January 2019

Influence of nitrogen and sprig planting rates on surface runoff losses during 'Latitude 36' bermudagrass establishment

Lance A. Rice
Louisiana State University and Agricultural and Mechanical College, larice32@yahoo.com

INFLUENCE OF NITROGEN AND SPRIG PLANTING RATES ON SURFACE RUNOFF LOSSES DURING ‘LATITUDE 36’ 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 Department of Plant, Environmental Management and Soil Sciences

by
Lance Allen Rice
A.S., Arkansas State University at Beebe, 2015
B.S., University of Arkansas, 2017
May 2019

ACKNOWLEDGEMENTS

I would like to thank the Louisiana State University Agricultural Center and the School of Plant, Environmental, and Soil Sciences for their support of this research and the opportunity to pursue and complete my graduate degree. I owe my advisor and major professor, Dr. Jeffrey Beasley, my appreciation for his guidance and mentorship throughout my program. Also, I would like to extend my gratitude to my committee members, Dr. Lewis Gaston and Dr. Brian LeBlanc for their assistance and advice throughout my program. I would like to thank Ms. Kayla Sanders for her instruction and assistance with laboratory analysis and field data collection. I would also like to thank Dr. Lisa Fultz and Mr. Jeff Kuehny for their assistance with laboratory analysis.

I owe my greatest appreciation to my wife, Hayley Rice for her constant support and encouragement throughout this journey. I also want to thank my parents for their time and support in helping reach this milestone in my life.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The hybrid bermudagrass (*Cynodon dactylon* x *C. transvaalensis*) ‘Latitude 36’ is grown because of its quality, excellent wear tolerance and fast recuperation. Hybrid bermudagrasses are vegetatively propagated as sprigs with N applied to accelerate establishment. Since losses of soil and associated nutrients in runoff are relatively high when ground coverage is low, rapid establishment is desirable from an environmental besides aesthetic basis. However, neither the interactive effect of sprig density and N fertilization on the rate of bermudagrass expansion nor soil and nutrient loss during establishment has been carefully examined. The current work measured bermudagrass coverage, runoff volume and concentrations of inorganic N, total P (TP) and total solids during 30-min rainfall simulations at 10, 20, and 30 DAP (days after planting) from replicate trays of bermudagrass established at 494 or 1482 bu ha^{-1} and fertilized at 12 or 48 kg N ha^{-1} wk^{-1}. All treatment combinations of sprig planting and N rates resulted in > 88% groundcover 35 DAP. Increasing sprig planting rates accelerated bermudagrass establishment, whereas increasing N fertility did not. Higher bermudagrass coverage led to lower runoff volumes and reduced total solids in runoff. The lower sprig rate resulted in higher sediment losses of 507,082 compared to 392,810 g/ha for the higher rate. Respective P losses were 271 and 200 g/ha. Dissolved N losses at the higher application rate were 327 and 207 g/ha for sprig planting rates of 494 and 1482 bu ha^{-1} respectively, compared to N losses of 1282 g and 586 g/ha at the lower N rate. The use of the lower N rate was sufficient across both sprig planting rates to achieve >88% within 35 DAP.

CHAPTER 1. LITERATURE REVIEW

1.1. Bermudagrass Characterization

Bermudagrass (Cynodon dactylon L.) is a warm-season perennial grass used throughout the world for diverse purposes including cattle forage, soil erosion protection, and turf for golf courses, athletic fields, and homelawns. Bermudagrass is native to Africa (Carey, 1995). It has excellent heat and disease tolerance as well as finer leaf texture and color that are suitable for many turfgrass applications (McCarty and Miller, 2002). Bermudagrass also has excellent drought tolerance due to deep rooting (Carey, 1995). It grows best in tropical and subtropical climates where the daytime air temperatures are between 26° to 37°C and receives 63.5 to 254 cm of rainfall annually (Duble 1989, McCarty and Miller 2002). While bermudagrass can grow in both acidic and alkaline soil, it grows best in well-drained soil at a pH of 6.0-6.5 (Landry, 2018).

Development of hybrid species for high quality traits is common practice with many agricultural crops such as rice (Yuan, 1997) and corn (Dunvic, 2001) and turfgrasses are no exception to this process. Hybrid bermudagrasses have been developed through crosses of two different species of bermudagrass to create an offspring that shows hybrid vigor in desired traits. Most improved hybrids in the United States are the result of breeding common bermudagrass (*Cynadon dactylon*) and an African bermudagrass, *Cynadon transvaalensis* (Emmons, 2000). Due to interspecies crossing, the seed of offspring are typically sterile, thus requiring that hybrids be vegetatively propagated (Polomski et al., 2016). Hybrid bermudagrasses have been bred for characteristics including aesthetics and vigor as well as biotic and abiotic tolerances. Since hybrid bermudagrasses used for turf are grown on highly visible sites, they are intensively managed for high density, pest control, rich color and finer texture (Emmons, 2000; Murphy et al., 2003). Hybrid bermudagrasses are a favorite of many sod farmers because they can be established quickly with sprigs and sod harvested in as little as 12-16 weeks (Martin and Wells, 2001).

In recent years, new cultivars of bermudagrasses have been developed specifically for high traffic athletic fields, including Latitude 36 and Celebration. Latitude 36 (*Cynadon dactylon* x *Cynadon transvaalensis*) is a hybrid introduced by Oklahoma State University for intensively managed sods such as golf courses and high traffic sports fields (Martin, 2018). This grass has finer texture, greater winter hardiness, improved disease and drought tolerance, and exceptional quality (Wu, 2014). Latitude 36 is recommended to be maintained between 1.0 and 3.2 cm height with routine mowing (Martin, 2018). Su et al. (2013) compared the drought tolerance of Latitude 36 to that of Celebration and Premier bermudagrasses and concluded that Latitude 36 had the highest visual appearance when grown in both well-watered and droughty conditions.

1.2. Bermudagrass Establishment

Cynodon L. is a rhizomatous and stoloniferous turfgrass species (Carey, 1995) that is characterized as having vigorous growth under suitable conditions. Common bermudagrass can be established through seeding or planting vegetative material such as plugs, sprigs, or sod (Emmons, 2000). Seeding bermudagrass is a preferred method for some sites due to lower cost of establishment compared to vegetative establishment (Patton et al.; 2004). However, establishment of bermudagrass through seed can lead to a mosaic appearance in the turf over time due to the genetic variability among seeds and established bermudagrass (McCarty and Miller 2002). However, hybrid bermudagrass can only be planted vegetatively. Establishment is either by sod and sprigs. Sodding is a very common method to quickly establish turf but can be very costly. Sprigging is a method in which rhizomes and stolons are broadcast over bare soil and allowed to root and grow (McCarty and Miller, 2002). Sprigging is an effective planting method for bermudagrass because of its aggressive growth through stolons (which can commonly reach lengths of 1.5 to 1.8 meters; Emmons, 2000) and use of less vegetative material. Although establishment from sprigs is common, there is less published information on the practice than on establishment of turfgrasses from seed.

1.3. Bermudagrass Sprigging Studies

Previous studies evaluating bermudagrass propagation from sprigs have commonly focused on sprig and nitrogen (N) rates. Johnson et al. (1973) analyzed the effect of increasing sprig planting rates from 870, 1740, to 3480 ft^3/acre on 'Tifway' bermudagrass establishment, and concluded that the highest sprig rate led to the faster establishment. Similarly, Duble (1989) reported that bermudagrass sprigs planted at rates between 218 and 653 bu/acre led to establishment within 12 weeks after planting, and establishment at 1089 bu $acre^{-1}$ was less than 10 weeks. More recently, Munshaw et al. (2016) examined establishment of Latitude 36 at sprigging rates of 494, 988, 1482, and 1976 bu ha^{-1} and N rates of 12, 24, 36, 48 kg N ha^{-1} wk^{-1} in Kentucky, Louisiana, Mississippi, and Oklahoma. Their results indicated that increasing the sprig planting rate consistently resulted in faster establishment whereas N application rate was less important. They suggested that N rates of 12 or 24 kg N ha^{-1} wk^{-1} were sufficient, rather than the commonly used 48 kg N ha^{-1} wk $^{-1}$. Guertal and Evans (2006) evaluated the effects of N rate and mowing heights on 'TifEagle' bermudagrass establishment on putting greens. They concluded that in all cases the highest N application rate of 4.8 g N m^{-2} wk^{-1} was not needed and did not benefit establishment. In several other studies evaluating other bermudagrass cultivars results have shown a similar pattern, i.e. increasing sprig planting rates can lead to faster establishment (Brede, 2000; Duble, 1989). Taliaferro et al. (2004) agreed with these studies, concluding that the time required to achieve full ground cover was dependent on sprigging rate, initial stand density, and growing conditions during the establishment period. Furthermore, rapid establishment can be achieved by planting more sprigs or by selecting a faster growing cultivar (Taliaferro et al., 2004).

