TURF QUALITY OF CREEPING BENTGRASS USING FOLIAR FERTILIZATION TANK-MIXED WITH SPRAYABLE ORGANIC AMENDMENTS

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Title

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MASTER OF SCIENCE

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ABSTRACT

The use of foliar fertilizer applications on creeping bentgrass (*Agrostis stolonifera* L.) is a popular method of achieving quality turfgrass. Tank-mixing foliar products may increase turfgrass quality, reduce amount of applications, and create synergism between products. The objective of this thesis was to determine the effectiveness of tank-mixing organic amendments with N fertilizers to improve turfgrass quality. A greenhouse study was conducted in 2012 and 2013 to determine turf quality of three different N forms tank-mixed with three different organic amendments. Generally, urea treatments received the highest VQ among all N forms ranging from 1.6-3.5 higher than control. Experiment one; TurfWorks® was always the highest VQ with an average of 6.5 compared to 5.8 for control. Experiment two; Ful-Power® was the highest VQ with a 6.7 average, compared to 6.0 for control. Clipping yield, green density, DGCI, NDVI, and clipping yield were all significant by N forms, but not OM.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1. LITERATURE REVIEW

Introduction

Creeping bentgrass (*Agrostis stolonifera* L.) is often used as high quality turfgrass and requires intensive management (Beard and Beard, 2005). Fine texture and the extremely high-density under close mowing make it the grass of choice for golf course greens. Creeping bentgrass also has an excellent tolerance to submersion and freezing, which adds to its adaptability to the environments in northern America.

Fertilization of turfgrass is one of three important basic cultural practices, including irrigation and mowing, to achieve consistency in color, vigor, and the ability to recover from damage. Unlike managing agricultural crops where yield is the major focus, fertilizer is used in turfgrass culture to achieve slow and consistent growth (White, 2011). Conventional nitrogen fertilizations are conducted in a few episodic applications throughout the growing season (Snyder, 1989). These large amounts of nitrogen cause a sudden boost in growth creating fluctuations and undesirable management complications. Nutrient leaching from the soil can potentially be greatly increased when fertilizer rates are higher than the rate of uptake by turfgrass and soil microbes (Nus, 2012). Therefore, high application rates, higher water solubility, heavy irrigation/rain, and porous soils conditions can greatly increase nitrogen leaching (Rieke and Ellis, 1974). Leached nitrogen can collect in surface water as well as ground water and pose severe environmental problems. For example, drinking water containing amounts of 22.9 to 27.4 mg L^{-1} N as nitrate has been shown to cause infants 6 months and younger to become seriously ill (Knobeloch et al., 2000). Also, nitrate contaminated drinking water can be toxic to cattle when their rumen converts nitrate to toxic nitrite (Mahler et al., 2007).

Nitrogen source affects not only N availability but also uptakes and growth of turfgrass (Pease et al., 2011). Organic sources of nitrogen release plant available nitrogen at a slower rate than synthetic nitrogen sources (Samples et al., 2011). An organic source of N such as humic acid may be used as a supplement to fertilization programs to help reduce fertilizer inputs and maintain overall turfgrass health (Zhang et al., 2003). Nitrogen form can affect N uptake by plants, visual quality, clipping yield, and plant health among other physiological aspects. Plants take up N as ammonium or nitrate through root hairs (Nus, 2012). The plants quickly use N for proteins and other N containing compounds. Snyder and Burt (1985) found evidence that foliar applications of NH_4NO_3 produced higher visual quality and slightly increased clipping yield than foliar applications of $NaNO_3$ and urea. Plant uptake of different nitrogen sources and fertilizer types has shown to be affected by the time of year and plant species (Spangenberg et al., 1986). Kentucky bluegrass received a better color rating in early spring with granular urea, and a better rating from foliar applied urea in the end of the growing season.

More frequent applications of nitrogen fertilizer at a lower rate have been suggested to stabilize nitrogen nutrient in turfgrass. Frequent nitrogen applications increase the efficiency of nitrogen uptake in turfgrass (Bowman, 2003). Frequent N application in combination with frequent mowing has shown to remove N before reaching its full effect on plant growth. Research has shown up to 75% of granular fertilizer loss due to mowing attributed to of N insolubility (Mancino et al., 2001). Also, most N leaching trends show more soluble N forms leach more quickly as compared to slow-release forms (Snyder et al., 1981).

Application method of N fertilizer including rates, frequency, time of year, fertilizer type and delivery method can influence the amount of N available for plant uptake. Application of monthly granular fertilizer has been shown to provide long-term productivity and N use efficiency (Bowman, 2003). Monthly applications of granular N fertilizer have also shown wide fluctuations of tissue growth when compared to daily foliar N fertilizer. Research has shown that foliar fertilization can result in uniform growth by applying small amounts of nitrogen fertilizer (Stiegler et al., 2010). The use of foliar fertilization has been shown to be efficient in plant uptake. In as little as one hour after foliar application of nitrogen fertilization, 24-57% of N was recovered, with the greatest absorption found to be four hours after application. Foliar fertilization has also shown to conveniently save time and labor costs with the ability to tank mix multiple products in a single application when compatible.

The use of humic amendments to improve N availability and uptake is a recent area of study in the turfgrass culture. Evidence has shown mixing granular humates into soil rootzone of creeping bentgrass has increased rooting depths (Liu and Cooper, 2000). Hydroponic solutions containing 400 ppm of humic acid materials resulted in increased root mass when compared to untreated turfgrass. Humic acid alone or in combination with seaweed extract has been shown to increase turfgrass visual quality (Zhang et al., 2003).

Visual quality is an effective measurement of turfgrass. A way to measure visual quality on turfgrass is by use of optical sensors. Optical sensors measure the reflectance of light by leaf surface (Richardson, et al., 2001). Reflectance spectroscopy has been used to estimate photosynthetic leaf pigments such as chlorophyll. Mathematical indices have been developed in order to reduce complex spectra to a single value to be used to estimate pigment content, stress, water content, amoung other measurements (Richardson, et al., 2001; Sims and Gamon, 2002).

Fertilization of Turfgrass and the Environmental Impact

Any time fertilizer is being applied to plants there is a risk of loss to the environment. A small fraction may be lost due to volatilization. Stiegler et al. (2010) found that following foliar urea fertilization, ammonia volatilization was as low as 1-3%. Runoff into surface water as well as leaching into ground water is a major environmental concern especially with N fertilizer. A large study involving 80 golf courses revealed a large amount of exceedances of EPA criteria of total phosphorus in surface water (Baris et al., 2010). The same study demonstrated low amounts of nitrate N (1.4%) exceeding EPA criteria in ground water. Leaching of N fertilizer is a concern for many golf course superintendents because of its environmental effects and economic losses. Many techniques in management, including using slow release fertilizers along with irrigation management, have shown to promote healthy turf with minimal N leaching (Snyder et al., 1989). Snyder and Cisar (1997) found that N leaching was greater at the early stages of turfgrass establishment. Their study also demonstrated that the use of a field monitoring system is a helpful tool not only for monitoring N fertilization but irrigation as well. Hull and Liu (2005) suggested that research needs to focus more on the understanding of the biological processes in which turfgrass obtains N and how to influence N fertilization efficacy.

Nitrogen Application Efficiency

Fertilizers traditionally have been applied in a few episodic periods of time to turfgrass, varying in rates and time between applications. With more recent advances in technology, slow release granular fertilizers have controlled the mineralization rate and increased the efficacy of these types of applications (Spangenberg et al., 1986). Granular fertilizers are a very effective way of making nitrogen and other nutrients available to the turf roots through the soil solution.

Highly water-soluble nitrogen carried by fertilizers, such as ammonium and urea, have been developed to deliver nitrogen and make it quickly available to turf (Samples et al., 2011). These types of fertilizers stimulate rapid growth and green up of turf, but also create potential for leaching.

Industry advancements have produced a few different types of slow release fertilizers. Slower rates of availability create an efficient opportunity for turfgrass to absorb all of the nutrients applied. Types of slow release fertilizers include natural organics with nitrogen bound in organic compounds; synthetic organics with urea bound in short-, medium-, or long-chain compounds; sulfur-coated urea; polymer-coated urea; polymer-coated, sulfur-coated urea; and carriers with a reactive layer coating (Samples et al., 2011). Coated urea slows the release rate, which in turn reduces the burn potential of the foliage. Granular fertilizers are relatively safe and easy to apply, when following the recommended procedures. Using a drop spreader or broadcast spreader, granular fertilizers can be applied accurately to small or very large areas of turf. However, at very low rate, large particle sizes of granular fertilizer may not have good coverage. Research conducted by the Prairie Turfgrass Research Center has shown that temperature is one of the greatest factors in the release rate of granular fertilizers (Anderson and Ross, 2006).

