 2004), whereas in grassed areas nutrient losses are the result of more soluble nutrient forms (Sharpley et al., 1994).

1.4 Literature Cited

Austin, N.R., J.B. Prendergast, and M.D. Collins. 1996. Phosphorus losses in irrigation runoff from fertilized pasture. J. Environ. Qual. 25:63-68.

Bowman, D.C., C.T. Cherney, and T.W. Rufty, Jr. 2002. Fate and transport of nitrogen applied to six warm-season turfgrasses. Crop. Sci. 42:833-841.

Bowman, D.C., D.A. Devitt, M.C. Engelke, and T.W. Rufty, Jr. 1998. The effects of root architecture on nitrate leaching from bentgrass turf. Crop Sci. 38:1633-1639.

Bowman, D.C., J.L. Paul, W.B. Davis, and S.H. Nelson. 1989. Rapid depletion of nitrogen applied Kentucky bluegrass turf. J. Am. Soc. Hortic. Sci. 114:229-233.

Bush, B.J., and N.R. Austin. 2001. Timing of phosphorus fertilizer application within an irrigation cycle for perennial pasture. J. Environ. Qual. 30:939-946.

Christians N.E. and M. C. Engelke. 1994. Choosing the right grass to fit the environment. In *Handbook of Integrated Pest Management for Turfgrass and Ornamentals*. Lewis Publishers, Boca Raton, FL, pp. 99-112.

Christians, Nick. 2004 Fundamentals of Turfgrass Management. Second Edition, John Wiley & Sons, Inc. Hoboken, NJ, pp. 59-73; 93-101.

Cole, J.T., J.H. Baird, N.T. Basta, R.L. Huhnke, D.E. Storm, G.V. Johnson, M.E. Payton, M.D. Smolen, D.L. Martin, and J.C. Cole. 1997. Influence of buffers on pesticide and nutrient runoff from bermudagrass turf. J. Environ. Qual. 26:1589-1598.

Duble, R.L. 2004. Turfgrasses: Their Management and Use in the Southern Zone. Second edition. Texas A&M University Press. College Station, TX. pp.38-130.

Easton, Z.M. and A.M. Petrovic. 2004. Fertilizer source effect on ground and surface water quality in drainage from turfgrass. J. Envrion. Qual. 33:645-655.

Ebdon, J.S., A.M. Petrovic, and R.A. White. 1999. Interaction of nitrogen, phosphorus, and potassium on evapotranspiration rate and growth of Kentucky bluegrass. Crop Sci. 39:209-218.

Fleming, N.K., and J.W. Cox. 2001. Carbon and phosphorus losses from dairy pasture in South Australia. Australian J. Soil Res. 39:969-978.

Fry, Jack and B. Huang. 2004 Applied Turfgrass Science and Physiology. John Wiley & Sons, Inc. 41-54.

Gross, C.M., J.S. Angle, R.L. Hill, and M.S. Welterlen. 1991. Runoff and sediment losses from tall fescue under simulated rainfall. J. Environ. Qual. 20:604-607.

Gross, C.M., J.S. Angle, and M.S. Welterlen. 1990. Nutrient and sediment losses from turfgrass. J. Environ. Qual. 19:663-668.

Guertal, E.A. and D.L. Evans. 2006. Nitrogen rate and mowing height effects on TifEagle bermudagrass establishment. Crop Sci. 46:1772-1778.

Hanson, A. A., F.V. Juska, and G.W. Burton. 1969. Species and varieties. In A. A. Hanson and F. V. Juska (Eds.) *Turfgrass Science, Agronomy* 14:370-409, Madison, WI.

Havlin, John L.; J.D. Beaton; S.L. Tisdale; W.L. Nelson. 1999 Soil Fertility and Fertilizers: An Introduction to Nutrient Management. Sixth Edition, Prentice Hall, Inc. 86-195.

Hay, F.J., D.M. Vietor, C.L. Munster, R.H. White, and T.L Provin. 2007. Leaching loss of NO3-N and dissolved P from manure and fertilizer during turfgrass establishment. Plant Soil 296:1-17.

Horgan, B.P., B.E. Branham, and R.L. Mulvaney. 2002. Mass balance of 15 N applied to Kentucky bluegrass including direct measurement of denitrification. Crop Sci. 42:1595-1601.

Humphry, J.B., T.C. Daniel, D.R. Edwards, and A.N. Sharpley (2002) A portable rainfall simulator for plot-scale runoff studies. Applied Engineering in Agriculture. 18:199-204.

Johnson, B.J. 1973. Herbicides, sprigging rates, and nitrogen treatments for establishment of Tifway bermudagrass. Agron. J. 65:969-972.

Krenitsky, E.C., M.J. Carroll, R.L. Hill, and J.M. Krouse. 1998. Runoff and sediment losses from natural and man-made erosion control materials. Crop Sci. 38:176-182.

Linde, D.T., and T.L. Watschke. 1997. Nutrients and sediment in runoff form creeping bentgrass and perennial ryegrass turfs. J. Environ. Qual. 26:1248-1254.

Linde, D.T., T.L. Watschke, A.R. Jarrett, and J.A. Borger. 1995. Surface runoff assessment from creeping bentgrass and perennial ryegrass turf. Agron. J. 87:176-182.

McCarty, L.B. 2001 Best Golf Course Management Practices. Prentice Hall, Inc. 3-44.

Mallin, M.A., and T.L. Wheeler. 2000. Nutrient and fecal coliform discharge from coastal North Carolina golf courses. J. Environ. Qual. 29:979-986.

MDA. 2007. Phosphorus Lawn Fertilizer Law. Minnesota Department of Agriculture, St. Paul, MN. Accessed online 21 Mar. 2011 <http://www.mda.state.mn.us/en/protecting/waterprotection/phoslaw.aspx>

Miller, W.P. (1987) A solenoid-operated, variable intensity rainfall simulator. Soil Science Society of America Journal. 51:832-834.

Miltner, E.D., B.E. Branham, E.A. Paul, and P.E. Rieke. 1996. Leaching and mass balance of 15N-labeled urea applied to a Kentucky bluegrass turf. Crop Sci. 36:1427-1433.

Morton, T.G., A.J. Gold, and W.M. Sullivan. 1988. Influence of over-watering and fertilization on nitrogen losses from home lawns. J. Enviorn. Qual. 17: 124-130.

Petrovic, P.M. 1990. The fate of nitrogenous fertilizers applied to turfgrass. J. Environ. Qual. 19:1-14.