However, many extension publications and turfgrass managers continue to promote the idea that higher N rates alone will accelerate bermudagrass sprig establishment. Emmons (2000) stated that improved hybrid bermudagrasses are considered heavy users of nutrients because they grow vigorously and need higher amounts of nutrients to support more vigorous growth. Sports Turf Manager's Association (STMA, 2018) recommends applying 24 kg N ha^{-1} for native soils and up to 72 kg N ha^{-1} for sandy soils every two to four weeks during the establishment period. A joint extension publication from Purdue and the University of Illinois (2006) recommends 48 kg N ha^{-1} at two weeks and four weeks after sprigging. Many other different fertilizer recommendations can be found suggesting the use high N application rates (Han and Huckabay, 2008; Relf, 2009; Samples and Sorochan, 2007). Although previous studies have emphasized benefits of increasing sprig planting rate and cautioned against high N application rates during establishment, there are currently no published studies quantifying the environmental effects of sprig planting and N application rates during of establishment of bermudagrass.

1.4. Nitrogen and Turfgrass, General

Nitrogen fertilizer is applied more often than any other nutrient due to high plant demands (Yu et al., 2014). Requirements with turfgrasses vary depending on the species and function of the turfgrass. Turfgrass managers often apply between 150 and 300 kg N ha^{-1} yr^{-1} (Barton and Colmer, 2006; Erickson et al., 2001) depending on environmental conditions. Other factors such as clipping management can affect N fertility and thus fertilizer application rates and timings (Kopp and Guillard, 2002).

1.5. Nitrogen Losses through Water Movement

Yu et al. (2014) estimated that only 30 to 40% of the N applied is taken up in agricultural crops. The remainder is lost through ammonia (NH_3) volatilization, denitrification, nitrous oxide (N_2O) emissions, and nitrate (NO^{2-}) leaching (Cai et. al., 2002; Singh et. al.; 2013; Zhu 1997;). A major contributing factor to coastal eutrophication is nitrogen loading into the ecosystems (NRC, 2000). Ribaudo et al. (2001) estimated that approximately 50% of the N that enters the Gulf of Mexico via the Mississippi River comes from agricultural sources, particularly N fertilizer. Though turfgrass is a smaller source, irrigation rates and frequencies can greatly affect N losses (Barton and Colmer, 2006). Morton et al. (1988), for example, found that use of 244 kg N ha^{-1} yr^{-1} and heavy irrigation on a Kentucky bluegrass (*Poa pratensis*) lawn resulted in annual N losses of 32 kg N ha^{-1} compared to the unfertilized and non-irrigated control which only lost 2 kg N ha^{-1}. Thus, runoff from overwatered lawns can lead to nitrate contamination of surface waters (Morton et al., 1988).

1.6. Phosphorus

Phosphorus (P) is an essential nutrient for plant growth but is applied in lower quantities than N as a fertilizer. Nevertheless, P losses through surface runoff have become an increasing problem across the country. The major pathways of P loss are erosion of soil-bound P and surface runoff containing dissolved P (Kronvang 1990; Heathwaite 2000). Gaseous losses of P does not typically occur (Sims and Pierzynski, 2005). Losses in agricultural runoff are directly correlated to the amount of soil erosion /sediment loss (Strauss and Mentler, 1998). Exposure of grassland soil to erosive rainfall increases the amount of suspended soil particles, thus the amount of particulate P in surface runoff (Hanson et. al., 1999). Another major contributor to P loss are the high amounts of poultry litter applied to fields. Poultry litter is often applied to soils that have adequate P levels and such application in excess of crop requirements can cause a buildup of P in the soil (Sharpley et al., 1994). As the soil P concentration increases, so does P leaching and surface runoff. Leaching of P occurs but is typically only a problem in sandy soils or where P has been over-applied, as with organic wastes such as poultry litter (Sims et. al., 1997).

1.7. Non-Point Source Pollution

Bricker et al. (2007) found that two-thirds of 58 estuaries in the United States measured moderate to high levels of eutrophication, most from anthropogenic sources. According to Sonzogni et al. (1980), N and P discharge into the Great Lakes from intensively managed agricultural lands was 10-100 times higher than from forest and idle lands. The Birdfoot Delta of the Mississippi River in Louisiana is home to a productive ecosystem but also to the second largest zone of marine hypoxia in the world (Rabalais et al., 2002), presumably the result of eutrophication by non-point source loads of N and P.

1.8. Surface Runoff

Runoff transports sediment, nutrients (Fierer et al., 2002; Burwell et al., 1975) and pesticides (Gómez et al., 2011; Spencer and Cliath, 1991; Klöppel et al., 1997) that can have unintended off-target consequences. Loss of N and P from agricultural land is one of the main causes of freshwater pollution (White et al., 2009). Eutrophication with N and P can accelerate algal growth, potentially killing fish, clogging pipelines and reducing recreational opportunities (USEPA, 1998). Increased algal growth can be caused by P and N concentrations in surface waters as low as 25 mg L^{-1} and 1 mg L^{-1} respectively (Balogh et al.; 1992). The problem appears to be increasing in coastal waters and estuaries around the world (Nixon 1995; Boesh 2002).

Therefore, efforts must be made to reduce non-point source pollution of waterways and aquatic ecosystems by fertilizer. A major step is developing best management practices to reduce nutrient movement into surface waters. Ground cover, including turf, is important since it is effective in reducing surface runoff. Cole et al. (1997) tested the effectiveness of buffer strips, mowing height, and aerification in reducing surface runoff, and concluded that buffer strips were able to significantly reduce runoff of both pesticides and nutrients compared to with no buffer strips; however, mowing height and aerification did not affect surface runoff. Morvan et al. (2014) found that grassed inter-rows of a vineyard had a runoff coefficient of 1% compared to 80% for bare soil. They attributed the difference to greater infiltration under grass. Even low turf sand densities may greatly reduce runoff and sediment loss compared to bare soil (Gross et al., 1990). Another aspect to stand density is thatch. The heavier thatch under creeping bentgrass (*Agrosis stolonifera*) compared to perennial ryegrass (*Lolium perenne*), for example, slowed runoff and increased infiltration/reduced runoff due to more tortuous flow path (Linde et al., 1995). Similarly, Gutierrez and Hernandez (1996) found that plant type besides ground cover affected runoff and erosion, and that there were significant correlations between the percentage of ground cover and the amount of runoff and erosion. Results from Burwell et al. (2011) were consistent with the foregoing –runoff was decreased up to 84% at a bermudagrass coverage of 90% compared to 10%, and fertilizer N loss decreased over time. As plant density and coverage increase, more protection is provided to the soil from raindrop impact as well and more resistance to surface runoff flow.

1.9. Literature Cited

Balogh, J. C., and Walker, W. J. (1992). Golf Course Management and Construction: Environmental Issues. pp. 82. WATER ENVIRONMENT FEDERATION.

Barton, L., and Colmer, T. D. (2006). Irrigation and fertilizer strategies for minimizing nitrogen leaching from turfgrass. Agricultural Water Management 80, 160-175.

Boesch, D. F. (2002). Challenges and opportunities for science in reducing nutrient over-enrichment of coastal ecosystems. *Estuaries* 25, 886-900.

Brede, D. (2000). "Turfgrass Maintenance reduction handbook: Sports, lawns, and golf," Ann Arbor Press, Chelsea, MI.

Bricker, S. B. (2007). "Effects of nutrient enrichment in the Nation's estuaries [electronic resource]: a decade of change, assessing change in eutrophic condition from the early 1990s to 2004: National Estuarine Eutrophication Assessment update / Authors: Suzanne Bricker ... [et al.]," Silver Spring, Md.: National Centers for Coastal Ocean Science, 2007.

Burwell Jr, R. W., Beasley, J. S., Gaston, L. A., Borst, S. M., Sheffield, R. E., Strahan, R. E., and Munshaw, G. C. (2011). Losses of Surface Runoff, Total Solids, and Nitrogen during Bermudagrass Establishment on Levee Embankments. Journal of Environmental Quality 40, 1241.

Burwell, R. E., Timmons, D. R., and Holt, R. F. (1975). Nutrient Transport in Surface Runoff as Influenced by Soil Cover and Seasonal Periods1. *Soil Science Society of America Journal* 39, 523-528.

Cai, G. X., Chen, D. L., Ding, H., Pacholski, A., Fan, X. H., and Zhu, Z. L. (2002). Nitrogen losses from fertilizers applied to maize, wheat and rice in the North China Plain. *Nutrient Cycling in Agroecosystems* 63, 187-195.

Carey, J. H. (1995). Cynodon dactylon, Fire Effects Information System. Rocky Mountain Research Station, Fire Sciences Laboratory., United States Department of Agriculture, Forest Service.

Cliath, W. F. S. M. (1991). Pesticide Losses in Surface Runoff from Irrigated Fields. *In* "Chemistry for the Protection of the Environment", pp. 277-289.

Cole, J. T., Baird, J. H., Basta, N. T., Huhnke, R. L., Storm, D. E., Johnson, G. V., Payton, M. E., Smolen, M. D., Martin, D. L., and Cole, J. C. (1997). Influence of Buffers on Pesticide and Nutrient Runoff from Bermudagrass Turf. *Journal of Environmental Quality* 26, 1589-1598.

Duble, R. L. (1989). Southern Turfgrasses: Their management and use. TexScape, College Station, TX.

Dunvick, D. N. (2001). Biotechnology in the 1930's: the development of hybrid maize. Nature Reviews Genetics 2, 69-74.