Foliar fertilization has become another option with more accurate and efficient foliar sprayers available in recent years. Foliar fertilizers are directly absorbed by the foliar tissue of the turfgrass as opposed to granular fertilizers that are absorbed by the plant roots. Foliar applications have benefits including quick color changes in turf, the ability to create custom nitrogen, phosphorous, and potassium ratios and also the convenience of tank mixing micronutrients, pesticides, or other treatments to save application time (Totten et al., 2009). However, large amounts of nitrogen added by foliar application can cause leaf burning, so lower rate and more frequent applications, also commonly called spoon feeding, are needed. These frequent applications can have benefits in themselves by providing opportunities to be more accurate in applying macro- and micronutrients in the right ratios for specific situations. In high rate applications of macronutrients such as nitrogen, research has shown that foliar nitrogen uptake efficiency is reduced (Steigler et al., 2011).

Questions arise concerning whether to use strictly granular fertilizers, foliar applications, or a combination of both. Higher fertilizer loss due to mowing has shown to be tied to its solubility, granule size, and bulk density (Mancino et al., 2001). More soluble, finer grade fertilizes have shown to reduce loss due to mowing. The benefits and drawbacks of each make a challenging decision. Research has shown that anywhere from 31 to 61%, or 40% on average, of foliar fertilizers are absorbed by the plant (Kussow, 2001). What happens to the other 60% of fertilizer that has been applied and not absorbed by the turf? About 40% of this value is mowed off during normal management practices, and the remaining 20% is washed away either by rainfall or irrigation. A study has shown evidence that more water-soluble, finer grade granular fertilizers and also foliar fertilizers lower the amount of fertilizer removal by mowing (Mancino et al., 2001). Research is being conducted on various principles and procedures to increase the efficiency of foliar applications, for example, waiting to irrigate for a few hours after application to allow for uptake, then watering-in to wash off excess nitrogen in leaf surfaces to the soil for another chance of uptake by the root system (Stiegler et al., 2011). Fernandez and Eichert (2009) indicated that further research is needed to increase efficiency of foliar fertilizers including penetration and effects on plant tissues, timing, plant stresses, leaf surfaces, and the environment.

Organic Amendment

Humic acid has been under study for many years. Humic acid is classified as a biostimulant, which is a vague category because of its broadness. Humic substances have been found to have a greater effect on roots than on the above ground parts of plants (Sladky and Tichy, 1959). Foliar applications of humic acid have shown to increase root growth, increase chlorophyll content, and effect respiration. Research has shown that monthly field applications of seaweed extract and humic acid has shown increased visual quality of creeping bentgrass and also significantly reduced dollar spot (Zhang et al., 2003). Dollar spot has also been shown to be dramatically decreased with foliar applications of humic acid mixed with nitrogen, as compared to foliar applications of nitrogen alone (Schmidt and Zhang, 1998). Foliar applications of humic acid have also shown to increase photosynthetic capacity, especially during the hot summer months. Humic acid containing generic biostimulants used together with a commercial liquid fertilizer program has shown an increase in appearance and recovery time from spring cultivation in creeping bentgrass (Bigelow et al., 2010). Tank mixing humic acid with liquid fertilizers is a relatively new practice and needs further research.

The effect of humic substance on soil OM in sand-based root zones is another area of interst. The United States Golf Association (USGA) has developed criteria for the construction of golf course green root zones (USGA Green Section Staff, 1993). They are designed to contain medium to coarse sand to create good water infiltration and retention. Studies have shown that over time organic matter will accumulate near the top of the playing surface (Landrith, 2007). An accumulation of as little as 4 to 5% of organic matter can slow down the rate of water infiltration. Research has shown that the addition of humic acid to creeping bentgrass maintained at a golf course green height increased root length (Van Dyke et al., 2009). Schmidt and Zhang (1998) showed evidence that foliar applications of humic acid increased root development, especially along with high nitrogen applications. Root length is important in predicting the stress tolerance of turfgrass. Shorter roots cause plants to be less able to reach nutrients and water deeper in the soil. In a study of daily nitrogen applications, root length was decreased by increasing amounts of nitrogen application (Bowman, 2003).

Evaluation of Turf Quality

Traditional method of visual quality evaluation of turfgrass is the National Turfgrass Evaluation Program (NTEP), which is evaluated on a 1 to 9 rating scale. Turfgrass quality is rated with 9 being the best and 1 the worst, with 6 considered acceptable. Genetic color, turfgrass density, and texture are also considered on the 1 to 9 rating scale.

The use of optical sensors has developed a variety of vegetative indices based on reflected light to assess photosynthetic vegetation (Manigiafico and Guillard, 2006). Reflective measurements of different wavelengths through the photosynthetically active radiation (PAR, 400-700 nm) range and near-infrared radiation (NIR, 700-1300 nm) range have been researched as tools for estimating crop characteristics such as green biomass, leaf area, pigment content, water content, nitrogen content, and others (Sims and Gamon, 2002; Alvalro et al, 2007). One of the most commonly used is the normalized difference vegetation index (NDVI), which compares red light reflectance to infrared light reflectance. The comparison between high reflectance of near infrared and low reflectance of red light has been related to increased red absorption by chlorophyll resulting from denser vegetation, or increased chlorophyll concentration (Ferwerda et al., 2005). Much of leaf nitrogen is related to chlorophyll; so estimated chlorophyll content can be used to give indirect estimates of nitrogen content. In the case of dense green vegetation, the amount of red light reflectance is very small (Jackson and Huete, 1991). This means reflected red light must be measured accurately to receive reasonable red light reflectance to infrared light reflectance ratio values. Salinity stress has been found to be detectable of at least three indices calculated from single leaf reflectance spectrum ($mSR_{750/705}$, $mND_{750/705}$, and $SI_{710/760}$)(Gao and Li, 2012). Sims and Gamon (2003) found three regions of optimal wavelengths for ground-based remote sensing of vegetation water content, 950-970, 1150-1260, and 1520-1540 nm.

Visual quality of turfgrass determined by optical sensors, digital imagery, and the human eye is an indicator of overall turfgrass health. Turfgrass health is achieved through the three management practices including fertilization, irrigation, and mowing. Nitrogen fertilization needs to be carefully considered in terms of nitrogen form and application method in order to limit nitrogen loss. Organic amendments may aid in the efficiency of N availability and use by plants. The right combination of N form and organic amendments may be a method to increase nitrogen uptake by plants and reduce loss.

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CHAPTER 2. FOLIAR APPLICATION OF DIFFERENT NITROGEN FORMS TANK-MIXED WITH SPRAYABLE ORGANIC AMENDMENT ON CREEPING BENTGRASS

Abstract

In recent years, foliar chemical applications on short mowed turfgrass have become an increasingly popular practice. Meanwhile, humic substances have been used to improve turfgrass health as a biostimulant. The objective of this study is to determine if tank mixing different nitrogen forms with different organic amendment can improve visual quality in creeping bentgrass. Nitrogen forms NH_4-N, NO_3-N, and urea were tank-mixed with organic amendments Rev®, Turfworks®, Ful-Power®, and applied at an N rate of 12.5 kg ha^{-1}by a sprayer to creeping bentgrass grown in a greenhouse. Measurements of visual quality (VQ), clipping yield, green density, dark green color index (DGCI), normalized difference vegetative index (NDVI), and shoot weight were taken. Urea generally had the highest visual quality ranging from 1.6 to 3.5 higher than unfertilized control in the study. NH_4-N and NO_3-N also had better visual quality than control, on a few measurements NO_3 was better than NH_4-N. Turfworks® received the highest visual quality of the organic amendments with an average of 0.7 higher than the control in experiment one, while Ful-Power® received the lowest. Urea generally resulted in the greatest green density, DGCI, and NDVI supporting visual quality results. Results back up previous research of the effectiveness of foliar nitrogen applications. Few interactions between N sources and organic amendments lead us to believe further research will need to done to determine the effectiveness of the products used.

Foliar application of fertilizers on turfgrass is becoming a popular management practice. Nitrogen fertilizers applied foliarly have shown rapid uptake and improved use efficiency by turfgrass. Stiegler et al. (2010) reported that in the month of May, creeping bentgrass take up about 76% of N in 4 hours after fertilization with an average of 59% as compared to an average of 37% in the month of September. It has also been reported that plant uptake of different nitrogen sources and fertilizer types are affected by the time of application during the growing season as well as plant species (Spangenberg et al., 1986). Synthetic N fertilizers, such as urea and ammoniacal and nitrate-N are commonly used fertilizers because of their high concentration and solubility properties (Bosewell et al., 1985). Plant roots and leaves can absorb these N fertilizers as urea ($(NH_2)2CO$), ammonium (NH_4^+) and nitrate (NO_3^-). Ammonium has a positive charge, nitrate has a negative charge, while urea has no charge. When plants take up charged molecules, they typically release an oppositely charged molecule to balance pH inside the plant cells. Uptake of ammonium typically results in the release of H+ resulting in a decrease of pH. When plants take up nitrate, OH is typically released, resulting in a pH increase in the root environment. Urea can be absorbed directly resulting in no pH effect.