Puhalla, Jim; J. Krans, and M. Goatley. 1999 Sports Fields: A Manual for Design and Construction and Maintenance. John Wiley & Sons, Inc., Hoboken, NJ 3-27.

Rodriguez, I.R., G.L. Miller, and L.B. McCarty. 2002. Bermudagrass establishment on high sand-content soils using various N-P-K ratios. HortScience 37: 208-209.

Rosenthal, W.D., and B.W. Hipp. 1993. Field and model estimates of pesticide runoff from turfgrass. P.208-213. In K.D. Racke and A.R. Leslie (ed.) Pesticides in urban environments: Fate and significance. Am. Chem. Soc., Washington, DC.

Sharpley, A.N., S.C. Chapra, R. Wedephol, J.T. Sims, T.C. Daniel, and K.R. Reddy. 1994. Manaing agricultural phosphorus for protection of surface waters: Issues and options. J. Environ. Qual. 23:437-451.

Shuman, L.M. 2002. Phosphorus and nitrate in runoff following fertilizer application to turfgrass. J. Environ. Qual. 31:1710-1715.

Taliaferro, C. M. 1995. Diversity and vulnerability of Bermuda turfgrass species. Crop Sci. 35:327-332.

Turgeon, A.J. 2011. Turfgrass Mangement: Ninth edition. Pearson Education, Inc. Upper Saddle River, NJ. 82-84; 320-328.

USDA. 2008. National research project for simulated rainfall – surface runoff studies Protocol. USDA National Phosphorus Research Project. USDA, University Park, Pennsylvania. pp. 17. accessed online 22 Feb. 2011. <http://www.ars.usda.gov>.

USEPA. 2011. Sowing the seeds for Healthy Waterways: How your garden choices can have a positive impact in your watershed. USEPA, Washington, D.C. accessed online. 21 Mar. 2011http://nlquery.epa.gov/epasearch/epasearch?areaname=&areasearchurl=search.html&typeofsearch=epa&search_crumbs=no&result_template=epafiles_default.xsl&allquery=phosphorus+fertilizer+bans&allin=&phrasequery=&phrasein=&anyquery=&anyin=&nonequery=&nonein=&doctype=all&sort=term_relevancy>.

Valiela, I., G. Collins, J. Kremer, K. Lajtha, M. Geist, B. Seely, J. Brawley, and C.H. Sham. 1997. Nitrogen loading from coastal watersheds to receiving estuaries. New method and application. Ecol. Appl. 7:358-380.

Vietor, D.M., E.N. Griffith, R.H. White, T.L. Provin, J.P. Muir, and J.C. Read. 2002. Export of manure phosphorus and nitrogen in turfgrass sod. J. Environ. Qual. 31:1731-1738.

CHAPTER 2: INFLUENCE OF SPRIGGING AND NITROGEN RATES ON BERMUDAGRASS CV. CELEBRATION ESTABLISHMENT AND NITROGEN MOVEMENT

2.1 Introduction

Bermudagrass is grown on many athletic surfaces in the southern United States because of its aesthetics, vigorous growth, and excellent wear and stress tolerances (Duble, 2004; McCarty, 2001). Since the introduction of the cultivar 'Tifway' bermudagrass (*Cynodon dactylon x C. transvaalensis*) several bermudagrass cultivars have been developed to tolerate various environmental and anthropogenic uses. One of the most recent introduced cultivars is Celebration. Celebration has gained popularity along the Gulf South as a more aggressive bermudagrass capable of withstanding higher trafficked areas (personal communication Ron Strahan). In a study evaluating, thatch decomposition between Tifway and Celebration bermudagrass, it was reported Celebration had 3 to 4 times the amount of thatch as Tifway due to its vigorous growth (Beasley et al. 2012). To date, bermudagrass cultivars that can only be established vegetatively remain the predominant cultivars planted for many highly managed athletic areas.

Establishment of bermudagrass vegetatively from sprigs provides an economical propagation method for large-acreage sites compared to sod. During sprig establishment, irrigation and N are often applied at high application rates and/or frequencies to accelerate plant growth for faster, denser canopy coverage (Guertal and Evans, 2006; Hay et al., 2007). Nitrogen application rates of 48 kg ha^{-1} wk^{-1} until full canopy closure is attained is a common practice by turfgrass managers during bermudagrass establishment from sprigs (Rodriguez et al., 2002). Conventional wisdom suggests high rates of N applied more frequently accelerates bermudagrass growth to shorten the establishment duration for playability or susceptibility to erosion.

Low initial plant densities, frequent irrigation application, and high nitrogen (N) fertility associated during the initial weeks of bermudagrass established from sprigs is susceptible to changes in surface morphology from erosion on fine texture soils but also increases the potential for higher nutrient movement. Given the high rate of N applications and decreased resistance to surface runoff initiation due to low plant densities, losses of sediment and nutrients into areas that drain to surface waters can result in eutrophication, a leading cause of surface water impairment (USEPA, 2002). Soluble and sediment bound nutrients enrich surface waters to promote algal blooms that can lead to low dissolved oxygen concentrations associated with high decomposition rates. Concentrations as low as 1 mg N L^{-1} and 25 µg P L^{-1} have been reported to facilitate eutrophication of fresh water bodies (Walker and Branham, 1992; Koehler et al., 1982, Mallin and Wheeler, 2000) compared to the often cited United States Environmental Protection Agency (USEPA) maximum contaminant levels of 10 mg L^{-1} NO_3-N and 0.1 mg L^{-1} for PO_4-P allowed for potable water. In southern Louisiana, the movement of sediment and nutrients has been documented from areas vegetated with bermudagrass (Burwell et al., 2011). High precipitation volumes and intensities associated with southern Louisiana's climate as well as finer textured soils increase the potential for surface runoff to occur.

Parameters such as higher canopy coverage and density have been positively correlated to increased infiltration, delayed runoff, reduced volume, and decreased erosion (Easton and Petrovic, 2004). However, in a study conducted by Burwell et al. (2011), their results question conventional management practices regarding N fertilization during common bermudagrass establishment from seed. On levee embankments constructed from clay, an area prone to surface runoff located adjacently to open water bodies, in southern Louisiana, Burwell et al. (2011) reported fertilization of N at seeding or 50% bermudagrass coverage did not accelerate bermudagrass coverage sufficiently to reduce sediment losses compared to unfertilized controls over a 56 and 70-day establishment periods.