Emmons, R. D. (2000). "Turfgrass Science and Management," Delmar Publishers.

Erickson, J. E., Cisar, J. L., Volin, J. C., and Snyder, G. H. (2001). Comparing Nitrogen Runoff and Leaching between Newly Established St. Augustinegrass Turf and an Alternative Residential Landscape Journal Series No. R-08216 of the Florida Agricultural Experiment Station. Crop Science 41, 1889-1895.

Extension, P. U. E. a. U. o. I. (2006). Bermudagrass for Athletic Fields in Bermudagrass for Athletic Fields in Southern Indiana and Southern Illinois. *Turfgrass Science*, 5.

Fierer, N. G., and Gabet, E. J. (2002). Carbon and Nitrogen Losses by Surface Runoff following Changes in Vegetation. *Journal of Environmental Quality* 31, 1207-1213.

Gómez, S., Gorri, D., and Irabien, Á. (2011). Organochlorine pesticide residues in sediments from coastal environment of Cantabria (northern Spain) and evaluation of the Atlantic Ocean. *Environmental Monitoring and Assessment* 176, 385-401.

Gross, C. M., Angle, J. S., and Welterlen, M. S. (1990). Nutrient and Sediment Losses from Turfgrass. *Journal of Environmental Quality* 19, 663-668.

Guertal, E. A., and Evans, D. L. (2006). Nitrogen Rate and Mowing Height Effects on TifEagle Bermudagrass Establishment. Crop Science 46, 1772-1778.

Gutierrez, J., and Hernandez, I. I. (1996). Runoff and interrill erosion as affected by grass cover in a semi-arid rangeland of northern Mexico. *Journal of Arid Environments* 34, 287-295.

Hanson, B., S. R. G., and Fulton, A. (1999). Agricultural salinity and drainage. University of California, Davis, CA, University of California Irrigation Program.

Heathwaite, A. L., and Dils, R. M. (2000). Characterizing phosphorus loss in surface and subsurface hydrological pathways. *Science of The Total Environment* 251-252, 523-538.

Huckabay, D. Y. H. a. E. (2008). Bermudagrass Lawns. *In* "Alabama Cooperative Extension System", pp. ANR-29.

Johnson, B. J. (1973). Herbicides, sprigging rates, and nitrogen treatments for establishment of Tifway bermudagrass / Herbicides, sprigging rates, and nitrogen treatments for establishment of Tifway bermudagrass. [Cynodon, weed control]. *Agronomy journal*.

Klöppel, H., Kördel, W., and Stein, B. (1997). Herbicide transport by surface runoff and herbicide retention in a filter strip — Rainfall and runoff simulation studies. *Chemosphere* 35, 129-141.

Kronvang, B. (1990). Sediment-associated phosphorus transport from two intensively farmed catchment areas. *In* "Soil erosion on agricultural land", pp. 313-330.

Kopp, K. L., and Guillard, K. (2002). Clipping Management and Nitrogen Fertilization of Turfgrass Contribution no. 1970 of the Storrs Agric. Exp. Stn. Crop Science 42, 1225-1231.

Landry, G. (2018). Bermudagrass Lawn Management. University of Georgia Cooperative Extension Service, Georgia Turf.

Linde, D. T., Watschke, T. L., Jarrett, A. R., and Borger, J. A. (1995). Surface Runoff Assessment from Creeping Bentgrass and Perennial Ryegrass Turf. *Agronomy Journal* 87, 176-182.

Martin, D. (2018). Two new turf bermudagrasses released. Oklahoma State University Turfgrass Science.

Martin, S. and Wells, W. (2001). Economics of Turfgrass Establishment. *MSU Research Reports* 22, 6.

McCarty, L. B., and Miller, G. L. (2002). "Managing bermudagrass turf: selection, construction, cultural practices, and pest management strategies," Chelsea, MI: Ann Arbor Press, c2002.

Mentler, A., Strauss, P. (1998). Phosphorus transport with sediment particles as affected by the location of rainstorm peak intensity. *In* "Practical and innovative measures for the control of agricultural phosphorus losses to water.", pp. 136-137. Dep. of Agric. for Northern Ireland, Greenmount College of Agric. and Hortic., Belfast.

Morton, T. G., Gold, A. J., and Sullivan, W. M. (1988). Influence of Overwatering and Fertilization on Nitrogen Losses from Home Lawns. Journal of Environmental Quality 17, 124-130.

Morvan, X., Naisse, C., Malam Issa, O., Desprats, J. F., Combaud, A., and Cerdan, O. (2014). Effect of ground-cover type on surface runoff and subsequent soil erosion in Champagne vineyards in France. *Soil Use and Management* 30, 372-381.

Munshaw, G. C., Beasley, J. S., Baldwin, C. M., Moss, J. Q., Cropper, K. L., Philley, H. W., Segars, C. A., and Stewart, B. R. (2017). Nitrogen and Sprigging Rate Effects on 'Latitude 36' Hybrid Bermudagrass Establishment. *HortTechnology* 27, 382-385.

Murphy, T., W, R., & Waltz, C. (2003). Bermudagrass Cultivation. University of Georgia Cooperative Extension Service, Geogia Turf.

Nixon, S. W. (1995). Coastal marine eutrophication: A definition, social causes, and future concerns. *Ophelia* 41, 199-219.

NRC (2000). Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution. National Research Council, National Academies Press, Washington DC.

Patton, A. J., Hardebeck, G. A., Williams, D. W., and Reicher, Z. J. (2004). Establishment of bermudagrass and zoysiagrass by seed. *Crop Science* 44, 2160-2167.

Polomski, B., D. S., Hale, T.C., and Forrester, G. (2016). Bermudagrass. Vol. 2018. Clemson University, Clemson Cooperative Extension.

Rabalais, N. N., Turner, R. E., and Jr., W. J. W. (2002). Gulf of Mexico Hypoxia, A.K.A. "The Dead Zone". *Annual Review of Ecology and Systematics* 33, 235-263.

Relf, D. (2009). Establishing Lawns. *Virginia Coop. Ext. Publ.*, 426-718.

Ribaudo, M. O., Ralph Heimlich, Roger Claassen, Mark Peters (2001). Least-Cost Management of Nonpoint Source Pollution: Source Reduction versus Interception Strategies for Controlling Nitrogen Loss in the Mississippi Basin. *Ecological Economics* 37, 183-197.

Sharpley, A. N., Chapra, S. C., Wedepohl, R., Sims, J. T., Daniel, T. C., and Reddy, K. R. (1994). Managing Agricultural Phosphorus for Protection of Surface Waters: Issues and Options. *Journal of Environmental Quality* 23, 437-451.

Sims, J. T., Simard, R. R., and Joern, B. C. (1998). Phosphorus Loss in Agricultural Drainage: Historical Perspective and Current Research. Journal of Environmental Quality 27, 277-293.

Sims, J.T., G. M. P. (2005). Chemistry of Phosphorus in Soils. *Soil Science Society of America Journal* 8, 151.

Singh, J., Kunhikrishnan, A., Bolan, N. S., and Saggar, S. (2013). Impact of urease inhibitor on ammonia and nitrous oxide emissions from temperate pasture soil cores receiving urea fertilizer and cattle urine. *The Science of the Total Environment* 465, 56-63.

Sonzogni, W.C., Chesters, G., Coote, D. R., Jeffs, D. N., Konrad, J. C., Ostry, R. C., and Robinson, J. B. (1980). Pollution from Land Runoff. *Environmental Science and Technology*.

Sorochran, T. S. a. J. (2007). Turfgrass Establishment: Sprigging. *University of Tennessee Ext. Serv. Publ.* W160-D.

STMA (2018). Sprigging Bermudagrass. (S. I. O. Committee, ed.). Sports Turf Manager's Association.

Su, K., Moss, J. Q., Martin, D. L., Zhang, G., and Wu, Y. (2013). "Bermudagrass Drought Tolerance Associated with Dehydrin Protein Expression during Drought Stress."

Taliaferro, C. M., Rouquette, F. M., and Mislevy, P. (2004). Bermudagrass and Stargrass. In "Warm-Season (C4) Grasses" (L. E. Moser, B. L. Burson and L. E. Sollenberger, eds.), pp. 417-475. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Madison, WI.

USEPA (1998). National Water Quality Inventory: 1996 Report to Congress. Office of Water, Washington, DC, 521 pp.

White, M. J., Storm, D. E., Busteed, P. R., Stoodley, S. H., and Phillips, S. J. (2009). Evaluating Nonpoint Source Critical Source Area Contributions at the Watershed Scale. *Journal of Environmental Quality* 38, 1654-1663.

Wu, Y. S., OK, US), Martin, D. L. S., OK, US), Taliaferro, C. M. S., OK, US), Anderson, J. A. S., OK, US), and Moss, J. Q. P., OK, US) (2014). Latitude 36 Turf Bermudagrass. The Board of Regents for Oklahoma State University (Stillwater, OK, US)

Yu, Q., Ma, J., Zou, P., Lin, H., Sun, W., Yin, J., and Fu, J. (2014). "Effects of combined application of organic and inorganic fertilizers plus nitrification inhibitor DMPP on nitrogen runoff loss in vegetable soils."