Many studies have been conducted on the uptake of different N sources (Young, et al., 2009; Cisar et al., 2005; Brauen and Nus, 1989) and factors affecting N uptake in turfgrass (Henning et al., 2013; Hull and Liu, 2005; Pease et al., 2011; Picchioni and Quiroga-Garza, 1999). There are also studies that report foliar applications of organic amendments affect soil moisture retention (VanDyke et al., 2009). There is a growing interest in the effects of humic substances to plant growth. Foliar applications of humic acid have shown to increase root growth, increase chlorophyll content, and effect respiration (Sladky and Tichy, 1959). Hydroponic solutions containing 400 ppm of humic acid materials resulted in increased root mass to when compared to untreated turfgrass (Liu and Cooper, 2000). Visual quality has also been shown to increase with foliar applications of humic acid (Zhang et al., 2003). Research done by Bigelow et al., 2010 concentrated on the effectiveness of commercially available plant nutrient and biostimulant programs, but did not explore the effects of nitrogen form. Schmidt and Zhang (1998) researched different N rates as a dry product, with or without humic acid as a foliar application, and their effect on root dry weight and dollar spot. Zhang et al. (2003) studied low and high nitrogen fertilizer treatments compared separately with treatments of humic acid alone, seaweed extracts alone, humic acid plus seaweed extract, and a control. Superoxide dismutase activity, photochemical activity, and turf quality were measured for all treatments. Again, organic amendment and nitrogen fertilization were applied and measured separately. Little is known about the effects of N forms tank-mixed with organic amendments for foliar application. This leads us to wonder how the results would differ if tank-mixed and applied as a single treatment.

Tank mixing fertilizers is an efficient way to reduce the number of applications and application time (Stiegler et al., 2010). Tank mixing foliar fertilizers with liquid organic amendments may be a way to increase turfgrass visual quality without increasing clipping yield (Gao and Li, 2012). The combination of tank-mixing nitrogen forms with humic amendments may increase turfgrass quality. The objective of this study was to determine if tank mixing different nitrogen forms with different humic acid containing products were synergetic in creeping bentgrass when applied foliarly.

Materials and Methods

The greenhouse experiments were conducted in 2012 and 2013 on well-established ‘Pencross’ creeping bentgrass. The washed sod was transplanted to square pots of 15 cm by 15 cm and 15 cm deep, with root zone material consisting of 90% sand and 10% peat on volumetric basis. The turfgrass was cut to 2-cm height with scissors once weekly. Gypsum (24.3% Ca, 20.9% S, 1.3 mg kg^{-1} of Mg) was applied as a dry product 1 wk after establishment in all pots at a rate of 5% the weight of sand in the root zone to provide sufficient Ca, Mg, and S macronutrients. One week after establishment, the turfgrass was fertilized using Nusion 29-2-3 (The Andersons, Inc. Maumee, OH) at a N rate of 1.25 $g \cdot m^{-2}$ every two weeks for 6 wk to achieve consistency. Irrigation was scheduled every morning using an automatic controller system to bring the soil water content to pot capacity. The greenhouse had temperatures range from 5°C (night) to 30°C (day), relative humidity ranging from 5 to 60%, and a 12-h photoperiod. Natural light was supplemented by metal halide lamps that provide minimum midday photosynthetically active radiation of 400 $\mu mol \cdot m^{-2} \cdot s^{-1}$.

The experiment treatments were initiated 6 wk after the grass was established. Nitrogen form and liquid organic matter were used in combinations with four levels for each factor. Nitrogen form consisted of $(NH_4)_2SO_4$, $Ca(NO_3)_24H_2O$, Urea, and with a blank control (Table 1). Liquid organic matter included Rev® (Dakota Peat, Grand Forks, ND), Turf Works® (Custom Agronomics, Palm City, FL), Ful-Power® (Faust Bio-Agricultural Services, Independence, OR), and a blank control. The experiment was arranged in a randomized complete block design with 16 treatments randomized within each of the four replicates.

The organic amendment Rev®, is a liquid suspension derived from naturally mined humic materials with a pH of 6.2. The material has particle size smaller than 100 μm, 21.2 % humic acid, and 0.8 % fulvic acid based on dry weight. Turf Works®, is derived from leonardite ore, and is 20.0% humic acid. Ful-Power®, is derived from the fulvic fraction of raw humic substances, has a pH of 3.5, and contains 0.015% fulvic acid. All nitrogen sources were applied at an N rate of 1.25 $g \cdot m^{-2}$ at 2-wk intervals.

Table 1. Treatment list of N fertilizers and organic amendments to be applied to ‘Pencross’ creeping bentgrass in the studies during April 2012 to Jan. 2013.

N-Form	N-Rate	OM	OM-Rate
	kg ha^{-1}		%
$(NH_4)_2SO_4$	12.5		
$Ca(NO_3)_2\ 4H_2O$	12.5		
Urea	12.5		
CK	0		
$(NH_4)_2SO_4$	12.5	Rev®[†]	1
$Ca(NO_3)_2$	12.5	Rev®	1
Urea	12.5	Rev®	1
CK	0	Rev®	1
$(NH_4)_2SO_4$	12.5	TurfWorks®[‡]	1
$Ca(NO_3)_2$	12.5	TurfWorks®	1
Urea	12.5	TurfWorks®	1
CK	0	TurfWorks®	1
$(NH_4)_2SO_4$	12.5	Ful-Power®[§]	0.75
$Ca(NO_3)_2$	12.5	Ful-Power®	0.75
Urea	12.5	Ful-Power®	0.75
CK	0	Ful-Power®	0.75

[†] Rev® (Dakota Peat, Grand Forks, ND) is derived from naturally mined humic materials with pH 6.2, 9.2 mg·kg^{-1} nitrate N, 5.3 mg·kg^{-1} ammonical N, 4 mg·kg^{-1} P, and 10 mg·kg^{-1} K. The material had particle sizes smaller than 100 µm, 21/2% humic acid, and 0.8% fulvic acid based on dry weight; 1 mg·kg^{-1} = 1 ppm, and 1 µm = 1 micron.

[‡] Turf Works® (Custom Agronomics, Palm City, FL) is derived from fresh water leonardite ore with 20% humic acid.

[§] Ful-Power® (Faust Bio-Agricultural Services, Independence, OR) is derived from the fulvic fraction of raw humic substances with a pH of 3.5 and is 0.015% fulvic acid.

All nitrogen forms were dissolved into water before adding organic amendment and brought to final volume before spraying application. All liquid organic amendments were added to the spray solution at 1% of the total volume except Ful-Power®, which has a maximum label rate of 0.75% of the total volume. All treatments included 0.13% volumetric basis of Minors Package 0-1-1 (The Andersons, Inc. Maumee, OH) containing 1% P2O5, 1% K2O, 1%Mg, 0.02% B, 2.45% Fe, 0.25% Mn, and 0.05% Zn to supply adequate micronutrients for plant growth. The foliar treatments were applied with a CO_2-pressurized hand sprayer at 250 kPa using three flood nozzles (TeeJet 8004VS, TeeJet Spray Systems Co., Springfield, IL) to apply a spray volume of 75 mL per treatment area of 1 m^2. The turfgrass was cut to 2-cm height with scissors once weekly. Irrigation was scheduled every morning using an automatic controller system to bring the soil water content to pot capacity.

A weekly visual rating of the turf qualities also was conducted on a 1 to 9 scale, with 1 being dead grass, 9 as the best, and 6 as the minimum acceptable level. Clipping yield was obtained biweekly and dried in an over at 68º C for 48 h., then weighed to determine biomass. A digital image was taken every 2 wk before the N applications from each pot under greenhouse light using a Canon Power Shot G3 digital camera (Canon Inc., Japan) with settings of F2.0 and 1/60 s. Turfgrass green density, hue, color saturation, brightness, and dark green color index (DGCI) were calculated following the methods of Richardson et al. (2001) and Karcher and Richardson (2003, 2005). Two weeks after the first and last treatments the reflectance spectrum from 350 to 1000 nm was collected with a temperature regulated fiber optic spectrometer (S2000-TR;Ocean Optics, Dunedin, FL), which has a fiber optic cable connected to a lens allowing a view field the size of the turfgrass surface in the pot. $NDVI_{775}$ was calculated from the reflectance spectra using the equation: $NDVI_{775} = (R_{775} - R_{675})/(R_{775} + R_{675})$, where R is the relative reflectance at a given wavelength (Volterrani et al., 2005). A modified normalized difference (*m*ND) vegetation index $m\mathrm{ND}_{750/705}$ (Sims and Gamon, 2002) was calculated from the relative reflective spectra using the equation: $m\mathrm{ND}_{750/705} = (R_{750} - R_{705})/(R_{750} + R_{705} - 2R_{445})$, where R is the relative reflectance at a given wavelength. At the end of the study, biomass above soil surface was harvested as shoot biomass, and the roots were washed free of sand. The root and shoot biomass were derived after drying in an oven at 68 C° for 48 h.

The study was repeated a second time with similar schedules for treatment applications and measurements. The data were subjected to analysis of variance (ANOVA) using mixed procedures in SAS (version 9.3; SAS Institute, Cart, NC) with replication blocks treated as a random variable. Treatment means were separated using Fisher's protected least significant difference at 0.05 *P* level.