Research examining sprigging rates and N application regimens during bermudagrass sprig establishment has generally reported higher sprigging rates reduce the duration for full canopy closure while high frequent N applications do not appreciably accelerate bermudagrass establishment from sprigs (Johnson, 1973; Guertal and Evans, 2006). Although, many of these studies suggest lower N rates during establishment will reduce available N for offsite movement, none of the studies have directly evaluated N losses from surface runoff. Therefore, this research focused on evaluating the effect sprigging rates and nitrogen fertility have on vegetative Celebration bermudagrass establishment; as well as the relationship these management practices have on movement of nutrient and sediment via surface runoff during Celebration establishment.

2.2 Materials and Methods

2.2.1 Bermudagrass Establishment and Post-plant Maintenance

2.2.1.1 Site characterization and treatments. Research was initiated 2 June 2010 and 7 August 2011 at the Louisiana State University Agricultural Center Burden Botanical Gardens located in Baton Rouge, La (30°24'42"N, 91° 6'12"W) on an Oliver silt loam (fine-silty, mixed, thermic, typic fragiudalf). Four sprig establishment rates of 80, 160, 320, and 480 bu ha^{-1} of bermudagrass cv. Celebration, henceforth refered to as Celebration, and four N application rates at 0, 12.5, 25, and 50 kg N ha^{-1} wk^{-1} were evaluated in a split-plot design with N rates (2 m by 8 m) as the main plots and sprig establishment rates as sub-plots (2 m x 2 m). The N source applied was ammonium-nitrate (33-0-0).

During the first 3 weeks after planting (WAP) irrigation was applied at 2.54 cm d^{-1} and reduced to 1.27 cm every 3 and 4 days in subsequent weeks. Pre and post-emergence herbicides were applied including oxadiazon (3-[2,4-dichloro-5-(1-methylethoy)phenyl]-5-(1,1-dimethylethyl)-1,3,4-oxadiaxol-2(3H)-one) was applied at 2 lbs ai $acre^{-1}$ the day bermudagrass sprigs were planted and MSMA (monosodium acid methanearsonate) and quinclorac (3,7-dichloro-8-quinolinacarboxylic acid) at 2.2 kg ai ha^{-1} and 1.2 kg ai ha^{-}1, respectively, 6 WAP to reduce broadleaf and grassy weed encroachment. Mowing was performed twice per week at 7.5 cm beginning 3 WAP.

2.2.1.2 Bermudagrass establishment measurements**.** Measurements for bermudagrass growth included canopy coverage photos captured weekly and rated for percent coverage. At 4 and 8 WAP soil cores with a 7.5 cm diameter were harvested and shoot biomass collected. Desiccated sprigs were removed with only green leaf and stem tissues excised at the turfgrass-soil interface for biomass measurement. Biomass was dried for 48 hrs at 60^{o}C and mass determined gravimetrically.

2.2.2 Rainfall Simulation Experiments

2.2.2.1 Bermudagrass sprig establishment for rainfall simulation. Nutrient and sediment runoff studies were also conducted at the Louisiana State University Agricultural Center Burden Botanical Gardens located in Baton Rouge, La (30°24'42"N, 91° 6'12"W) on an Oliver silt loam (fine-silty, mixed, thermic, typic fragiudalf). Bermudagrass sprig establishment rate and N fertility combinations of 160 or 320 bu ha^{-1} fertilized at 12.5 or 50 kg N ha^{-1} wk^{-1} for a total of four treatments were evaluated. Sprig and N fertility regimens were propagated in 1.5 m^2 plots (210 cm x 75 cm) with trays for runoff collection. On the lower side of the trays bars with a 90° angle were used to funnel water through exit ports 6 cm in length with a diameter of 2.5 cm. To prevent rainfall from collecting directly in troughs during runoff events or natural rainfall events, plastic covers were secured over each trough. Collection reservoirs of 120 L were used to collect runoff waters from rainfall simulations.

The nitrogen source was ammonium-nitrate (33-0-0) applied by hand using shaker jars for even distribution. Nitrogen applications ceased at the end of 8 WAP. During bermudagrass sprig establishment, irrigation and herbicide regimens followed the rates and application frequencies previously detailed in the bermudagrass sprig establishment and nitrogen application experiments.

2.2.2.2 Rainfall simulations. Rainfall simulations were conducted at 3, 6, and 9 WAP following the United States Department of Agriculture's (USDA) National Phosphorous Research Project's (NPRP) protocols for rainfall simulation (USDA, 2008). Simulated rainfall was applied to all treatments using a Tlaloc 3000 Rainfall Simulator (Joern's Inc.; West Lafayette, IN), based on the designs of Miller (1987) and Humphry et al. (2002). The rainfall simulator is fitted with a Spraying Systems Co. Fulljet ½HH SS 50WSQ nozzle with a spray angle of 104° (±5%) and delivered 16 L per minute at 10 psi (USDA, 2008). The rainfall intensity represents a 2-year average rainfall for Southern Louisiana. The nozzle was elevated 3 m above the soil surface.

2.2.2.3 Data collected during rainfall simulations. During simulated rainfall events, data was collected and analyzed for: time until the initiation of surface runoff, total surface runoff volume, total solids, and dissolved N (NH_3-N + NO_3-N). Total runoff volume was recorded 30 minutes after initial runoff of each rainfall event. One-liter composite runoff water samples were collected from each collection reservoir with samples were stored at 4^oC until analyzed.

2.2.2.4 Total solids and nitrogen analyses. Water samples were analyzed for NH_3-N, NO_3-N, and sediment within 48 h after collection. Erosion was quantified by centrifuging 800 mL of each sample at 3500 rpm for 15 min using an Algera-6 table-top centrifuge (Beckman Coulter Inc., Brea, CA). Liquid was decanted with the remaining soil dried at 60 C for 7 d prior to soil mass measurements being recorded.

Nitrogen (NH_3-N and NO_3-N) analyses were performed following a modified version of EPA Method 351.2 that excludes the digestion procedure. Water-soluble N was quantitated through titanous chloride reduction of NO_3-N to NH_3-N prior to automated colorimetric analysis (Quickchem 8500 FIA, Lachat Instruments, Milwaukee, WI, USA) at a detection limit of 0.01 mg L^{-1}. Soluble N data for NH_3-N and NO_3-N are combined and presented as dissolved N (DN).

2.2.2.5 Statistical analysis. The Celebration vegetative establishment study was replicated four times in a split-plot design with N fertility regimens serving as the main plots and sprig planting rates as subplots. Percent canopy coverage was analyzed using the mixed procedure using repeated measures in the statistical software, SAS (SAS, 2012). Data were combined across experimental runs if the interaction term was significant at an alpha level of 0.20. Otherwise, means were separated following Fisher's LSD at an alpha level of 0.05. Biomass accumulation was analyzed following the GLM procedure in SAS with means separated following Fisher's LSD at an alpha level of 0.05.