Yuan, L. (1997). Hybrid rice breeding for super high yield. In "China and IRRI: Improving China's rice productivity in the 21st century" (G. L. D. a. T. W. Mew, ed.), pp. 10-12. Chinese academy of agricultural sciences, Beijing, People's Republic of China.

ZL, Z. (1997). Fate and management of fertilizer nitrogen in agroecosystems. *Nitrogen in Soils of China*, 239-279.

CHAPTER 2. INFLUENCE OF SPRIG PLANTING RATE AND NITROGEN FERTILITY RATE ON ESTABLISHMENT AND SURFACE RUNOFF LOSSES OF LATITUDE 36 BERMUDAGRASS

2.1. Introduction

Bermudagrass provides a dense, vigorous turfgrass with excellent heat, drought, and wear tolerances (Kowalewski et. al., 2015; Su et. al.; 2013) for use on athletic surfaces, homelawns, and right-of-ways in the southern United States. However, unlike common bermudagrass species propagated by seed, most high quality bermudagrasses are vegetatively propagated through sod or sprigs (McCarty et al.; 2002). Sod provides immediate soil coverage with a relatively short establishment period but is expensive as acreage increases (Patton et. al.; 2004). The alternative relies on bermudagrass sprigs, segments of rhizomes or stolons, for a more economical albeit slower propagation method (Munshaw et al., 2017; Taylor, 2014). In an effort to achieve full bermudagrass ground coverage as quickly as possible, it is common practice for turf managers to apply high rates and frequencies of both N fertilizer and irrigation (Guertal and Evans, 2006; Hay et al., 2007).

A practice that has been reported to shorten the duration of establishment is increasing sprig planting rates (Brede 2000; Duble 1989; Johnson, 1973). Both Johnson (1973) and Duble (1989) reported higher planting rates of 'Tifway' bermudagrass led to faster bermudagrass establishment. Duble (1989) suggested rates between 538 and 1612 bu^{-1} ha^{-1} are sufficient to establish bermudagrass within 10 to 12 weeks after planting (WAP) even though rates up to 2690 bu^{-1} ha^{-1} had been evaluated in the study. In more recent studies examining sprig planting rates and N fertility of newer, more aggressive bermudagrass cultivars, results support previous findings that increasing sprig planting rates consistently leads to faster bermudagrass establishment (Geurtal and Evans, 2006; Munshaw et al., 2017) but indicate the effects of high N fertility are less obvious. For example, a study evaluating Latitude 36 establishment conducted in four states in the southeastern United States examined sprig planting rates of 494, 988, 1482 and 1976 bu ha^{-1} fertilized at 0, 12, 24, or 48 kg N ha^{-1} wk^{-1}. As the planting rate increased to 1482 bu ha^{-1} bermudagrass establishment increased 94% compared to 82% at 4 WAP when relying on N application rates above 12 kg N ha^{-1} wk^{-1} at lower or corresponding planting rates (Munshaw et al, 2017).

Although several published studies examining parameters for bermudagrass establishment from sprigs clearly indicate planting rates are a more important factor in bermudagrass establishment than increasing N fertility, several extension publications continue to suggest high N rates are beneficial (Han and Huckabay, 2008; Relf, 2009; Samples and Sorochan, 2007). Recommending higher N fertility may be to prevent turfgrass managers from limiting N and thus plant uptake and growth but could also be the result of adopting the perception that vigorous bermudagrass cultivars require higher fertility. Regardless, if N applications is applied above plant requirements offsite movement of nutrients could have negative unintended environmental consequences to surface waters especially in high-precipitation receiving areas along the Gulf Coast of the United States.

In areas that have finer textured soils and high rainfall, offsite movement of nutrients from various horticulture and agronomic commodities have been extensively reported (Baker and Laflen, 1982; Bilderback 2002; Nicholaichuk and Read, 1978; Zhu et al., 1989). In the case of turfgrass, dense turfgrass coverages reduce the incident of surface runoff and trap suspended sediments to reduce pollutant transfer (Morvan et. al., 2014; Burwell et al. 2011 Krenitsky et al., 1998; Gross et al., 1991). In Kentucky bluegrass (*Poa pratensis* L.) and perennial ryegrass (*Lolium perenne* L.), Easton and Petrovic (2004) reported turfgrass density greatly affects surface runoff occurrence and severity and therefore nutrient movement. Given the low plant density and high soil moisture that occurs during establishment, establishment represents a period a site is extremely susceptible to surface runoff and movement of nutrients and sediment. Accelerating bermudagrass establishment through higher sprig planting rates or increasing N fertility could alter surface runoff severity and thereby affect nutrient and sediment movement with denser groundcover.

There is limited information regarding the effect of sprig planting rates and N fertility during vegetative establishment from sprigs compared to seed establishment of turfgrasses (Brede et al., 1984; Leinauer et al., 2010; Maddison 1966, Munshaw et al., 2001; Patton et al., 2004;) and less information regarding best management practices during establishment. Therefore, a study was conducted to examine the effects sprig planting rate and N fertility has on Latitude 36 hybrid bermudagrass establishment as well as characterize the potential impact of these practices on nutrient and sediment losses during surface runoff in order to develop sound best management practices.

2.2. Materials & Methods

2.2.1. Site Characterization, and Sprig Planting, and N Rates

2.2.2.1. The study was conducted at the Louisiana State University Agricultural Center (LSU AgCenter) Botanic Gardens in Baton Rouge, Louisiana (30°24'25.3"N 91°06'09.5"W) on a horizon material of an Oprairie silt loam (fine-silty, mixed, semiactive, thermic Fragiaquic Glossudalfs) to examine the effects of sprig planting and N fertilization rates on establishment of Latitude 36 bermudagrass. Repeated experiments were initiated 5 June 2018 and 2 September 2018. In particular, Latitude 36 was sprigged into runoff trays (1.8 m width x 6.1m length x 0.35 m depth) of soil under a rainout shelter. Trays were inclined 3° and subdivided using wooden inserts to form plots measuring1.4 m^2. Prior to planting sprigs, soil samples were analyzed at the LSU AgCenter Soil Testing and Plant Analysis Laboratory for pH (1:1, soil:water; = 7.2), and Mehlich 3 concentrations of P (= 68 mg kg^{-1}) and K (= 172 mg kg^{-1}). The soil surface was prepared by tilling and raking before planting sprigs. Latitude 36 bermudagrass was planted at 494 or 1482 bu. sprigs ha^{-1} and fertilized at either 12 or 48 kg N ha^{-1} wk^{-1} at 7, 14, 21 and 28 DAP using a granular ammonium sulfate (21-0-0). There were three replicates of each treatment (N = 12). The sprig planting and N fertilization rates selected for this study were based on Munshaw et al (2017), with the sprigging rate of 494 bu ha^{-1} and N rate of 48 kg ha^{-1} wk^{-1} representing current establishment practices. During the first 7 days after planting (DAP), irrigation was applied up to five times per day using watering cans to prevent surface runoff. After the initial rainfall simulation (10 DAP), irrigation application occurred as needed based on visual inspection.

2.2.2. Rainfall Simulation Measurements and Analyses.

Installation of runoff collection systems were at the base of each plot and consisted of two right-angle-inserts to direct water through a PVC gutter into 68-L reservoirs. Rainfall was simulated at 7.6 cm hr^{-1} for a duration of 30 minutes per events at 10, 20, and 30 DAP using stainless steel nozzles (2HH-SS30WSQ, Spraying Systems Co., Wheaton, Illinois) positioned above each tray.

Prior to each rainfall simulation bermudagrass groundcover was recorded. Bermudagrass groundcover were measured using a quadrat fitted with 1 cm x 1 cm wire mesh. Observations of grass presence or absence at 100 pre-marked cross sections of the wire mesh and counted for three random areas within each plot to determine a mean groundcover. At the conclusion of the 30-min rainfall simulation total runoff water volume was determined as mass of water collected in reservoirs. After mixing runoff water, 1-L subsamples were collected in glass containers and transported to the laboratory for storage at 5° C until analyses occurred.

Total solids analysis were performed at the LSU AgCenter W. A. Callageri Environmental Laboratory by evaporation at 105° C for 23 h and further heating at 180° C for one h. Samples were analyzed for total solids, inorganic N (NH_4^+-N + NO_3^--N), and total P. The microplate method of Hood-Nowotny (2010) was used for inorganic N. Total P was determined by persulfate digestion as described by Pote et al. (2009), with analysis as per Murphy and Riley (1962). At 35 DAP bermudagrass groundcover, shoot biomass, and shoot count were measured. Total biomass was based on harvest from a 6.35 cm^2 area dried for 72 hours at 55°C before weighing biomass. Shoot counts were for a 2.54 cm^2 area within each treatment.

2.2.3. Statistical Analysis.

The study was a complete randomized design and utilized repeated measures analysis for the measurements of groundcover, runoff volume, and losses of total solids, dissolved N, and total P losses. Fixed effects were sprig planting rate and N application rate with experimental run considered a random variable. Data were analyzed using the MIXED procedure in the statistical software of SAS 9.4 (SAS Institute, Cary NC) with means separated following Tukey post-hoc procedure at $\alpha = 0.05$. Data for total runoff volume and total solids losses during each 30-min rainfall simulations across both experimental runs were modeled as a function of bermudagrass groundcover for all sprig planting rates and N fertilities.