Results and Discussion

The ANOVA showed different variability from the first and second experiments, and therefore, the results are reported separately by experiment.

Visual Quality

The turfgrass visual quality (VQ) in the first experiment was significantly different among different N forms for all five measurements (Table 2). In the second experiment, N form showed different effects on VQ for four out of five measurements (Table 3). Generally, throughout both experiments, the urea treatment received the highest VQ among all N forms for all measurement dates and ranged from 1.6 to 3.5 higher than the control. NH_4-N and NO_3-N also had better VQ than control, on a few measurements, NO_3 was better than NH_4-N. This was

Table 2. Visual quality of 'Pencross' creeping bentgrass as affected by foliar application of N fertilizers tank mixed with liquid organic amendment (Rev®, TurfWorks®, and Ful-Power®) in the study during April to June 2012. Nitrogen from NH4-N, NO3-N, and Urea forms was applied at an N rate of 1.25 g·m^{-2} at 2-week intervals.

			17 Apr. 2012	1 May 2012	15 May 2012	30 May 2012	13 June 2012
N form							
	NH$_4$-N		6.5bc[¶]	6.4b	6.1bc	6.3b	6.2b
	NO$_3$-N		6.9a	7.0a	6.6ab	6.4b	6.1b
	Urea		6.6ab	7.1a	7.0a	7.3a	6.8a
	Control		6.2c	5.5c	4.6c	3.9c	4.1c
OM							
	Control		6.3b	6.2c	5.9b	5.3b	5.4c
	Rev®[†]		6.6ab	6.6ab	6.2ab	6.1a	6.1a
	TurfWork®[‡]		6.8a	6.8a	6.4a	6.4a	6.1a
	Ful-Power®[§]		6.6a	6.4bc	5.7c	6.1a	5.5b
				ANOVA			
Source of variance		df			*F*-test		
N form (N)		3	5.92*	60.57**	37.73**	56.17**	64.18**
OM		3	5.36*	6.57*	4.19*	6.36*	5.94*
N x OM		9	2.38*	2.76*	2.23	1.84	2.33*

[†] Rev® (Dakota Peat, Grand Forks, ND) is derived from naturally mined humic materials with pH 6.2, 9.2 mg·kg^{-1} nitrate N, 5.3 mg·kg^{-1} ammonical N, 4 mg·kg^{-1} P, and 10 mg·kg^{-1} K. The material had particle sizes smaller than 100 μm, 21/2% humic acid, and 0.8% fulvic acid based on dry weight; 1 mg·kg^{-1} = 1 ppm, and 1 μm = 1 micron.

[‡] Turf Works® (Custom Agronomics, Palm City, FL) is derived from fresh water leonardite ore with 20% humic acid.

[§] Ful-Power® (Faust Bio-Agricultural Services, Independence, OR) is derived from the fulvic fraction of raw humic substances with a pH of 3.5 and is 0.015% fulvic acid.

[¶] Numbers within a factor in the same column followed by same letter are not significantly different at 0.05 *P* level.

Table 3. Visual quality of ‘Pencross’ creeping bentgrass as affected by foliar application of N fertilizers tank mixed with liquid organic amendment (Rev®, TurfWorks®, and Ful-Power®) in the study during Nov. to Jan. 2013. Nitrogen from NH_4-N, NO_3-N, and Urea forms was applied at an N rate of 1.25 g·m^{-2} at 2-week intervals.

			5 Nov. 2012	19 Nov. 2012	3 Dec. 2012	17 Dec. 2012	2 Jan. 2013
N form							
	NH_4-N		6.4a[¶]	6.4b	6.8b	6.9b	6.9b
	NO_3-N		6.3a	6.4b	6.8b	6.7b	6.8b
	Urea		6.3a	7.0a	7.4a	7.6a	7.7a
	Control		5.6a	5.8c	4.3c	4.2c	4.2c
OM							
	Control		5.8a	6.1b	5.9b	6.1a	6.2a
	Rev®[†]		6.3a	6.3b	6.3ab	6.4a	6.3a
	TurfWork®[‡]		6.2a	6.4ab	6.5a	6.4a	6.5a
	Ful-Power®[§]		6.3a	6.8a	6.6a	6.5a	6.6a
				ANOVA			
Source of variance		df			*F*-test		
N form (N)		3	3.04	8.45**	117.07**	117.98**	199.45**
OM		3	1.03	4.80*	5.78*	2.02	3.78
N x OM		9	1.47	1.14	0.81	0.91	1.00

[†] Rev® (Dakota Peat, Grand Forks, ND) is derived from naturally mined humic materials with pH 6.2, 9.2 mg·kg^{-1} nitrate N, 5.3 mg·kg^{-1} ammonical N, 4 mg·kg^{-1} P, and 10 mg·kg^{-1} K. The material had particle sizes smaller than 100 μm, 21/2% humic acid, and 0.8% fulvic acid based on dry weight; 1 mg·kg^{-1} = 1 ppm, and 1 μm = 1 micron.

[‡] Turf Works® (Custom Agronomics, Palm City, FL) is derived from fresh water leonardite ore with 20% humic acid.

[§] Ful-Power® (Faust Bio-Agricultural Services, Independence, OR) is derived from the fulvic fraction of raw humic substances with a pH of 3.5 and is 0.015% fulvic acid.

[¶] Numbers within a factor in the same column followed by same letter are not significantly different at 0.05 *P* level.

consistent with the results of Spangenberg et al. (1986) who compared urea in granular and foliar application on Kentucky bluegrass and found that a better color rating in early spring with granular urea, while foliar applied urea maintained better VQ in the end of the growing season. This N form resulted in differences in VQ, reaffirming previous studies on the effects of N forms on turfgrass quality (Henning et al., 2013; Hull and Liu, 2005; Pease et al., 2011; Picchioni and Quiroga-Garza, 1999).

The OM treatments were significant for all five measurements in the first experiment (Table 2), but only so for two out of five measurements in the second experiment (Table 3). Turfworks® was always the highest average visual quality in the first experiment with average of 6.5 as compared to an average of 5.8 for control. Ful-Power® and Rev treatments received better VQ than the control in 3 out of 5 measurements (Table 2). In the second experiment, Ful-Power® was the only treatment that showed better visual quality in two out of five measurements with an average of 6.7 as compared to an average of 6.0 for control (Table 3). These results indicate foliar organic amendment applications may increase visual quality of creeping bentgrass, and is consistent with results of Zhang et al. (2003). These results may lead to further research of the interactions of plant physiology with organic amendments.

There were three interactions between N form and OM in experiment one, with none in experiment two. Interactions were seen in the first two measurement dates and the last date. The first measurement showed NH_4-N in combination with TurfWorks® had the highest visual quality (Figure 1). The control, Rev®, and TurfWorks® showed the highest visual quality in combination with NO_3-N, while TurfWorks® and Ful-Power® in combination with urea showed to have the highest visual quality. In the control with no N source, Rev® showed to have the highest visual quality rating.

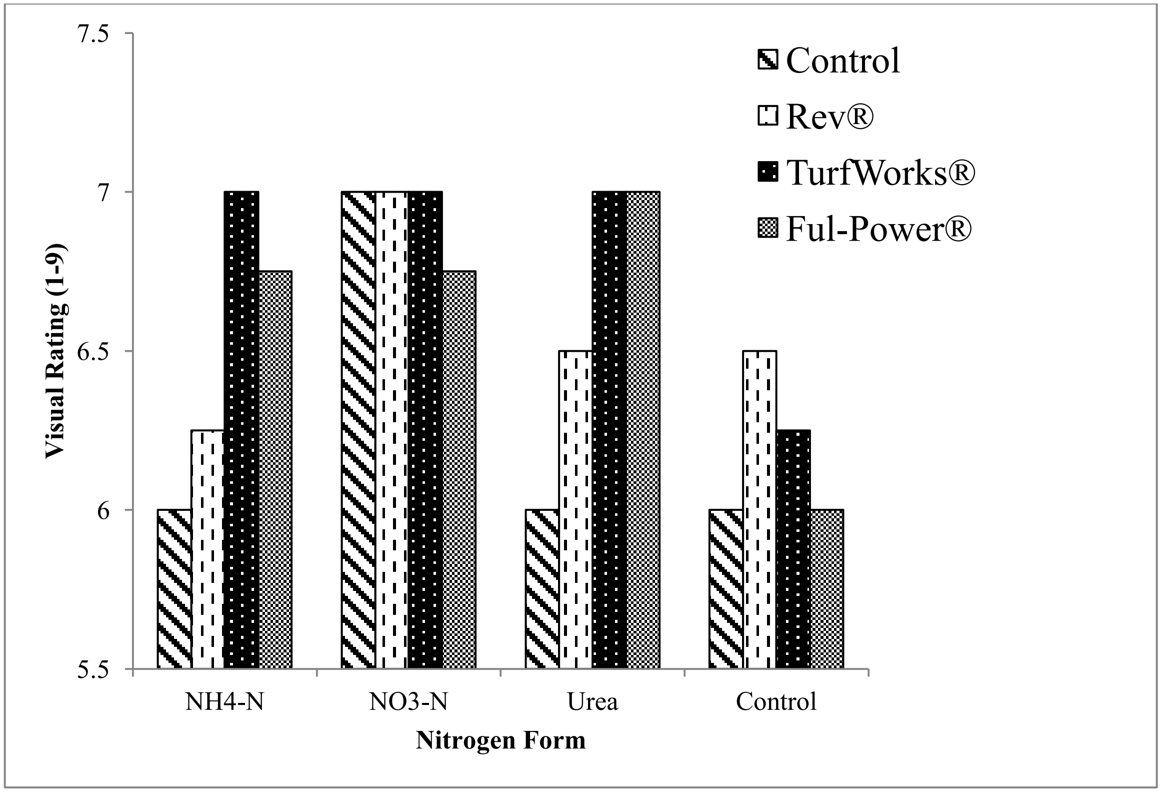

Figure 1. Visual quality of ‘Pencross’ creeping bentgrass as affected by foliar application of N fertilizers tank mixed with liquid organic amendment (Rev®, TurfWorks®, and Ful-Power®) on the date of April 17, 2012.