The rainfall simulation experiments were arranged as a completely randomized design with three replications with two factors, sprig planting rate and N fertility rate, at two levels each. Data concerning canopy coverage, time until runoff, runoff volume, total solids lost, and DN loading were analyzed using the generalized linear method in SAS. Data were combined across experimental runs if the interaction term was significant at an alpha level of 0.20. Means were then separated following Fisher's LSD at an alpha level of 0.05.

2.3 Results

2.3.1 Celebration Bermudagrass Establishment

The establishment of Celebration vegetatively from sprigs was evaluated over an 8-week period in each of the experimental runs. All sprigging rates exhibited trends of increasing canopy coverage over time albeit at different rates depending on sprig planting rate, N fertility, and environmental conditions (Figure 1). In the first experimental run, sprigging rates of 320 and 480 bu ha^{-1} resulted in ≥85% coverage within 6 WAP when fertilized at 12.5, 25, or 50 kg N ha^{-1} wk^{-1} compared to sprigging rates of 80 and 160 bu ha^{-1} fertilized at corresponding rates. Differences in N fertilization rates were not apparent for the higher sprigging rates. Lower sprigging rates required additional time to increase canopy coverages ≥80 % for fertilization rates of 12.5, 25, or 50 kg N ha^{-1} wk^{-1} over the 8-week establishment period; with the exceptions of 80 bu ha^{-1} fertilized at 12.5 and 25 kg N ha^{-1} wk^{-1} that resulted in 72% and 77% canopy coverages. At the 80 and 160b ha^{-1} sprigging rates, effects of increasing N fertilization rates Celebration establishment were not visible during the establishment period with the exception of sprigs that received no N fertility. Sprigs that received no N fertility during the 8-week establishment period resulted in 42, 64, 62, and 71% canopy coverages for increasing sprig establishment rates. However, all sprigging rates appeared to stagnate in growth within 5 WAP.

The trends observed in first experimental run were also observed in 2011. Sprigging rates of 320 and 480 bu ha^{-1} fertilized at 25 and 50 kg N ha^{-1} wk^{-1} resulted in ≥85% canopy coverage within 6 WAP compared to sprigging rates of 80 and 160 bu ha^{-1} at all fertilization rates. The exception to the first experimental run was the slower establishment of Celebration sprigs planted at 320 and 480 bu ha^{-1} at the 12.5 kg N ha^{-1} wk^{-1} that required 7 WAP to achieve 85% canopy coverage. Again, sprigs established with no N fertilization had the lowest canopy coverages compared to corresponding

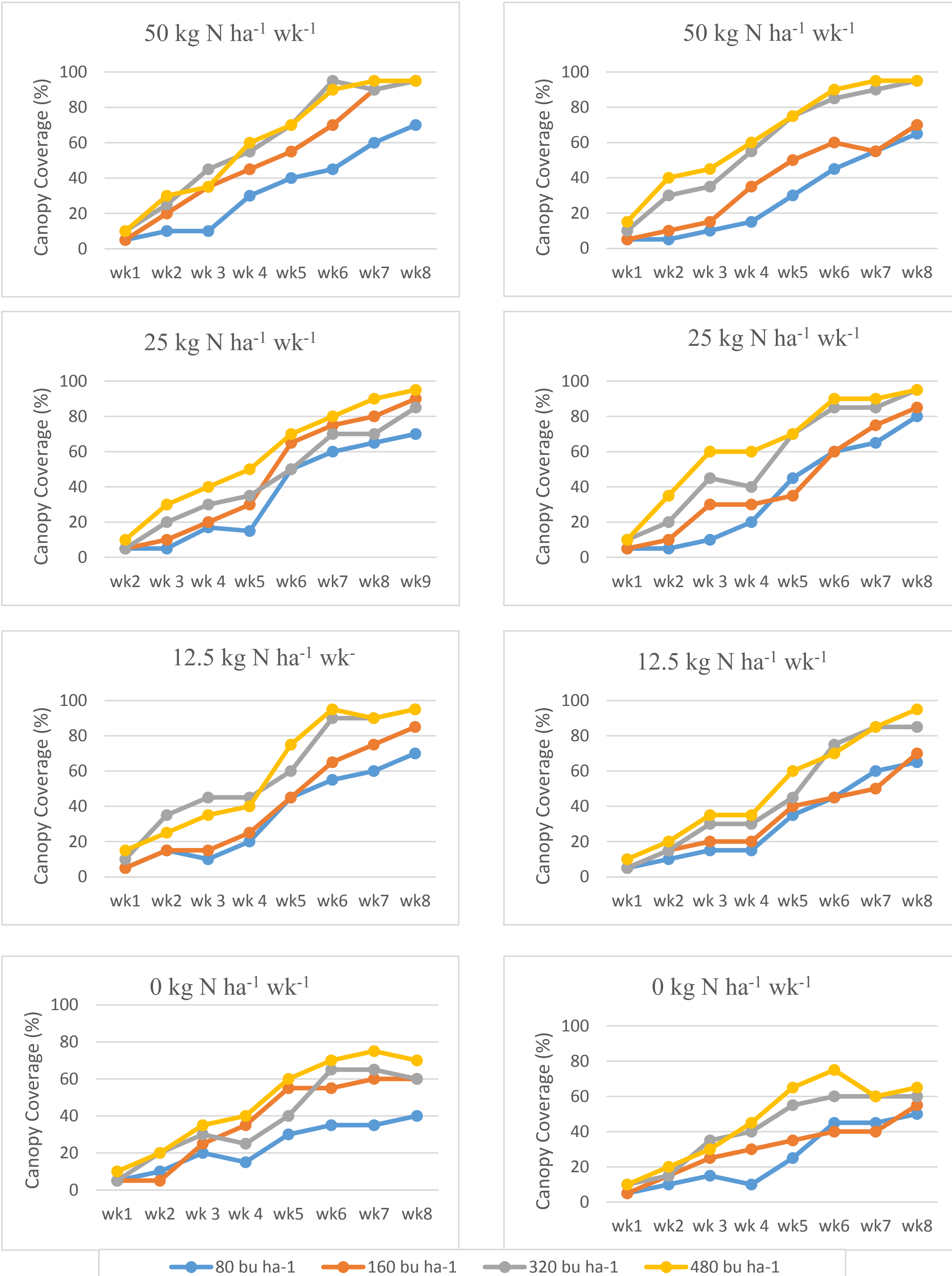

Figure 1. Combination of various sprigging rates (80, 160, 320 and 480 bu ha-1) fertilized at 0, 12.5, 25, or 50 kg N ha-1 during the establishment of Celebration bermudagrass in 2010 (left column) and 2011 (right column).

sprigging rates that received N applications. However, increasing sprigging rate for the no N fertility sprigs did allow the establishment of Celebration within the 8-week period similar to the lowest sprigging rate of 80 bu ha^{-1} under fertilization.