2.3. Results

2.3.1. Latitude 36 Bermudagrass Establishment

All treatment combinations of sprig planting and N fertilizer rates led to bermudagrass attaining >88% groundcover 35 DAP (Figure 1). However, the effects of sprig planting rate and N fertilization on groundcover differed over time. The higher sprigging rate of 1482 bu ha^{-1} resulted in higher bermudagrass groundcover compared to the lower sprig planting rate of 494 bu ha^{-1} regardless of N fertility. For example, 10 DAP bermudagrass planted at 1482 bu ha^{-1} attained 46 and 50% ground coverage for lower and higher N regimens, respectively, compared to 23 and 25% groundcover for sprigs planted at 494 bu ha^{-1}. This led to the higher sprig planting rate attaining > 90% groundcover within 20 DAP, whereas sprigs planted at the lower rate did not have a similar bermudagrass groundcover until 30 DAP. Increasing N fertility did not correspond to higher bermudagrass groundcover regardless of the sprig rate planted or measurement date.

At the conclusion of the 35-day experiments, bermudagrass shoot biomass did not differ between sprig planting and N fertility treatments with a range of 194.4 to 307.2 kg ha^{-1} (Table 1). However, bermudagrass established at the 494 bu ha^{-1} exhibited an overall lower tiller density than sprigs established at 1482 bu ha^{-1} (Table 1). Tiller density increased slightly with each increase in either sprig planting rate and/or N application rate. The highest density, 27.2 $shoots^{-1}$ cm^2, occurred at the 1482 bu ha^{-1} planting rate fertilized with 48 kg N ha^{-1} wk^{-1} and the lowest density, of 17.2 $shoots^{-1}$ cm^2, occurred for sprigs planted at 494 bu ha^{-1} and fertilized at 12 kg N ha^{-1} wk^{-1}. Nitrogen fertility did not affect plant density for sprigs planted at the same rate.

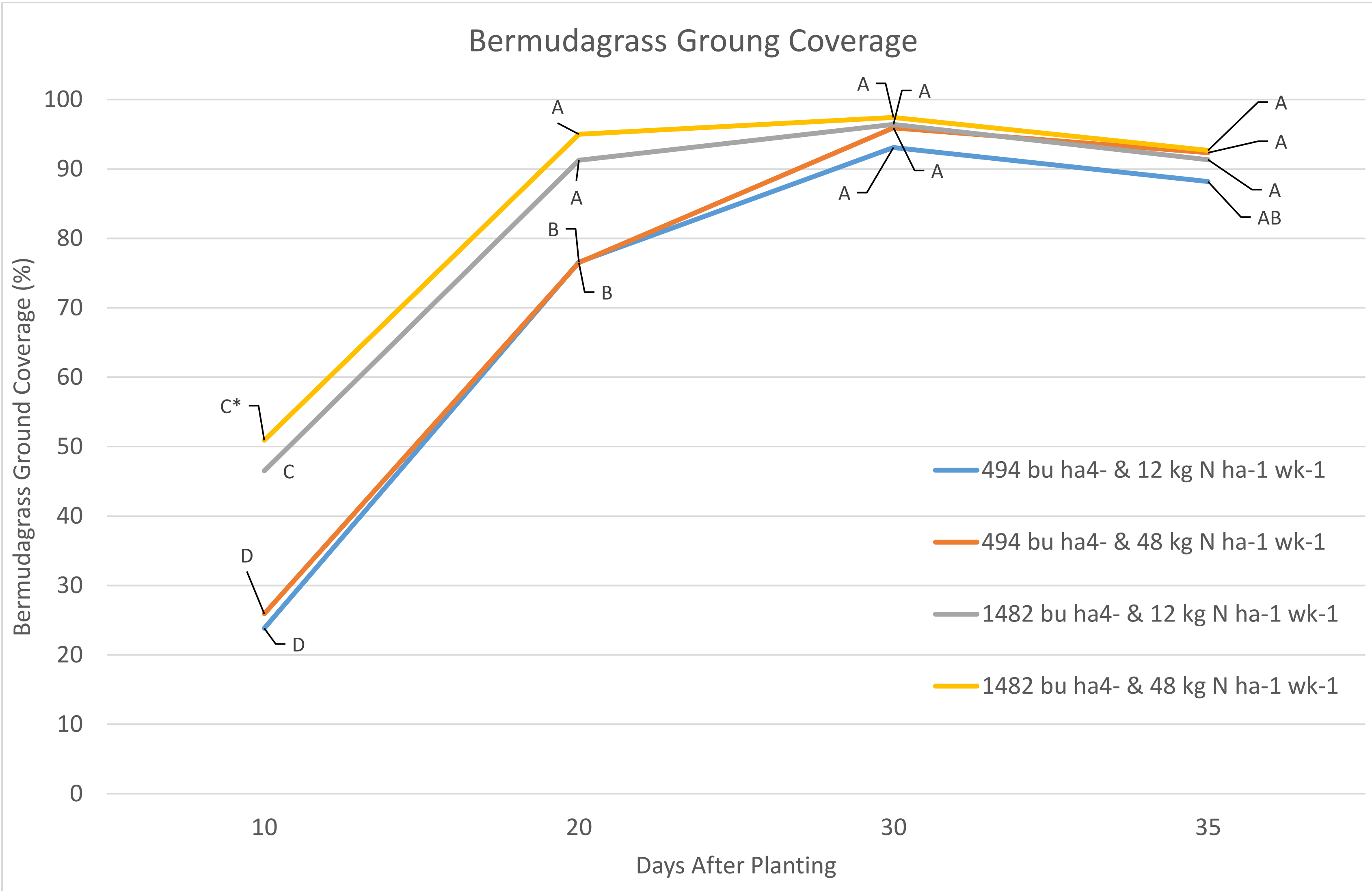

Figure 1. Bermudagrass cv Latitude 36 ground coverage established at sprig planting rates of 494 or 1482 bu ha-1 and fertilized at 12 or 48 kg N ha-1 wk-1 over a 35-day establishment for two experimental runs in Baton Rouge, LA. in 2018.

* Means on the graph are separated using Tukey's method ($P<0.05$). Means are different if followed by different letters

Table 1. ANOVA table for Bermudagrass cv Latitude 36 establishment at two sprig planting and N fertilization rates for 35 days after planting for two experiments conducted in 2018.

Effect	Degrees of Freedom	Runoff Volume	Sediment Losses	Dissolved N Losses	Total P Losses
Sprig Planting Rate (SPR)	1	NS	**	*	*
Nitrogen Rate (NR)	1	**	NS	**	NS
SPR * NR	1	NS	NS	NS	NS
Days after Planting (DAP)	2	***	***	***	***
SPR * DAP	2	NS	*	NS	NS
NR * DAP	2	NS	NS	**	NS
SPR * NR * DAP	2	NS	NS	NS	NS

*, **, *** represent significant at <0.1, <0.05, and <0.001.

Table 2. Bermudagrass cv Latitude 36 biomass and plant density for two sprig planting and N fertilization rates at 35 days after planting for two experiments conducted in 2018.

Sprig Planting Rate	Nitrogen Fertility	Biomass	Density
bu ha^{-1}	kg N ha^{-1} wk^{-1}	Kg ha^{-1}	no. of Shoots cm^{-2}
494	12	194.4 a	17.2 b
494	48	205.6 a	19.7 b
1482	12	210.3 a	23.0 ab
1482	48	307.2 a	27.2 a

* Means within a column within a sprig planting rate and nitrogen fertility rate are separated using Tukey's method (P<0.05). Means are different if followed by different letters.

2.3.2 Surface Runoff of Latitude 36 Bermudagrass during Establishment

Increasing bermudagrass coverage provided greater resistance to surface water flow and filtered more suspended solids (Figures 2 and 3) as illustrated when the two measurements were regressed against groundcover for all treatments and rainfall events across the two experimental runs. In the case of runoff volume, volumes did not decrease until bermudagrass groundcover exceeded 60%; whereas sediment losses declined linearly with increasing bermudagrass coverage. However, if the factors of sprig planting rate and N applications are accounted, both parameters affected runoff volume and sediment losses differently. Increasing the N application rate from 12 to 48 kg N ha^{-1} wk^{-1} led to a decrease of 19 % in runoff volume with average runoff volumes declining from 44.6 to 24.6 and 13.0 L ha^{-1} at 10, 20, and 30 DAP, respectively, as bermudagrass coverage increased across all treatment combinations.

Conversely, increasing N did not significantly accelerate bermudagrass sprig groundcover to reduce sediment losses; but increasing the sprig planting rate to 1482 bu ha^{-1} led to an overall decline of 361,528 from 1,144,514 g ha^{-1} for the lower sprig planting rate of 494 bu ha^{-1}. Similar to the trend of declining runoff volumes lost over the sequential runoff events, sediment declined from 318,371 to 123,679 and 39,821 g ha^{-1} at 10, 20, and 30 DAP across all treatments. The cumulative sediment lost over the three rainfall events were consistently decreased at the higher sprig planting rate of 1482 bu ha^{-1} while the lower sprig rate of 494 bu ha^{-1} resulted in a decline of 191,572 g ha^{-1} or 29% following the higher N regimen versus lower N regimen.