The second measurement in experiment one showed NH_4-N in combination with Rev® receiving the highest visual quality rating (Figure 2). No difference was seen NO_3-N in combination with OM amendments. Urea in combination with the control and TurfWorks® resulted in the highest visual quality. The control in combination with Ful-Power® resulted in the highest visual quality rating.

The last measurement in experiment one resulted in N forms NH_4-N and NO_3-N in combination with Ful-Power® to receive the highest visual quality (Figure 3). Nitrogen in the urea form in combination with TurfWorks® resulted in the highest visual quality, but the lowest visual quality in the control treatment, where Rev® and Ful-Power® where the highest.

Clipping Yield

Clipping yield was significantly different among N forms for all four measurements in the first experiment and four of five measurements in the second experiment. The first experiment showed NO_3 generally had the highest clipping yield with a range of 6.18 to 8.71 $g \cdot m^{-2}$ higher than the unfertilized control (Table 4). Urea and NH4-N had higher clipping yield than the control but generally not differentiated from each other. However, in experiment two, urea produced the highest clipping yield for the last three measurements with a range of 6.49 to 18.10 $g \cdot m^{-2}$ greater than control (Table 5), while NH4-N and NO_3 performed similarly and were both higher than the control. . Snyder and Burt (1985) found evidence that foliar applications of NH_4NO_3 produced higher visual quality and slightly increased clipping yield than foliar applications of $NaNO_3$ and urea. The results from this study show inconsistencies of N form clipping yield over time.

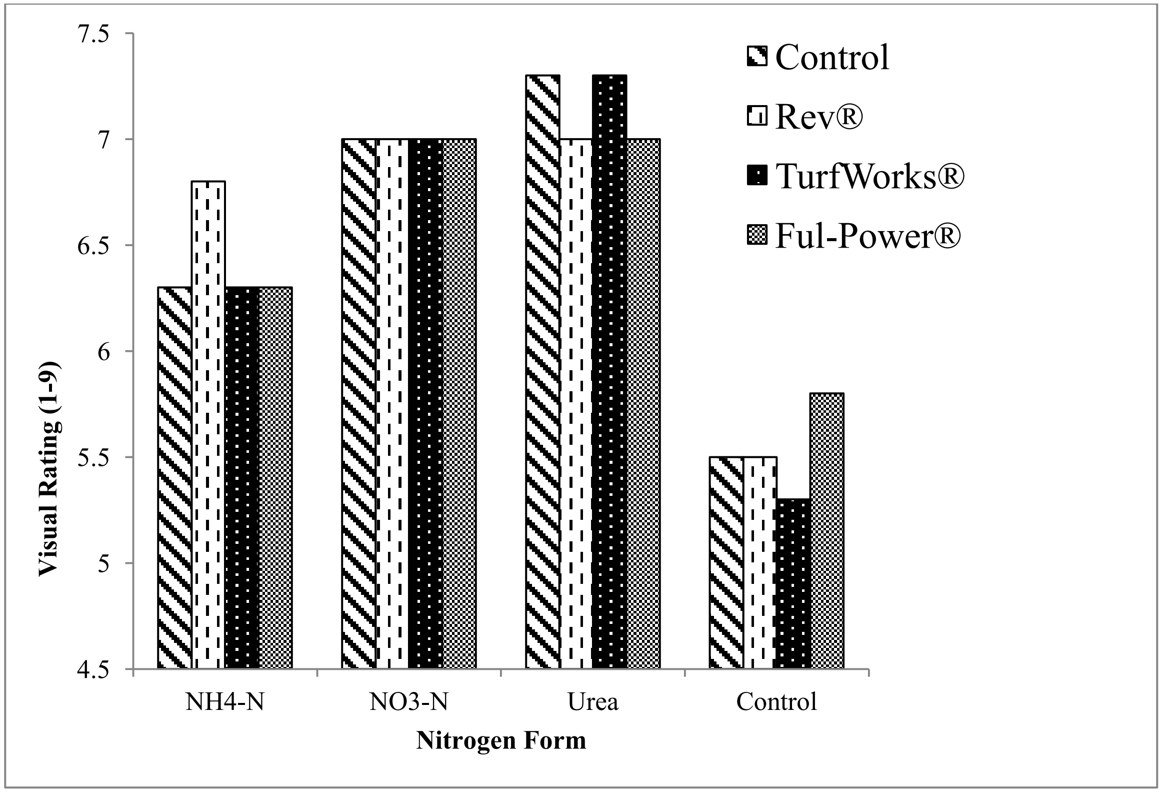

Figure 2. Visual quality of 'Pencross' creeping bentgrass as affected by foliar application of N fertilizers tank mixed with liquid organic amendment (Rev®, TurfWorks®, and Ful-Power®) on the date of May 1, 2012.

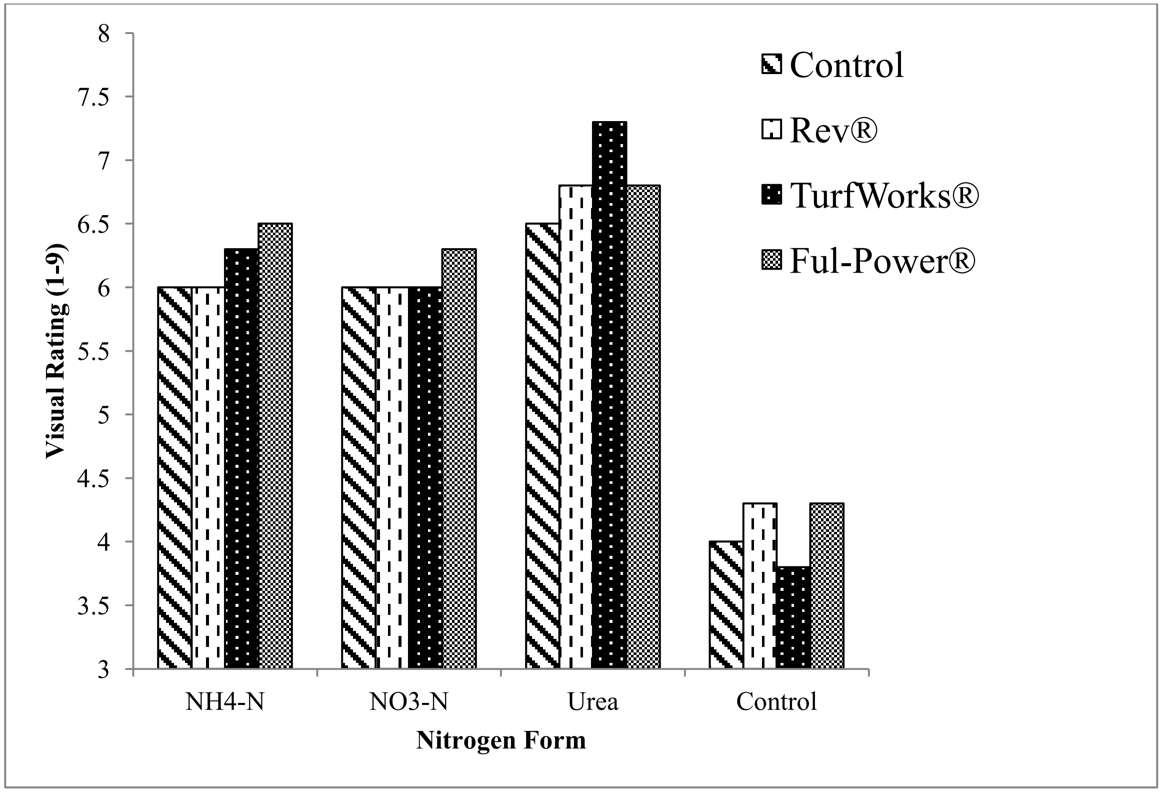

Figure 3. Visual quality of 'Pencross' creeping bentgrass as affected by foliar application of N fertilizers tank mixed with liquid organic amendment (Rev®, TurfWorks®, and Ful-Power®) on the date of June 13, 2012.