Increases in canopy coverage resulted in greater biomass accumulation at 4 and 8 WAP (Table 1). Celebration biomass was generally higher for the highest sprig rates of 320 and 480 bu ha^{-1} within each N fertility regimen. At 4 WAP, sprig planting rates of 320 and 480 bu ha^{-1} had biomasses between 2.2 and 3.6 g across all N regimens compared to corresponding biomass of 0.4 to 2.3 for sprigs planted at 80 and 160 bu ha^{-1}. This pattern continue at 8 WAP with the exception of the 160 bu ha^{-1} sprig planting rate accumulating similar biomass as sprigs planting rates of 320 and 480 bu ha^{-1}. In general, N fertility >12.5 kg ha^{-1} wk^{-1} resulted in similar biomasses 8 WAP. Sprigs that did not receive any addition N fertility resulted in the lowest biomass of 1.9, 1.8, 2.1, and 2.4 g for increasing sprig planting rates.

Table 1. Biomass of Celebration bermudagrass established at four sprig planting rates and four fertility regimens.Data are pooled across 2010 and 2011.

		Biomass	
Nitrogen Fertility	Sprig Planting Rate	4 weeks	8 weeks
---kg N ha^{-1} wk^{-1}---	----- bu ha^{-1} ------	g	
0	80	0.7 b*	1.9 b
	160	0.4 b	1.8 b
	320	1.7 a	2.1 b
	480	1.9 a	2.4 a
12.5	80	1.6 b	2.8 b
	160	1.9 ab	3.6 a
	320	2.8 a	4.3 a
	480	3.6 a	3.5 ab
25	80	1.4 b	4.2 b
	160	1.9 b	5.4 a
	320	3.4 a	5.8 a
	480	3.1 a	6.3 a
50	80	1.1 b	3.9 a
	160	2.3 a	4.3 a
	320	2.7 a	4.7 a
	480	2.9 a	5.2 a

* Means within a column within a sprig planting rate are separated using Fisher's LSD at an alpha level of 0.05. Means are different if followed by different letters.

2.3.2 Surface Runoff of Celebration Bermudagrass during Vegetative Establishment

The sprig planting rates chosen for the experiments represent a commonly implemented sprig planting rate of 160 bu ha^{-1} and a doubling of that rate to 320 bu ha^{-1}. In each of the experimental runs canopy coverages were between 20% and 40% for all sprig planting rates and N fertility combinations 3 WAP (Tables 1 and 2). However, as the duration for Celebration establishment increased to 6 WAP, the effect of sprig planting rate became more evident. Sprigs planted at 160 bu ha^{-1} exhibited canopy coverages of 42% and 58% compared to 89% and 93% canopy coverages for the higher sprig planting rate regardless of N fertility regimen. By 9 WAP, canopy coverage differences between sprig planting rates and N fertility combinations had dissipated with all treatment combinations attaining >86% canopy coverage. A similar pattern for changes in canopy coverages was also observed in 2011 (Table 3). At 6 WAP, the higher sprig rate of 320 bu ha^{-1} resulted in >83% canopy coverage compared to 52% and 63% at the lower sprig planting rate of 160 bu ha^{-1}. Again, all treatments exceeded 92% canopy coverage 9 WAP.

Table 2. Growth and surface runoff parameters of Celebration bermudagrass sprigs established at two sprig planting rates and fertilized following two nitrogen fertility regimens rainfall simulated at 3, 6 and 9 weeks after planting in 2010.

Sprig planting rate	Nitrogen fertility	Canopy Coverage			Time Until Runoff			Runoff Volume		
		3 weeks	6 weeks	9 weeks	3 weeks	6 weeks	9 weeks	3 weeks	6 weeks	9 weeks
bu ha$^{4 -}$	kg N ha^{4}wk^{-1}	--------------%------------			--------------%-------------			--------------%----------		
160	12.5	20c*	42b	87b	217b	316c	483a	123.6a	86.9a	39.4a
160	50	23bc	58b	92ab	255b	339c	471a	135.2a	95.6a	38.4a
320	12.5	32ab	93a	96a	346a	446a	506a	72.7b	68.7b	37.1a
320	50	38a	89a	94a	258a	397a	523b	53.8c	45.4c	28.5a

*Means within a column are separated using Fisher's LSD at an alpha level of 0.05. Means are different if followed by different letters.

The effect of canopy coverage from an increased sprig planting rate increased the duration required for surface runoff to occur. For example, Celebration planted at 160 bu ha^{-1} increased the period for runoff to occur from 217 and 255 s 3 WAP to 483 and 471 s 9 WAP, respectively, while

Table 3. Growth and surface runoff parameters of Celebration bermudagrass sprigs established at two sprig planting rates and fertilized following two nitrogen fertility regimens rainfall simulated at 3, 6 and 9 weeks after planting in 2011.

		Canopy Coverage			Time Until Runoff			Runoff Volume		
Sprig planting rate	Nitrogen fertility	3 weeks	6 weeks	9 weeks	3 weeks	6 weeks	9 weeks	3 weeks	6 weeks	9 weeks
bu ha$^{4 -}$	kg N ha^{4}wk^{-1}	--------------%---------			--------------%--------------			--------------%--------------		
160	12.5	27b*	52b	95a	251b	361bc	357b	93.9a	64.7a	38.3a
160	50	28b	63b	93a	243b	349c	349b	142.9a	78.6a	37.5a
320	12.5	32ab	84a	98a	341a	423a	436a	47.5c	33.1b	28.4b
320	50	36a	92a	94a	335a	392ab	424a	43.9c	37.7b	39.4a

*Means within a column are separated using Fisher's LSD at an alpha level of 0.05. Means are different if followed by different letters.

sprig planting rates at 320 bu ha^{-1} increased the duration from 346 and 358 s to 506 and 423 s during the same time period. Similar results were also observed in 2011.