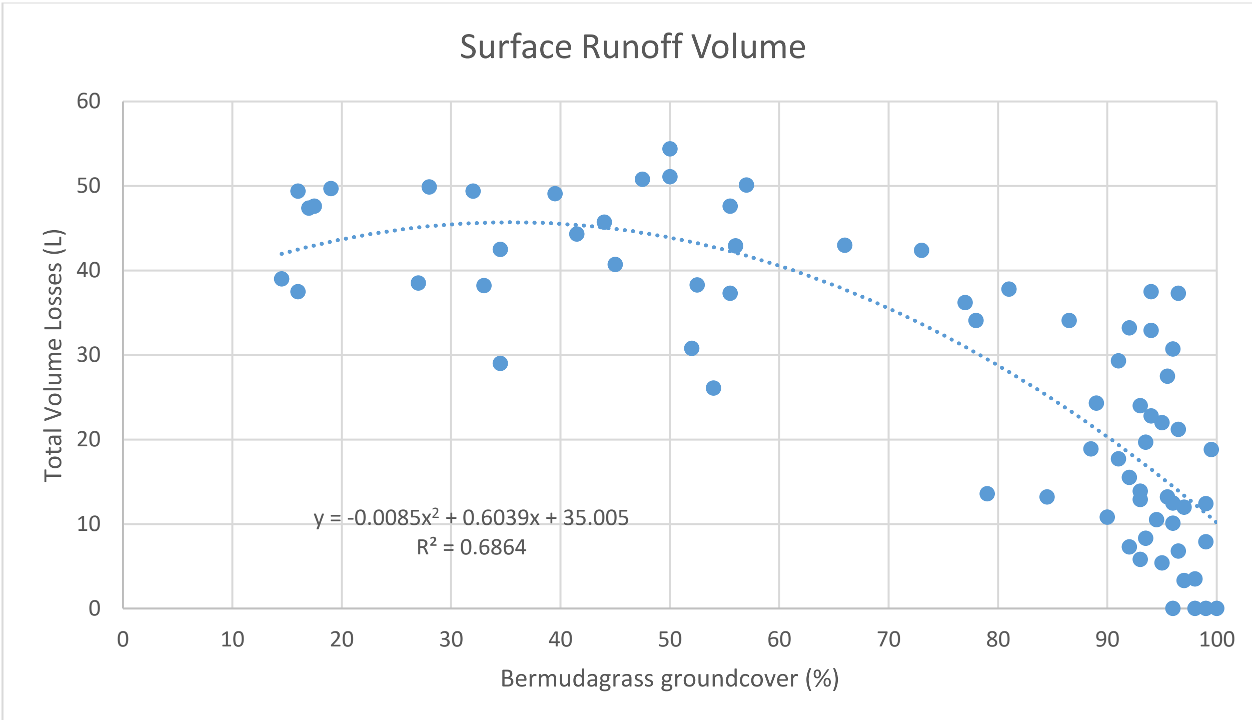

Figure 2. Total surface runoff volume lost from two sprig planting rates (494 and 1482 bu ha-1) and two N application rates (12 and 48 kg N ha-1 wk-1) for both experiments.

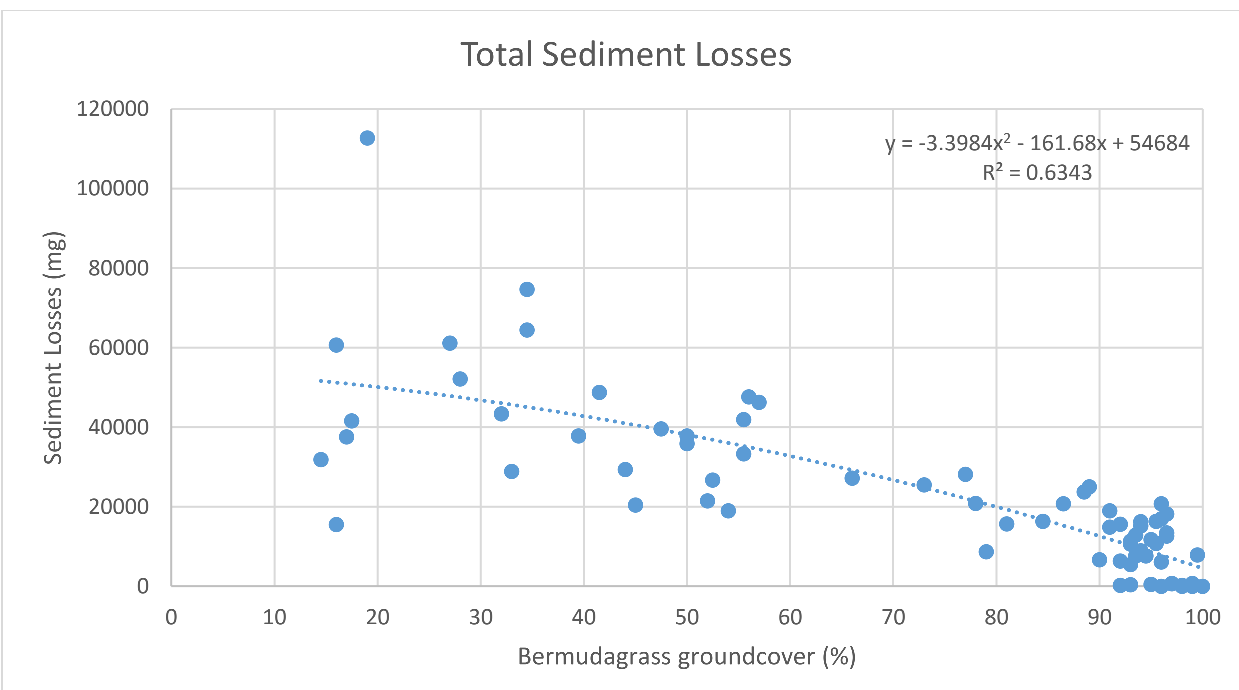

Figure 3. Total Solids lost from two sprig planting rates (494 and 1482 bu ha-1) and two N application rates (12 and 48 kg N ha-1 wk-1) for both experiments.

Table 3. Total volume, sediment, and phosphorus losses at 10, 20, and 30 DAP for both experimental trials.

	Total Volume	Total Sediment	Total Phosphorus
DAP	L/ha	g/ha	
10	321429 a*	318371 a	264 a
20	178571 b	123679 b	71 b
30	92857 c	39821 c	14 c

* Means within a column within a sprig planting rate and nitrogen fertility rate are separated using Tukey's method (P<0.05). Means are different if followed by different letters.

Table 4. Total sediment, phosphorus, and dissolved nitrogen losses from two sprig planting rates and two N application rates for both experimental trials.

Sprig Planting Rate	Nitrogen Fertility	Total Sediment	Total Phosphorus	Dissolved Nitrogen
bu ha4-	kg N ha4 wk-1		g/ha	
494	12	668043 a*	450 a	1079 b
494	48	476471 ab	357 a	2343 a
1482	12	388586 b	300 a	679 b
1482	48	394400 b	307 a	1486 ab

* Means within a column within a sprig planting rate and nitrogen fertility rate are separated using Tukey's method (P<0.05). Means are different if followed by different letters.

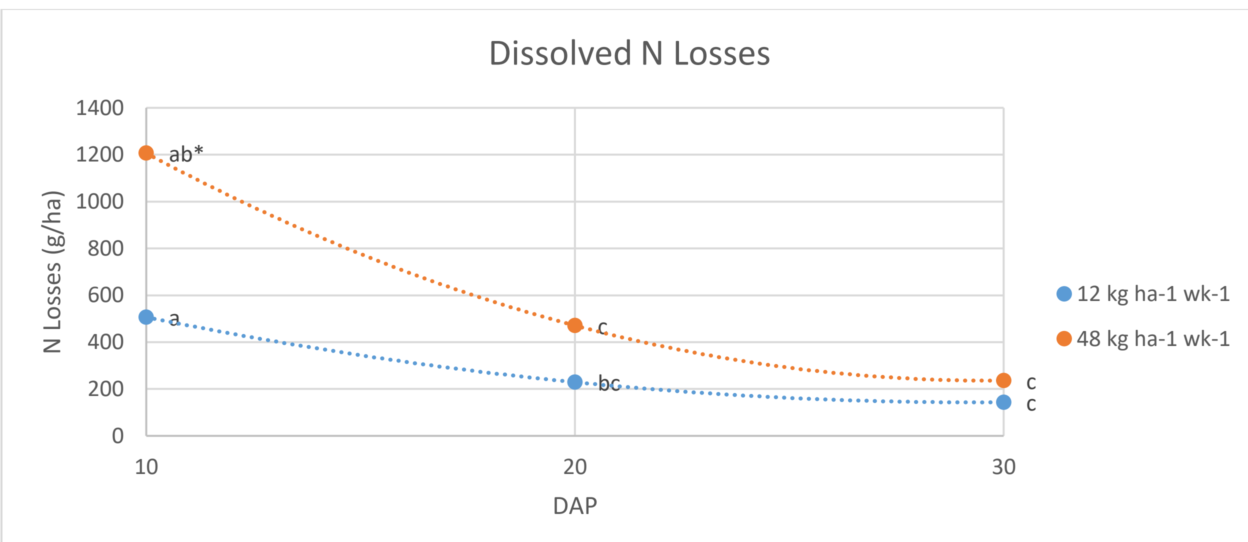

Figure 4. Dissolved N losses for both N fertility rates at 10, 20, and 30 DAP for both experimental trials in 2018.
* Means within a column within a sprig planting rate and nitrogen fertility rate are separated using Tukey's method (P<0.05). Means are different if followed by different letters.