Table 4. Clipping yield of ‘Pencross’ creeping bentgrass as affected by foliar application of N fertilizers tank mixed with liquid organic amendment (Rev®, TurfWorks®, and Ful-Power®) in the study during April to May 2012. Nitrogen from NH_4-N, NO_3-N, and Urea forms was applied at an N rate of 1.25 g·m^{-2} at 2-week intervals.

			17 Apr. 2012	1 May 2012	15 May 2012	30 May 2012
N form					g·m^{-2}	
	NH_4-N		12.93b[¶]	14.58ab	12.63ab	15.81a
	NO_3-N		16.39a	16.27a	13.86a	15.07a
	Urea		13.23b	14.35b	12.00b	14.31a
	Control		10.21c	9.28c	5.15c	6.41b
OM						
	Control		11.59c	12.27c	10.23a	11.38a
	Rev®[†]		12.69bc	12.62bc	10.26a	12.19a
	TurfWork®[‡]		14.81a	14.88a	12.72a	13.40a
	Ful-Power®[§]		13.66ab	14.71a	10.43a	14.64a
				ANOVA		
Source of variance		df			*F*-test	
N form (N)		3	9.35**	28.54**	53.91**	32.89**
OM		3	9.52**	5.40*	3.04	2.24
N x OM		9	2.30*	1.97	1.99	0.60

[†] Rev® (Dakota Peat, Grand Forks, ND) is derived from naturally mined humic materials with pH 6.2, 9.2 mg·kg^{-1} nitrate N, 5.3 mg·kg^{-1} ammonical N, 4 mg·kg^{-1} P, and 10 mg·kg^{-1} K. The material had particle sizes smaller than 100 µm, 21/2% humic acid, and 0.8% fulvic acid based on dry weight; 1 mg·kg^{-1} = 1 ppm, and 1 µm = 1 micron.

[‡] Turf Works® (Custom Agronomics, Palm City, FL) is derived from fresh water leonardite ore with 20% humic acid.

[§] Ful-Power® (Faust Bio-Agricultural Services, Independence, OR) is derived from the fulvic fraction of raw humic substances with a pH of 3.5 and is 0.015% fulvic acid.

[¶] Numbers within a factor in the same column followed by same letter are not significantly different at 0.05 *P* level.

Table 5. Clipping yield of 'Pencross' creeping bentgrass as affected by foliar application of N fertilizers tank mixed with liquid organic amendment (Rev®, TurfWorks®, and Ful-Power®) in the study during Nov. to Dec. 2012. Nitrogen from NH_4-N, NO_3-N, and Urea forms was applied at an N rate of 1.25 g·m^{-2} at 2-week intervals.

		5 Nov. 2012	19 Nov. 2012	4 Dec. 2012	17 Dec. 2012	Dec. 26 2012
N form				g·m^{-2}		
	NH_4-N	32.88a[¶]	25.14a	18.46b	16.14b	21.89ab
	NO_3-N	30.60a	26.85a	17.05b	14.09c	17.99b
	Urea	30.45a	25.70a	21.08a	18.57a	25.59a
	Control	28.42a	18.57b	14.59c	9.66d	7.49c
OM						
	Control	30.71a	23.07a	17.19a	14.24a	18.67a
	Rev®[†]	30.01a	24.96a	17.62a	15.14a	18.02a
	TurfWork®[‡]	30.71a	24.15a	17.85a	14.09a	17.87a
	Ful-Power®[§]	30.91a	24.09a	18.51a	14.98a	18.40a
			ANOVA			
Source of variance	df			*F-test*		
N form (N)	3	1.40	38.85**	31.57**	56.75**	37.65**
OM	3	0.08	1.78	1.31	0.72	0.19
N x OM	9	1.04	0.81	0.98	1.25	1.83

[†] Rev® (Dakota Peat, Grand Forks, ND) is derived from naturally mined humic materials with pH 6.2, 9.2 mg·kg^{-1} nitrate N, 5.3 mg·kg^{-1} ammonical N, 4 mg·kg^{-1} P, and 10 mg·kg^{-1} K. The material had particle sizes smaller than 100 µm, 21/2% humic acid, and 0.8% fulvic acid based on dry weight; 1 mg·kg^{-1} = 1 ppm, and 1 µm = 1 micron.

[‡] Turf Works® (Custom Agronomics, Palm City, FL) is derived from fresh water leonardite ore with 20% humic acid.

[§] Ful-Power® (Faust Bio-Agricultural Services, Independence, OR) is derived from the fulvic fraction of raw humic substances with a pH of 3.5 and is 0.015% fulvic acid.

[¶] Numbers within a factor in the same column followed by same letter are not significantly different at 0.05 *P* level.

In the first experiment, OM was significant for the first two measurements only and there was no significance in the second experiment. Rev® had the lowest clipping yield throughout the experiment with an average of 0.73 $g{\cdot}m^{-2}$ higher than control, while Turfworks® showed the highest with an average of 2.92 $g{\cdot}m^{-2}$ higher than control.

Green Density

Green density was significant for N-form in experiment one for the last four of five measurements, and significant in the second experiment for the last three of five measurements (Table 6). In the first experiment, urea initially had the highest green density for the first three measurements, but NH_4 had the highest green density for the last two measurements. In the second experiment, urea consistently had the highest green density with an average of 3.15% higher than control (Table 7). This is consistent with research by Pease et al. (2011) finding urea treatments producing a greater shoot density than ammonium sulfate.

There was no OM efffects on green density in either experiment. There wasone interaction between N form and OM on the final measurement of experiment two.

Dark Green Color Index

The dark green color index for N forms in experiment one was significant for all measurements. In experiment two, the only significance was the last measurement and was due to difference between N forms and the control. In experiment one, the DGCI is initially higher for NO_3 for the first two measurements with an average of 0.06 greater than control, but urea became the highest for the last three measurements with an average of 0.06 greater than the control (Table 8). No significance was found between OM treatments in either experiment, but

Table 6. Green density of ‘Pencross’ creeping bentgrass as affected by foliar application of N fertilizers tank mixed with liquid organic amendment (Rev®, TurfWorks®, and Ful-Power®) in the study during April to June 2012. Nitrogen from NH_4-N, NO_3-N, and Urea forms was applied at an N rate of 1.25 g·m^{-2} at 2-week intervals.

			17 Apr. 2012	1 May 2012	15 May 2012	30 May 2012	13 June 2012
N form					%		
	NH_4-N		87.74a[¶]	89.51b	86.96a	92.46a	85.18a
	NO_3-N		87.64a	89.14b	86.11ab	91.35ab	84.55a
	Urea		88.42a	90.49a	87.09a	91.55ab	85.11a
	Control		87.48a	88.65b	84.88b	90.40bc	81.49b
OM							
	Control		87.35a	89.61a	84.93a	91.37a	83.28a
	Rev®[†]		88.16a	89.64a	87.29a	91.57a	85.39a
	TurfWork®[‡]		87.64a	89.29a	87.01a	91.14a	83.88a
	Ful-Power®[§]		88.14a	89.24a	85.80a	91.68a	83.78a
				ANOVA			
Source of variance		df			*F*-test		
N form (N)		3	1.49	8.25**	4.46*	5.35*	10.10**
OM		3	1.35	0.62	2.14	0.42	1.68
N x OM		9	0.31	0.73	0.92	0.69	2.03

[†] Rev® (Dakota Peat, Grand Forks, ND) is derived from naturally mined humic materials with pH 6.2, 9.2 mg·kg^{-1} nitrate N, 5.3 mg·kg^{-1} ammonical N, 4 mg·kg^{-1} P, and 10 mg·kg^{-1} K. The material had particle sizes smaller than 100 μm, 21/2% humic acid, and 0.8% fulvic acid based on dry weight; 1 mg·kg^{-1} = 1 ppm, and 1 μm = 1 micron.

[‡] Turf Works® (Custom Agronomics, Palm City, FL) is derived from fresh water leonardite ore with 20% humic acid.

[§] Ful-Power® (Faust Bio-Agricultural Services, Independence, OR) is derived from the fulvic fraction of raw humic substances with a pH of 3.5 and is 0.015% fulvic acid.

[¶] Numbers within a factor in the same column followed by same letter are not significantly different at 0.05 *P* level.

Table 7. Green density of ‘Pencross’ creeping bentgrass as affected by foliar application of N fertilizers tank mixed with liquid organic amendment (Rev®, TurfWorks®, and Ful-Power®) in the study during Nov. to Jan. 2013. Nitrogen from NH_4-N, NO_3-N, and Urea forms was applied at an N rate of 1.25 g·m^{-2} at 2-week intervals.