Overall, the duration necessary to initiate runoff were similar between N fertility regimens within sprig planting rates. However, differences in the duration necessary to initiate runoff were apparent at 3 and 6 WAP between sprig planting rates. Celebration sprigs planted at 320 bu ha^{-1} resulted in longer durations of 346 and 358 s compared to 217 and 255 s for sprigs planted at 160 bu ha^{-1} in 2010. These differences in time until surface runoff occurred were also evident between sprig planting rates 6 WAP. However, 9 WAP the duration needed to initiate runoff was similar between all sprig planting rate and N fertility regimen combinations. A similar pattern, albeit was not as apparent as data in 2010, increasing sprig planting rate extended the duration necessary to initiate surface runoff at 3 and 6 WAP, but dissipated by 9 WAP 2011.

The increases in canopy coverage from increased sprig planting rates also affected surface runoff volumes. The lower sprig establishment rate resulted in higher runoff volumes of 123.6 and 135.2 L compared to 72.7 and 53.8 L for the higher sprig planting rate 3 WAP in 2010 and 93.9 and 142.9 L compared to 47.5 and 43.9 L for corresponding sprig planting rates 3 WAP in 2011. In each year, runoff volume decreased over time with increasing bermudagrass canopy coverages and differences in runoff volumes between treatments dissipating 9 WAP when canopy coverages attained >86%.

2.3.3 Total Solids and Nitrogen Losses from Surface Runoff during Celebration Establishment

Similar to the patterns observed regarding canopy coverage, time until runoff, and runoff volumes, sprig planting rate was the most significant factor on total solid losses (Tables 4 and 5). During the first rainfall simulation 3 WAP sprigs planted at 320 bu ha^{-1} reduced total solid losses from 0.84 and 0.78 kg ha^{-1} for Celebration planted at 160 bu ha^{-1} to 0.35 and 0.28 kg ha^{-1}. As bermudagrass canopy coverage increased total solid loading rates declined. However, the decline in total solid loading was accelerated at the higher sprig planting rate. For example, sprigs planted at 160 reduced total solid loading from 3 WAP at 0.84 and 0.78 kg ha^{-1} to 0.58 and 0.62 kg ha^{-1} 6 WAP and 0.29 and 0.24 kg ha^{-1} 9 WAP compared to the higher sprig rate reductions of total solid loading of 0.35 and 0.28 kg ha^{-1} 3 WAP to 0.31 and 0.33 kg ha^{-1} 6 WAP and 0.21 and 0.22 kg ha^{-1} WAP in 2010. A similar pattern between sprig planting rates was also observed in 2011 with the exception of Celebration planted at 320 kg ha^{-1}at 0.41 kg ha^{-1} total solid loading similar to the lower sprig planting rate 6 WAP.

Table 4.Total solids and dissolved nitrogen lost during surface runoff from simulated rainfall at 3, 6 and 9 weeks after planting from Celebration bermudagrass established at two sprig planting rates and nitrogen fertility regimens in 2010.

Sprig planting rate	Nitrogen fertility	Total Solids			Dissolved Nitrogen		
		3 weeks	6 weeks	9 weeks	3 weeks	6 weeks	9 weeks
bu ha^{-1}	kg N ha^{-1}wk^{-1}	-------------kg ha^{-1}--------------			-------------------mg-------------------		
160	12.5	0.84a*	0.58a	0.29a	3.3b	6.5c	4.3b
160	50	0.78a	0.62a	0.24a	11.5a	85.6a	43.4a
320	12.5	0.35b	0.31b	0.21a	4.9b	12.2c	9.3b
320	50	0.28b	0.33b	0.22a	15.6a	61.6b	31.3a

*Means within a column are separated using Fisher's LSD at an alpha level of 0.05. Means are different if followed by different letters.

Unlike total solid loading data, N loading was not as greatly affected by sprig planting rate, but rather N fertility regimen. Regardless of sprig planting rate, nitrogen losses were reduced under the lower N fertility regimen of 12.5 kg N ha^{-1} wk^{-1} compared 50 kg N ha^{-1} wk^{-1}. In 2010, sprigs fertilized

Table 5.Total solids and dissolved nitrogen lost during surface runoff from simulated rainfall at 3, 6 and 9 weeks after planting from Celebration bermudagrass established at two sprig planting rates and nitrogen fertility regimens in 2011.

Sprig planting rate	Nitrogen fertility	Total Solids			Dissolved Nitrogen		
		3 weeks	6 weeks	9 weeks	3 weeks	6 weeks	9 weeks
bu ha^{-1}	kg N $ha^{-1}wk^{-1}$	-------------kg ha^{-1}--------------			------------------mg-------------------		
160	12.5	0.62b*	0.49a	0.34a	4.2b	11.6b	11.4b
160	50	0.83a	0.42a	0.31a	10.6a	96.5a	52.5a
320	12.5	0.44c	0.24b	0.19b	3.9b	10.4b	14.6b
320	50	0.38c	0.41a	0.16b	14.0a	83.4a	44.2a

*Means within a column are separated using Fisher's LSD at an alpha level of 0.05. Means are different if followed by different letters.

at the lower N regimen resulted in 3.3 and 4.9 mg DN compared to 11.5and 15.6 mg DN 3 WAP. Nitrogen loading between the two N regimens increased at 6 WAP with sprigs fertilized at the higher N regimen exhibiting losses of 85.6 and 61.6 mg DN for sprigs planting rates of 160 and 320 bu ha^{-1}, respectively, compared to corresponding DN losses of 6.5 and 12.2 mg DN. This increase in DN losses at 6 WAP also occurred in 2011. Sprigs fertilized at the higher N regimen resulted in 96.5 and 83.4 mg DN for sprig planting rates of 160 and 320 bu ha^{-1}, respectively, compared to 11.6 and 10.4 mg DN for sprig planting rates of 160 and 320 bu ha^{-1} fertilized at 12.5 kg N ha^{-1} wk^{1}. Dissolved N losses reduced at 9 WAP, 1 week after ceasing N fertilizer applications. However, sprigs fertilized at the higher N regimen continued to exhibit higher DN losses compared to sprigs following the lower N regimen.