2.3.3. Nutrient Losses during Surface Runoff of Latitude 36 Bermudagrass

Higher total dissolved N losses occurred with the higher N application rate (Table 4) but was unaffected by sprig planting rate. Losses of DN declined to 507 to 229 and 143 g ha^{-1} at 10, 20, and 30 DAP for sprigs fertilized at 12 kg N ha^{-1} compared to 1207, 471, and 236 g ha^{-1} for sprigs fertilized at 48 kg N ha^{-1} over the same time (Figure 4). The rainfall event 10 DAP accounted for 58 and 63% of the total DN losses during the 35-day experiment period for the two N regimens. For example, bermudagrass at 494 bu ha^{-1} and 48 kg N ha^{-1} wk^{-1} had N losses of 1,300 g ha^{-1} compared to 371 g ha^{-1} N for the higher sprigging and lower N rate. Across sprigging rates, N losses were 46% greater from the higher than lower N rate. However, by 30 DAP dissolved N losses decreased 74% compared to losses at 10 DAP regardless of the N rate applied. At the conclusion of the experiments, fertilizing at the lower N application rate of 12 kg ha-1 wk-1 consistently resulted in the lower cumulative DN losses of 679 and 1079 g ha^{-1} compared to the combination of a low sprig planting rate and high N application rate.

Total P losses from the sprig planting treatments consistently declined over time as bermudagrass groundcover increased but did not differ with changes in sprig planting or N fertilization rates (Table 4). Similar to dissolved N losses, the highest P losses occurred during the initial rainfall simulation and accounting for 70% and 79% of the total P lost with TP losses at 30 DAP accounting for less than 7% of the cumulative P losses.

2.4. Discussion

Increasing the rate of bermudagrass establishment is not only advantageous for limiting the period an area is unavailable for use but has potential environmental benefits of curbing erosion and nutrient losses. In this study, planting bermudagrass sprigs at 1482 bu ha^{-1} resulted in >90% groundcover at 20 DAP compared to 30 DAP for the lower sprig planting rate. The acceleration in groundcover from increasing the sprig planting rate has been consistently reported for various bermudagrass cultivars (Brede 2000; Duble 1989; Johnson et al., 1973; Munshaw et al., 2017). However, fertilizing at a higher N rate did not sufficiently accelerate bermudagrass growth for sprigs planted at the same rate; or more importantly sprigs planted at the rate of 494 bu ha^{-1} and fertilized at the higher N rate did not expand as fast as sprigs planted at the higher sprig rate and fertilized with 75% less N. Although several studies have reported that high N application rates and frequencies are not required to achieve bermudagrass establishment from sprigs (Geurtal and Evans, 2006; Munshaw et al., 2016), the results of this study not only agree with previously published work but work that focused on Latitude 36 establishment from sprigs (Munshaw et al., 2017).

In addition to not accelerating bermudagrass establishment, the higher N application rate led to >137% greater N lost during three surface runoff events regardless of sprig planting rate when following the higher N regimen. Runoff volumes, total sediment, and total P losses were highest for all treatments 10 DAP and declined over time as bermudagrass groundcover increased a similar pattern that has been modeled previously (Burwell et al., 2011). Although the higher N rate did show an overall decrease in runoff volumes, this decline was unable to translate into reduced sediment loading and P losses. Conversely, planting at the higher sprig rate was the only establishment practice that reduced sediment losses and showed a potential for reducing P sediment losses (P-value 0.0560). Factors such as surface runoff intensity, duration, and timing during the establishment period would affect losses particularly if multiple runoff events occurred during the first 10 DAP.

If the effect of increasing N fertility did not sufficiently accelerate bermudagrass sprig growth during establishment then it is important to understand the potential drawbacks associated with higher N application rates. In areas of the mid-South such as Louisiana where annual precipitation can exceed 150 cm yr^{-1} (Weather Service, 2018), sediment and nutrient losses will occur during establishment on fine textured soils due to low plant density (Burwell et al., 2011) and soil moisture from routine irrigation to prevent sprig desiccation. A dense turfgrass can delay the onset of surface runoff to reduce runoff volumes, sediment and nutrient transport (Cole et al., 1997; Gross et al., 1990; Morvan et al., 2014; Wherley et al., 2009). Greater bermudagrass groundcover led to reduced runoff volumes and sediment losses due to increased water infiltration, tortuous flow path and entrapment of suspended sediments (Burwell et al., 2011; Linde et al., 1995). Previous work with turfgrass establishment by Easton and Petrovic (2004), and Burwell et al (2011) found that increasing density and groundcover of Kentucky blue grass and common bermudagrass (*Cynadon dactylon* L.) led to declining water volume and sediment losses.

Although a dense turfgrass groundcover decreases surface runoff occurrence and severity, a higher rate of N fertilization above 12 kg ha^{-1} wk^{-1} does not sufficiently accelerate bermudagrass growth to offset nutrient and sediment losses, and therefore is unjustified for this purpose. Furthermore, since most P losses in runoff is associated with sediment P losses, increasing sprig planting rates above 1484 bu ha^{-1} could further reduce erosion (Lentz et al., 1998). Increasing sprig planting rates may create a physical soil barrier that reduces splash erosion (CITE). In the current study, as coverage increased over time, the ability of the turfgrass to filter out the P increased and losses decreased.

The lack of response of bermudagrass sprigs to higher N fertilization during establishment reflected initial plant density, and N uptake and utilization. Declines in N losses were measured for all treatment combinations from 10 DAP to 30 DAP even though additional N was applied weekly. Nutrient uptake is governed by several factors such as plant age, rooting, nutrient availability, and abiotic environmental factors (Alam 1999; Baldwin 1975; Clarkson 1985). Since sprigs are segments of stolons that have undeveloped root systems this is a physical limit on N uptake. Root architecture has been shown to be positively related to N uptake and reduced N leaching for other turfgrass species (Bowman et al., 1998). Although the N uptake and utilization is not fully understood for bermudagrass sprigs during establishment, declining N loses from 10 DAP to 30 DAP and higher bermudagrass groundcover suggests that nutrient uptake was a significant factor. Further, stress during the initial days after planting may have affected uptake. The effect may have been similar to findings of Sermons et al. (2017) on reduced fertilizer N uptake and changes in N utilization for bermudagrass when exiting dormancy. Overall, the application of N above 12 kg N ha^{-1} provided no benefit to accelerating Latitude 36 establishment from sprigs; but further study is needed to better define N uptake and utilization during establishment and therefore improve fertility guidelines.

During the establishment period of bermudagrass from sprigs, surface runoff will result in sediment and nutrient losses. However, efforts can be made to mitigate some of those losses. Many negative environmental effects are associated with planting at low sprig rates and attempting to compensate with high N applications. In this study, N rates above 12 kg N ha^{-1} wk^{-1} were unable to increase bermudagrass growth sufficiently to offset sediment and nutrient losses and therefore unnecessary. The use of 48 kg N ha^{-1} wk^{-1} only led to higher initial N losses through surface runoff regardless of the sprig planting rate. The best method of reducing N losses through surface runoff is to apply less N. In an effort to achieve full bermudagrass groundcover faster and reduce surface runoff losses, planting at a higher sprig rate is more effective.

2.5. Literature Cited

Alam, S. M. (1999). Nutrient Uptake by Plants Under Stress Conditions. *In* "Handbook of Plant and Crop Stress". Marcel Dekker, Inc.

Baker, L., J., and M. Laflen, J. (1982). Effects of Corn Residue and Fertilizer Management on Soluble Nutrient Runoff Losses. Transactions of the ASAE 25, 344-0348.

Baldwin, J. P. (1975). A quantitative analysis of the factors affecting plant nutrient uptake from some soils. *Journal of Soil Science* 26, 195-206.

Bilderback, T. E. (2002). Water management is key in reducing nutrient runoff from container nurseries. Vol. 12, pp. 541-544.

Bowman, D. C., Devitt, D. A., Engelke, M. C., and Rufty, T. W. (1998). Root Archutecture Affects Nitrate Leaching from Bentgrass Turf. *Crop Science* 38, 1633-1639.

Brede, A. D., and Duich, J. M. (1984). Establishment Characteristics of Kentucky Bluegrass-Perennial Ryegrass Turf Mixtures as Affected by Seeding Rate and Ratio1. Agronomy Journal 76, 875-879.

Brede, D. (2000). "Turfgrass Maintenance reduction handbook: Sprots, lawns, and golf," Ann Arbor Press, Chelsea, MI.