		5 Nov. 2012	19 Nov. 2012	3 Dec. 2012	17 Dec. 2012	2 Jan. 2013
N form				%		
	NH_4-N	93.23a[¶]	90.95a	92.58a	95.59ab	91.84b
	NO_3-N	93.63a	90.94a	91.16b	94.82b	90.04c
	Urea	93.99a	91.94a	93.40a	96.32a	93.11a
	Control	93.40a	89.81a	91.09b	93.43c	88.87c
OM						
	Control	93.27a	90.14a	91.39a	94.69a	90.58a
	Rev®[†]	93.50a	91.26a	92.41a	95.36a	90.54a
	TurfWork®[‡]	93.89a	91.04a	92.10a	95.06a	91.19a
	Ful-Power®[§]	93.58a	90.56a	92.33a	95.04a	91.55a
			ANOVA			
Source of variance	df			*F-test*		
N form (N)	3	0.47	3.44	6.72*	19.00**	24.35**
OM	3	0.50	1.90	1.27	0.93	1.66
N x OM	9	0.94	0.37	0.46	1.20	3.53**

[†] Rev® (Dakota Peat, Grand Forks, ND) is derived from naturally mined humic materials with pH 6.2, 9.2 mg·kg^{-1} nitrate N, 5.3 mg·kg^{-1} ammonical N, 4 mg·kg^{-1} P, and 10 mg·kg^{-1} K. The material had particle sizes smaller than 100 μm, 21/2% humic acid, and 0.8% fulvic acid based on dry weight; 1 mg·kg^{-1} = 1 ppm, and 1 μm = 1 micron.

[‡] Turf Works® (Custom Agronomics, Palm City, FL) is derived from fresh water leonardite ore with 20% humic acid.

[§] Ful-Power® (Faust Bio-Agricultural Services, Independence, OR) is derived from the fulvic fraction of raw humic substances with a pH of 3.5 and is 0.015% fulvic acid.

[¶] Numbers within a factor in the same column followed by same letter are not significantly different at 0.05 *P* level.

Table 8. Dark green color index of ‘Pencross’ creeping bentgrass as affected by foliar application of N fertilizers tank mixed with liquid organic amendment (Rev®, TurfWorks®, and Ful-Power®) in the study during April to June 2012. Nitrogen from NH_4-N, NO_3-N, and Urea forms was applied at an N rate of 1.25 g·m^{-2} at 2-week intervals.

		17 Apr. 2012	1 May 2012	15 May 2012	30 May 2012	13 June 2012
N form						
	NH_4-N	0.367a	0.439a	0.403b	0.386b	0.449b
	NO_3-N	0.378a	0.449a	0.411b	0.393ab	0.440b
	Urea	0.375a	0.437a	0.428a	0.403a	0.464a
	Control	0.337b	0.377b	0.372c	0.348c	0.402c
OM						
	Control	0.358a	0.415a	0.404a	0.375a	0.423a
	Rev®[†]	0.361a	0.423a	0.409a	0.384a	0.447a
	TurfWork®[‡]	0.371a	0.436a	0.405a	0.387a	0.444a
	Ful-Power®[§]	0.367a	0.429a	0.396a	0.385a	0.440a
			ANOVA			
Source of variance	df			*F*-test		
N form (N)	3	7.86**	36.70**	25.15**	28.66**	15.14**
OM	3	0.74	2.67	2.96	1.79	3.40
N x OM	9	0.68	1.93	1.69	1.20	0.67

[†] Rev® (Dakota Peat, Grand Forks, ND) is derived from naturally mined humic materials with pH 6.2, 9.2 mg·kg^{-1} nitrate N, 5.3 mg·kg^{-1} ammonical N, 4 mg·kg^{-1} P, and 10 mg·kg^{-1} K. The material had particle sizes smaller than 100 μm, 21/2% humic acid, and 0.8% fulvic acid based on dry weight; 1 mg·kg^{-1} = 1 ppm, and 1 μm = 1 micron.

[‡] Turf Works® (Custom Agronomics, Palm City, FL) is derived from fresh water leonardite ore with 20% humic acid.

[§] Ful-Power® (Faust Bio-Agricultural Services, Independence, OR) is derived from the fulvic fraction of raw humic substances with a pH of 3.5 and is 0.015% fulvic acid.

[¶] Numbers within a factor in the same column followed by same letter are not significantly different at 0.05 *P* level.

one interaction was recorded for the second measurement of experiment two. Regardless of N forms, lowest DGCI was the lowest without OM. However, in NH_4-N treatment, TurfWorks® had the highest DGCI, in NO_3-N treatment and the control, Ful-Power® had the highest DGCI, and in urea treatment, Rev® had the highest DGCI (data not shown).

Normalized Difference Vegetative Index

The difference between normalized difference vegetative index (NDVI) for N form was found to be significant at the end of studies for both experiments (Table 9). $NDVI_{775}$ and mND_{705} were both found to be significant for both studies. In the first experiment, urea was found to have the highest $NDVI_{775}$ value of 0.93, which is 0.08 higher than the control. Experiment one also resulted in urea obtaining the highest mND_{705} value of 0.59, which is 0.15 higher than the control.

Experiment two showed similar results of urea receiving the highest $NDVI_{775}$ value of 0.94, which is 0.06 higher than the control (Table 10). Urea also recorded the highest mND_{705} value of 0.51 in experiment two, which is 0.11 higher than the control. Sims and Gamon (2002) defined mND_{705} as modified indices that produced substantially better correlations than NDVI with total chlorophyll. This is consistent with results of Ferwanda et al. (2005), showing that much of leaf nitrogen is tied together with chlorophyll; so estimated chlorophyll content can be used to give indirect estimates of nitrogen content. This is supported by research done by Stiegler et al. (2005), concluding that chlorophyll pigments have a greater influence on NDVI than accessory pigments. No significance was found between OM in either experiment

Table 9. NDVI of 'Pencross' creeping bentgrass as affected by foliar application of N fertilizers tank mixed with liquid organic amendment (Rev®, TurfWorks®, and Ful-Power®) in the study during April to June 2012. Nitrogen from NH_4-N, NO_3-N, and Urea forms was applied at an N rate of 1.25 $g \cdot m^{-2}$ at 2-week intervals.

		17 Apr. 2012		13 June 2012	
		$NDVI_{775}$[#]	mND_{705}[††]	$NDVI_{775}$	mND_{705}
N form					
	NH_4-N	0.907a[¶]	0.464a	0.917a	0.566ab
	NO_3-N	0.893a	0.439a	0.916a	0.542b
	Urea	0.890a	0.451a	0.927a	0.586a
	Control	0.880a	0.434a	0.852b	0.437c
OM					
	Control	0.882a	0.436a	0.904a	0.531a
	Rev®[†]	0.892a	0.450a	0.912a	0.542a
	TurfWork®[‡]	0.911a	0.465a	0.895a	0.520a
	Ful-Power®[§]	0.887a	0.437a	0.903a	0.539a
		ANOVA			
Source of variance	df			*F*-test	
N form (N)	3	1.35	2.17	18.00**	55.46**
OM	3	1.76	2.11	0.64	1.43
N x OM	9	1.06	0.87	0.47	0.74

[†] Rev® (Dakota Peat, Grand Forks, ND) is derived from naturally mined humic materials with pH 6.2, 9.2 $mg \cdot kg^{-1}$ nitrate N, 5.3 $mg \cdot kg^{-1}$ ammonical N, 4 $mg \cdot kg^{-1}$ P, and 10 $mg \cdot kg^{-1}$ K. The material had particle sizes smaller than 100 μm, 21/2% humic acid, and 0.8% fulvic acid based on dry weight; 1 $mg \cdot kg^{-1}$ = 1 ppm, and 1 μm = 1 micron.

[‡] Turf Works® (Custom Agronomics, Palm City, FL) is derived from fresh water leonardite ore with 20% humic acid.

[§] Ful-Power® (Faust Bio-Agricultural Services, Independence, OR) is derived from the fulvic fraction of raw humic substances with a pH of 3.5 and is 0.015% fulvic acid.

[¶] Numbers within a factor in the same column followed by same letter are not significantly different at 0.05 *P* level.

[#] $NDVI_{775} = (R_{775} - R_{675})/(R_{775} + R_{675})$, where R is the relative reflectance at a given wavelength.

[††] $mND_{750/705} = (R_{750} - R_{705})/(R_{750} + R_{705} - 2R_{445})$, where R is the relative reflectance at a given wavelength

Table 10. NDVI of 'Pencross' creeping bentgrass as affected by foliar application of N fertilizers tank mixed with liquid organic amendment (Rev®, TurfWorks®, and Ful-Power®) in the study during Nov. to Jan. 2013. Nitrogen from NH_4-N, NO_3-N, and Urea forms was applied at an N rate of 1.25 $g \cdot m^{-2}$ at 2-week intervals.