2.4 Discussion

Areas in Louisiana that plan to establish Celebration bermudagrass vegetatively can accelerate canopy coverage and biomass accumulation by increasing sprig planting rates from 80 or 160 bu ha^{-1} to 360 or 480 bu ha^{-1} rather than relying on higher N fertility regimens. In general, Celebration established vegetatively at sprig planting rates of 360 or 480 bu ha^{-1} was able to attain ≥85% canopy coverage 6 WAP and 95% canopy coverage within 8 WAP when fertility was applied at 12.5 kg N ha^{-1} wk^{-1} or above. Similar findings have been reported in the scientific literature concerning the combination of vegetative establishment rates and N fertility for other bermudagrass cultivars (Geurtal and Evans, 2009; Rodriguez et al., 2002). In a study evaluating Johnson (1973) reported increasing sprig planting rates not only accelerated the rate of establishment, but higher fertility was less effective in accelerating establishment compared to altering sprig planting rate.

In a study conducted by Geurtal et al. (2009), they suggested differences in vegetative establishment of two bermudagrass cultivars Tifway and Tifsport were a function of stolon vigor. Although this may provide insight into differences in cultivar establishment rates, it does not provide insight into why higher sprigging rates within a cultivar decrease the duration of establishment. Increases in establishment rate of Celebration at higher sprigging rates was not only affected by increased plant material but most likely as a result statistically of higher sprig survivability. In research investigating nutrient applications on bermudagrass establishment on a golf green, Rodriguez et al. (2002) acknowledged the importance of frequent irrigation to prevent sprig desiccation during establishment. An immature or undeveloped root system limits water uptake and thus plant growth. Even though irrigation was applied throughout these studies, some sprig desiccation was visibly observed. Since only one bermudagrass cultivar was evaluated and irrigation regimens were not considered, the combination of higher plant material and proportional sprig survival appear to better explain differences between canopy coverages and biomass accumulation between sprig planting rates observed during the first 6 WAP. Greater sprig growth early in the establishment period translated to higher canopy coverages and biomass accumulation for faster canopy closure. Further research is needed to more clearly elucidate the influence irrigation, fertility, and sprig planting rates affect bermudagrass establishment.

Compared to sprig planting rate, N fertility was a less effective management practice during the vegetative establishment of Celebration. For example, N fertility above 12.5 kg N ha^{-1} did not accelerate canopy coverage when fertility rates were compared within sprigging rates. Geurtal and Evans (2006) reported N applications above 48 kg N ha^{-1} wk^{-1} also did not result in faster sprig establishment of 'Tifeagle' hybrid-bermudgrass nor did N applications above 24 kg N ha^{-1} wk^{-1} accelerate 'Tifway' or 'Tifsport' during vegetative establishment (Geurtal et al., 2009). Johnson (1973) also found excessive N did not appreciably attribute to increased Tifway bermudagrass establishment.

The frequent application of high N rates up to 50 kg N ha^{-1} is often applied by turf managers to prevent N from being a limiting nutrient during establishment. Numerous horticulture and agronomic studies have clearly described the impact low N fertility has on plant growth and development (cites). However, Celebration sprigs established with no additional N applications resulted in similar establishment rates to corresponding fertilized-sprig planting rates the first 4 WAP. This suggests plant N demand, a factor reported to govern N uptake (Bowman et al., 1989), was most likely not limiting available N uptake given the similarity in growth. Rather, the similarity in canopy coverages of the unfertilized control to the remaining sprigs under the various fertility regimens was most likely limited by an undeveloped root system that not only limited water uptake but also N uptake needed to accelerate growth. In a mature creeping bentgrass, Bowman et al. (1998) showed nitrogen uptake was positively correlated to increasing rooting architecture. It appears, sprigs are reliant on stored carbohydrates reserves during the first 4 WAP similar to bermudagrass processes associated with active growth post-winter dormancy (Munshaw et al., 2001).

The inability of Celebration sprigs to accelerate establishment at higher N fertility rates could have negative consequences on N offsite movement. In this study, it was evident the conditions such as high soil moisture and N fertility during vegetative establishment of Celebration can contribute to increased occurrence and severity of surface runoff as reported with data from the rainfall simulation experiments. Factors such as soil moisture, reduced vegetative canopy coverage, and sward density have been correlated to increased surface runoff incidence (Gross et al., 1990; Morton et al., 1988). In this experiment, higher sprig planting rates resulted in faster canopy coverage over the 9-week observation period to reduce runoff volume and sediment loading while increasing the duration for surface runoff to initiate. For example, the higher sprig planting rate of 320 bu ha^{-1} resulted in reducing surface runoff volumes from 47.5 L to 33.1 and 28.4 L and total solid loading 0.44 0.19 kg ha^{-1} to 0.24 and 0.19 kg ha^{-1} from 3 WAP to 6 and 9 WAP in 2011 while extending the duration necessary to initiate surface runoff from 341 s to 423 and 436 s. During this same time period sprigs planted at the lower rate of 160 bu ha^{-1} exhibited slower rates of change in these parameters over the establishment period especially at 3 WAP and 6 WAP. Initial differences between the two sprig planting rates are most likely a function of soil coverage. Although canopy coverages were similar at 3 WAP, canopy coverage is a measurement of green material and does not account for dessicated plant material acting as a mulch covering the soil. Plant material in the form actively growing and dessicated sprigs shielded the soil from raindrop impact erosion to increase the duration for surface runoff initiation while disrupting water flow to reduce surface runoff volume and filter suspended total solid movement compared to the more sparsely covered 160 bu ha^{-1} Celebration sprig planting rate.

Over the 9-week observation period, the differences in canopy coverage dissipated as noted with >82% canopy coverage for all sprig planting rate and N fertility regimen combinations. Dense grass swards increase water infiltration to reduce surface runoff occurrence and severity; reduce kinetic energy associated with splash erosion; and reduce total solids movement (Krenitsky et al., 1998; Easton and Petrovic, 2004; Burwell et al., 2011). However, the N applied to achieve a more resistance bermudagrass sward must be considered not only in terms of efficiency to promote sprig establishment but also in terms of potential environmental impact.

In this study, the higher fertility rate of 50 kg N ha^{-1} consistently resulted in greater N losses from surface runoff compared to sprigs established following a regimen of 12.5 kg N ha^{-1}. Over the course of the 9-week observation period with 3 rainfall events, sprigs fertilized at the higher N regimen lost a total of 108.5 to 159.5 mg N compared to loses of 14.1 to 28.9 mg N for sprigs fertilized with the lower N regimen. Moreover, gains in reduced total solid movement one may expect to gain through accelerating sprig establishment with increased N fertility were not recognized. Rather sprig planting rate, regardless of N regimen, was a more important factor when discussing total solid transport. The results of the surface runoff portion of the study were similar to the findings of Burwell et al. (2011), in which they reported early N applications did not sufficiently accelerate bermudagrass established from seed to reduce total solid movement from levee embankments; and that N applications at 50% canopy coverage resulted in similar DN losses as pre-plant N applications.