Burwell Jr, R. W., Beasley, J. S., Gaston, L. A., Borst, S. M., Sheffield, R. E., Strahan, R. E., and Munshaw, G. C. (2011). Losses of Surface Runoff, Total Solids, and Nitrogen during Bermudagrass Establishment on Levee Embankments. *Journal of Environmental Quality* 40, 1241.

Clarkson, D. T. (1985). Factors Affecting Mineral Nutrient Acquisition by Plants. *In* "Annual Review Plant Physiology", pp. 77-115. Annual Reviews, Inc. .

Cole, J. T., Baird, J. H., Basta, N. T., Huhnke, R. L., Storm, D. E., Johnson, G. V., Payton, M. E., Smolen, M. D., Martin, D. L., and Cole, J. C. (1997). Influence of Buffers on Pesticide and Nutrient Runoff from Bermudagrass Turf. *Journal of Environmental Quality* 26, 1589-1598.

Duble, R. L. (1989). Bermudagrass. Vol. 2018. Texas Cooperative Extension, Texas Cooperative Extension.

Dunn, J. H., Minner, D. D., Fresenburg, B. F., Bughrara, S. S., and Hohnstrater, C. H. (1995). Influence of Core Aerification, Topdressing, and Nitrogen on Mat, Roots, and Quality of 'Meyer' Zoysiagrass. *Agronomy Journal* 87, 891-894.

Easton, Z. M., and Petrovic, A. M. (2004). Fertilizer Source Effect on Ground and Surface Water Quality in Drainage from Turfgrass. *Journal of Environmental Quality* 33, 645-655.

Evans, E. A. G. a. D. L. (2006). Nitrogen and mowing height effects on Tifeagle bermudagrass establishment. *Crop Science* 46, 1772-1778.

Extension, P. U. E. a. U. o. I. (2006). Bermudagrass for Athletic Fields in Bermudagrass for Athletic Fields in Southern Indiana and Southern Illinois. *Turfgrass Science*, 5.

Frank, K. W., O'Reilly, K. M., Crum, J. R., and Calhoun, R. N. (2006). The Fate of Nitrogen Applied to a Mature Kentucky Bluegrass Turf. *Crop Science* 46, 209-215.

Gross, C. M., Angle, J. S., and Welterlen, M. S. (1990). Nutrient and Sediment Losses from Turfgrass. *Journal of Environmental Quality* 19, 663-668.

Gross, C. M., Angle, J. S., Hill, R. L., and Welterlen, M. S. (1991). Runoff and Sediment Losses from Tall Fescue under Simulated Rainfall. Journal of Environmental Quality 20, 604-607.

Guertal, E. A., and Evans, D. L. (2006). Nitrogen Rate and Mowing Height Effects on TifEagle Bermudagrass Establishment. *Crop Science* 46, 1772-1778.

HF. J. Hay, D. M. V., 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 establishmet. *Plant Soil* 296, 1-17.

Hood-Nowotny, R., Umana, N. H.-N., Inselbacher, E., Oswald-Lachouani, P., and Wanek, W. (2010). Alternative Methods for Measuring Inorganic, Organic, and Total Dissolved Nitrogen in Soil. *Soil Science Society of America Journal* 74, 1018-1027.

Huckabay, D. Y. H. a. E. (2008). Bermudagrass Lawns. *In* "Alabama Cooperative Extension System", pp. ANR-29.

Johnson, B. J. (1973). Herbicides, sprigging rates, and nitrogen treatments for establishment of Tifway bermudagrass / Herbicides, sprigging rates, and nitrogen treatments for establishment of Tifway bermudagrass. [Cynodon, weed control]. *Agronomy journal*.

Kowalewski, A. R., Schwartz, B. M., Grimshaw, A. L., Sullivan, D. G., and Peake, J. B. (2015). Correlations Between Hybrid Bermudagrass Morphology and Wear Tolerance. *HortTechnology* 25, 725.

Krenitsky, E. C., Carroll, M. J., Hill, R. L., and Krouse, J. M. (1998). Runoff and Sediment Losses from Natural and Man-Made Erosion Control Materials. Crop Science 38, 1042-1046.

Leinauer, B., Serena, M., and Singh, D. (2010). Seed Coating and Seeding Rate Effects on Turfgrass Germination and Establishment. HortTechnology.

Lentz, R. D., Sojka, R. E., and Robbins, C. W. (1998). Reducing Phosphorus Losses from Surface-Irrigated Fields: Emerging Polyacrylamide Technology. *Journal of Environmental Quality* 27, 305-312.

Madison, J. H. (1966). Optimum Rates of Seeding Turfgrasses1. Agronomy Journal 58, 441-443.

Mallin, M. A., and Wheeler, T. L. (2000). Nutrient and fecal coliform discharge from coastal North Carolina golf courses. *Journal of Environmental Quality* 29, 979-986.

McCarty, L. B., and Miller, G. L. (2002). "Managing bermudagrass turf : selection, construction, cultural practices, and pest management strategies," Chelsea, MI : Ann Arbor Press, c2002.

Mentler, P. S. a. A. (1998). Phosphorus transport with sediment particles as affected by the location of rainstorm peak intensity. *In* "Practical and innovative measures for the control of agricultural phosphorus losses to water.", pp. 136-137. Dep. of Agric. for Northern Ireland, Greenmount College of Agric. and Hortic., Belfast.

Morvan, X., Naisse, C., Malam Issa, O., Desprats, J. F., Combaud, A., and Cerdan, O. (2014). Effect of ground-cover type on surface runoff and subsequent soil erosion in Champagne vineyards in France. *Soil Use and Management* 30, 372-381.

Munshaw, G. C., Beasley, J. S., Baldwin, C. M., Moss, J. Q., Cropper, K. L., Philley, H. W., Segars, C. A., and Stewart, B. R. (2017). Nitrogen and Sprigging Rate Effects on 'Latitude 36' Hybrid Bermudagrass Establishment. *HortTechnology* 27, 382-385.

Munshaw, G. C., Williams, D. W., and Cornelius, P. L. (2001). Management Strategies during the Establishment Year Enhance Production and Fitness of Seeded Bermudagrass Stolons Published with the approval of the Director, KY Agric. Exp. Stn. as publication 00-06-90. *Crop Science* 41, 1558-1564.

Murphy, J., and Riley, J. P. (1962). A modified single solution method for the determination of phosphate in natural waters. *Analytica Chimica Acta* 27, 31-36.

Nicholaichuk, W., and Read, D. W. L. (1978). Nutrient Runoff from Fertilized and Unfertilized Fields in Western Canada1. Journal of Environmental Quality 7, 542-544.

Patton, A. J., Hardebeck, G. A., Williams, D. W., and Reicher, Z. J. (2004). Establishment of Bermudagrass and Zoysiagrass by Seed Purdue University Agriculture Experiment Station Journal 17281. *Crop Science* 44, 2160-2167.

Relf, D. (2009). Establishing Lawns. *Virginia Coop. Ext. Publ.*, 426-718.

Sermons, S. M., Wherley, B. G., Zhang, C., Bowman, D. C., and Rufty, T. W. (2017). The role of internal and external nitrogen pools in bermudagrass growth during spring emergence from dormancy. *Journal of Plant Nutrition* 40, 1404-1416.

Service, N. W. (2018a). National Oceanic Atmospheric Associaton.

Sorochran, T. S. a. J. (2007). Turgrass Establishment: Sprigging. *University of Tennessee Ext. Serv. Publ.* W160-D.

STMA (2018). Sprigging Bermudagrass. (S. I. O. Committee, ed.).

Su, K., Moss, J. Q., Martin, D. L., Zhang, G., and Wu, Y. (2013). "Bermudagrass Drought Tolerance Associated with Dehydrin Protein Expression during Drought Stress."

Taliaferro, C. M., Rouquette, F. M., and Mislevy, P. (2004). Bermudagrass and Stargrass. *In* "Warm-Season (C4) Grasses" (L. E. Moser, B. L. Burson and L. E. Sollenberger, eds.), pp. 417-475. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Madison, WI.

Taylor, R. W. (2014). Establishing and managing bermudagrass for pasture and hay. *In* "Crops and Soils Magazine", Vol. 47, pp. 28-34, American Society of Agronomy.

Wherley, B. G., Shi, W., Bowman, D. C., and Rufty, T. W. (2009). Fate of 15N-Nitrate Applied to a Bermudagrass System: Assimilation Profiles in Different Seasons. *Crop Science* 49, 2291-2301.

Zhu, J. C., Gantzer, C. J., Anderson, S. H., Alberts, E. E., and Beuselinck, P. R. (1989). Runoff, Soil, and Dissolved Nutrient Losses from No-Till Soybean with Winter Cover Crops. Soil Science Society of America Journal 53, 1210-1214.

VITA

Lance Rice, a native of Vilonia, Arkansas received his Associates in Agricultural Sciences from Arkansas State University at Beebe in May 2015 and then received his Bachelor of Crop Science from the University of Arkansas in Fayetteville in December of 2016. He was accepted in the Louisiana State University Graduate School and began his program in January of 2017. He anticipates to complete his degree requirements for Masters in Plant, Environmental Management, and Soil Sciences in May 2019.