		5 Nov. 2012		2 Jan. 2013	
		$NDVI_{775}$[#]	mND_{705}[††]	$NDVI_{775}$	mND_{705}
N form					
	NH_4-N	0.945a[¶]	0.524a	0.925a	0.462b
	NO_3-N	0.925a	0.494a	0.936a	0.461b
	Urea	0.929a	0.520a	0.940a	0.506a
	Control	0.927a	0.511a	0.877b	0.392c
OM					
	Control	0.934a	0.518a	0.906a	0.444a
	Rev®[†]	0.931a	0.512a	0.929a	0.466a
	TurfWork®[‡]	0.937a	0.512a	0.910a	0.432a
	Ful-Power®[§]	0.923a	0.507a	0.931a	0.478a
		ANOVA			
Source of variance	df	*F*-test			
N form (N)	3	1.81	1.88	5.28*	12.08**
OM	3	0.82	0.16	1.59	3.84
N x OM	9	1.24	0.71	1.22	0.91

[†] Rev® (Dakota Peat, Grand Forks, ND) is derived from naturally mined humic materials with pH 6.2, 9.2 $mg \cdot kg^{-1}$ nitrate N, 5.3 $mg \cdot kg^{-1}$ ammonical N, 4 $mg \cdot kg^{-1}$ P, and 10 $mg \cdot kg^{-1}$ K. The material had particle sizes smaller than 100 μm, 21/2% humic acid, and 0.8% fulvic acid based on dry weight; 1 $mg \cdot kg^{-1}$ = 1 ppm, and 1 μm = 1 micron.

[‡] Turf Works® (Custom Agronomics, Palm City, FL) is derived from fresh water leonardite ore with 20% humic acid.

[§] Ful-Power® (Faust Bio-Agricultural Services, Independence, OR) is derived from the fulvic fraction of raw humic substances with a pH of 3.5 and is 0.015% fulvic acid.

[¶] Numbers within a factor in the same column followed by same letter are not significantly different at 0.05 *P* level.

[#] $NDVI_{775} = (R_{775} - R_{675})/(R_{775} + R_{675})$, where R is the relative reflectance at a given wavelength.

[††] $mND_{750/705} = (R_{750} - R_{705})/(R_{750} + R_{705} - 2R_{445})$, where R is the relative reflectance at a given wavelength.

Shoot Biomass

Shoot weight was significant for Nform for both experiments. Experiment one showed the control receiving the greatest shoot weight of 10.6 g, and urea resulted in the second highest shoot weight of 8.7 g (Table 11). The second experiment also resulted in the control having the greatest shoot weight of 5.3 g, and urea resulted in the second highest shoot weight of 4.2 g. The second lowest shoot weight for experiment one and experiment two was NO_3-N with weights of 9.3 and 4.7 g, respectively. Bowman (2003) found a decrease in root and shoot biomass with increasing N treatment. Restricted root growth my also have resulted due to containment of the plastic pots the turfgrass was growing in. No significance was found between OM in either experiment.

Visual quality of turfgrass is a basis of overall acceptability of turfgrass management. Results showed urea to generally provide the highest visual quality. Treatments of OM showed variability to turfgrass visual quality. Clipping yield measurements can also provide information on turfgrass growth status of plants. High clipping yield is attributed to turfgrass undergoing photosynthesis, but growth surges must be monitored in close mowing programs. High clipping yield may also be a favorable environment for disease incidences due to lush leaf surfaces. The study resulted in variability between clipping yield and N form. Green density and DGCI are measurements of uniformity and color and our results indicate consistency with urea generally showing the best results reaffirming human eye visual quality measurements. NDVI is used to estimate plant health and chlorophyll content. Ferwanda et al. (2005) indicated leaf nitrogen is tied together with chlorophyll; so estimated chlorophyll content can be used to give indirect estimates of nitrogen content.

Table 11. Shoot weight of ‘Pencross’ creeping bentgrass as affected by foliar application of N fertilizers tank mixed with liquid organic amendment (Rev®, TurfWorks®, and Ful-Power®) in the study during April to May 2012. Nitrogen from NH_4-N, NO_3-N, and Urea forms was applied at an N rate of 1.25 $g{\cdot}m^{-2}$ at 2-week intervals.

			Experiment 1	Experiment 2
N form			g	
	NH_4-N		9.302b[¶]	4.674bc
	NO_3-N		8.676b	4.210c
	Urea		10.481a	5.190ab
	Control		10.584a	5.305a
OM				
	Control		9.340a	4.799a
	Rev®[†]		10.593a	4.930a
	TurfWork®[‡]		9.458a	4.556a
	Ful-Power®[§]		9.659a	5.094a
		ANOVA		
Source of variance		df	*F*-test	
N form (N)		3	8.66**	7.30**
OM		3	3.27	1.48
N x OM		9	0.62	1.47

[†] Rev® (Dakota Peat, Grand Forks, ND) is derived from naturally mined humic materials with pH 6.2, 9.2 $mg{\cdot}kg^{-1}$ nitrate N, 5.3 $mg{\cdot}kg^{-1}$ ammonical N, 4 $mg{\cdot}kg^{-1}$ P, and 10 $mg{\cdot}kg^{-1}$ K. The material had particle sizes smaller than 100 μm, 21/2% humic acid, and 0.8% fulvic acid based on dry weight; 1 $mg{\cdot}kg^{-1}$ = 1 ppm, and 1 μm = 1 micron.

[‡] Turf Works® (Custom Agronomics, Palm City, FL) is derived from fresh water leonardite ore with 20% humic acid.

[§] Ful-Power® (Faust Bio-Agricultural Services, Independence, OR) is derived from the fulvic fraction of raw humic substances with a pH of 3.5 and is 0.015% fulvic acid.

[¶] Numbers within a factor in the same column followed by same letter are not significantly different at 0.05 *P* level.

Again urea resulted in the greatest values for both indices in both experiments resulting in consistent measurements among visual quality, green density, DGCI, and NDVI.

Summary and Conclusion

In this study, different N forms were tank-mixed with different organic matter amendments to determine potential differences in turfgrass quality on creeping bentgrass. Overall, N form had a significant effect on visual quality, clipping yield, green density, DGCI, NDVI, and shoot weight. Generally urea treatments had the highest VQ among all N forms for both experiments ranging from 1.6-3.5 higher than control. In experiment one, TurfWorks® always had the highest VQ, while Ful-power® was the highest rated in experiment two. There were three interactions between N form and OM on visual quality in the first experiment. The first interaction showed N form NH_4-N in combination with TurfWorks® had the highest VQ, and the control OM, Rev®, and TurfWorks® in combination with NO_3-N received the highest VQ. Nitrogen form urea showed the highest VQ in combination with Turfworks® and Ful-Power®, while the control N treatment in combination with Rev® resulted in the highest VQ rating in the first interaction. The Second interaction showed Rev® in combination with NH_4-N had the highest visual quality. The second interaction also showed no VQ difference between NO_3-N and the OM treatments, while Urea in combination with TurfWorks® and the control had the highest VQ rating. The N form control treatment showed the highest VQ in combination with Ful-Power® in the second interaction. The third interaction showed both N forms NH_4-N and NO_3-N to have the highest VQ rating in combination with Ful-Power®. Nitrogen form urea in combination with Urea resulted in the highest VQ rating in interaction three. The control N treatment showed Rev® and Ful-Power® to have the highest VQ rating in the third interaction.

The were few similarities between these interactions. The combination of OM and NO_3-N seemed to show littler difference between VQ for all interactions. Also, Urea in combination with TurfWorks® showed to have the highest VQ rating for all interactions.

The effects of N form and OM clipping yield was inconclusive as to their effect on CY. Experiment one showed NO_3-N to generally have the highest CY while in experiment two NO_3-N showed to have the lowest CY. The lowest CY in experiment one was shown to be urea, while urea showed to be the highest CY in experiment two. These inconsistencies lead us to believe more research needs to be done to determine the effects on CY of foliarly applied N form on creeping bentgrass. Organic matter treatments were only significant in the first two measurements in experiment one, showing Rev® to have the lowest CY while TurfWorks® had the highest CY.

Green density showed to be positively influenced by N form urea for both experiments. There was no OM significance in either experiment, which reaffirms previous research that N form urea has an effect on green density (Spangenberg et al., 1986).

The DGCI was significant for all N form measurements in experiment one, but only one measurement of experiment two, with no OM difference. After the first two measurements, N form urea showed to have the highest DGCI in experiment one, which ties in to the results of urea providing the highest GD in both experiments.

Both $NDVI_{775}$ and mND_{705} showed difference in the second measurement at the end of the experiments. This was expected because the first measurement was taking only after one the first treatment. The second measurement showed difference in which we can determine treatment effects take longer than two weeks after treatment.

The shoot biomass for both experiments resulted in the control obtaining the highest biomass with no OM difference shown. This may be due to foliar effects of N form effecting the nodes and lower stems of the turfgrass, in which future research needs to be conducted.

Of the three N forms used in this study, urea showed to generally have the most positive influence on all measurements except for CY and shoot biomass. The OM treatments seemed to have a wide variety of effects on the measurements done in this study. Due to the low consistency of OM treatments further research is suggested on the OM products themselves to determine their effects on turfgrass when tank-mixed with N fertilizers.

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