Based on the data from two experiments of the study, N fertility rates >12.5 kg N ha^{-1} wk^{-1} do not accelerate Celebration establishment from sprigs. Rather establishment can be accelerated with higher sprig planting rates of 360 to 480 bu ha^{-1}. The higher sprig rates fertilized at 12.5 kg N ha^{-1} wk^{-1} not only established in 6 to 7 WAP but reduced total solid and N losses during runoff. Following a higher sprig planting rate and 12.5 kg N ha^{-1} wk^{-1} fertility regimen reduced N losses 4 to 10 times sprigs established following the common application rate of 50 kg N ha^{-1} wk^{-1}. Therefore, it is recommended that Celebration established vegetatively from sprigs should be planted at rates of 360 bu ha^{-1} and fertilized at 12.5 kg N ha^{-1} wk^{-1} until full canopy closure.

2.5 Literature Cited

Bowman, D.C., C.T. Cherney, and T.W. Rufty, Jr. 2002. Fate and transport of nitrogen applied to six warm-season turfgrasses. Crop. Sci. 42:833-841.

Bowman, D.C., D.A. Devitt, M.C. Engelke, and T.W. Rufty, Jr. 1998. The effects of root architecture on nitrate leaching from bentgrass turf. Crop Sci. 38:1633-1639.

Burwell, R.W.; J.S. Beasley, L.A. Gaston, S.M. Borst, R.E. Sheffield, R.E. Strahan, and G.C. Munshaw. 2011. Losses of surface runoff, total solids, and nitrogen during bermudagrass establishment on levee embankments. J. Environ. Qual. 40: 1241-1248.

Duble, R.L. 2004. Turfgrasses: Their Management and Use in the Southern Zone. Second edition. Texas A&M University Press. College Station, TX. pp.38-130.

Easton, Z.M. and A.M. Petrovic. 2004. Fertilizer source effect on ground and surface water quality in drainage from turfgrass. J. Envrion. Qual. 33:645-655.

Gross, C.M., J.S. Angle, R.L. Hill, and M.S. Welterlen. 1991. Runoff and sediment losses from tall fescue under simulated rainfall. J. Environ. Qual. 20:604-607.

Gross, C.M., J.S. Angle, and M.S. Welterlen. 1990. Nutrient and sediment losses from turfgrass. J. Environ. Qual. 19:663-668.

Guertal, E.A. and D.L. Evans. 2006. Nitrogen rate and mowing height effects on TifEagle bermudagrass establishment. Crop Sci. 46:1772-1778.

Hay, F.J., D.M. Vietor, C.L. Munster, R.H. White, and T.L Provin. 2007. Leaching loss of NO3-N and dissolved P from manure and fertilizer during turfgrass establishment. Plant Soil 296:1-17.

Humphry, J.B., T.C. Daniel, D.R. Edwards, and A.N. Sharpley (2002) A portable rainfall simulator for plot-scale runoff studies. Applied Engineering in Agriculture. 18:199-204.

Johnson, B.J. 1973. Herbicides, sprigging rates, and nitrogen treatments for establishment of Tifway bermudagrass. Agron. J. 65:969-972.

Krenitsky, E.C., M.J. Carroll, R.L. Hill, and J.M. Krouse. 1998. Runoff and sediment losses from natural and man-made erosion control materials. Crop Sci. 38:176-182.

Linde, D.T., and T.L. Watschke. 1997. Nutrients and sediment in runoff form creeping bentgrass and perennial ryegrass turfs. J. Environ. Qual. 26:1248-1254.

Linde, D.T., T.L. Watschke, A.R. Jarrett, and J.A. Borger. 1995. Surface runoff assessment from creeping bentgrass and perennial ryegrass turf. Agron. J. 87:176-182.

McCarty, L.B. 2001 Best Golf Course Management Practices. Prentice Hall, Inc. 3-44.

Mallin, M.A., and T.L. Wheeler. 2000. Nutrient and fecal coliform discharge from coastal North Carolina golf courses. J. Environ. Qual. 29:979-986.

Miller, W.P. (1987) A solenoid-operated, variable intensity rainfall simulator. Soil Science Society of America Journal. 51:832-834.

Morton, T.G., A.J. Gold, and W.M. Sullivan. 1988. Influence of over-watering and fertilization on nitrogen losses from home lawns. J. Enviorn. Qual. 17: 124-130.

Rodriguez, I.R., G.L. Miller, and L.B. McCarty. 2002. Bermudagrass establishment on high sand-content soils using various N-P-K ratios. HortScience 37: 208-209.

SAS Institute. 2008. Base SAS 9.1.3 procedures guide. SAS Institute, Cary, NC.

Turgeon, A.J. 2011. Turfgrass Mangement: Ninth edition. Pearson Education, Inc. Upper Saddle River, NJ. 82-84; 320-328.

USDA. 2008. National research project for simulated rainfall – surface runoff studies Protocol. USDA National Phosphorus Research Project. USDA, University Park, Pennsylvania. pp. 17. accessed online 22 Feb. 2011. <http://www.ars.usda.gov>.

USEPA. 2011. Sowing the seeds for Healthy Waterways: How your garden choices can have a positive impact in your watershed. USEPA, Washington, D.C. accessed online. 21 Mar. 2011http://nlquery.epa.gov/epasearch/epasearch?areaname=&areasearchurl=search.html&typeofsearch=epa&search_crumbs=no&result_template=epafiles_default.xsl&allquery=phosphorus

+fertilizer+bans&allin=&phrasequery=&phrasein=&anyquery=&anyin=&nonequery=&nonein=&doctype=all&sort=term_relevancy>.

Valiela, I., G. Collins, J. Kremer, K. Lajtha, M. Geist, B. Seely, J. Brawley, and C.H. Sham. 1997. Nitrogen loading from coastal watersheds to receiving estuaries. New method and application. Ecol. Appl. 7:358-380.

VITA

Matthew Turner was born in Louisiana and graduated from Ouachita Christian School in Monroe, La. He attended Louisiana State University and Agricultural and Mechanical College and earned his Bachelor of Science degree in 2009 from the School of Plant, Environmental, and Soil Sciences. Matthew continued with his Master's of Science in the School of Plant, Environmental, and Soil Sciences under the direction of Dr. Jeffrey Beasley. Just before completing his thesis, Matthew accepted employment with Crop Protection Services, Inc. in Mer Rouge, La.