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Central Florida Fertilizer Trials on 'Empire' Zoysiagrass and 'Pensacola' Bahiagrass

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There is increasing interest in alternatives to St. Augustinegrass for use in home lawns. Due to a lack of information about nutritional requirements of some alternative grass species, this research was undertaken to determine responses of 'Empire' zoysiagrass (*Zoysia japonica* Steud.) and 'Pensacola' bahiagrass (*Paspalum notatum* Flugge) to nitrogen and potassium. The research was conducted at Schroeder–Manatee Ranch Sod Farm in Bradenton, FL, from 2001 through 2003. Evaluations included visual quality and color ratings, multispectral reflectance measurements, and root and shoot growth. Data indicated that 'Empire' zoysiagrass could be adequately maintained under moderate maintenance levels in central Florida with nitrogen at 3 lb per 1000 ft² annually, but that higher rates of nitrogen would be required to maintain the same level of quality if cultural practices were less than adequate. 'Pensacola' bahiagrass did not respond well to increasing nitrogen rates, with best performance occurring from nitrogen at 2–3 lb per 1000 ft² annually. There were no responses to potassium for either grass. Results of this suggest that these grasses may be maintained with less nitrogen than would be required for a typical St. Augustinegrass lawn.

There are increasing concerns regarding fertilization of lawns and landscapes in Florida and the effects that nitrogen and phosphorus from lawn fertilizers may have on ground and surface waters. Current University of Florida (UF) lawn fertilization recommendations are based on research evaluating turf response to nutrients and potential nutrient leaching and are primarily limited to St. Augustinegrass (*Stenotaphrum secundatum* Walt. Kuntz) (Erickson et al., 2001; Saha et al., 2007; Trenholm and Unruh, 2007) and bermudagrass (*Cynodon dactylon* L. x *C. transvaalensis* Burtt-Davy) (Snyder and Cisar, 2000; Snyder et al., 1984). There are few published reports of fertilization trials on the other major lawn grass species used throughout Florida.

Use of 'Empire' zoysiagrass in home lawns has increased throughout Florida, but no research has documented the appropriate nitrogen (N) fertilization rates for this cultivar. Based on anecdotal observations, it appears that high N rates currently recommended for zoysiagrass may result in increased disease incidence and slow spring greenup in 'Empire' zoysiagrass. Bahiagrass is commonly used as a lawngrass in older neighborhoods, rural areas, or homes on multiple acres. It is also being specified in newer residential developments with low- to no-water-use mandates. Bahiagrass is typically thought of as a grass with low fertility requirements, but there are few published reports describing the responses of bahiagrass used as a lawngrass to varying N rates. Blue (1971) applied five different levels of N (0, 112, 224, 448, 672 kg·ha^{-1}) (2.3, 4.6, 9.2, 13.7 lb per 1000 ft²) to 'Pensacola' bahiagrass in a forage trial and observed that yield increased linearly with increasing N rates up to 448 kg·ha^{-1} (9.2 lb/1000 ft²).

Much of the published research on turf responses to fertilization includes visual and growth measurements. In the last decade, use of multispectral reflectance to quantify research responses has increased, including turf response to fertilization (Kruse et al., 2006; Trenholm and Unruh, 2005, 2007; Trenholm et al., 2001) and turf stress (Jiang and Carrow, 2007; Trenholm et al., 1999b, 2000). Reflectance at visible range wavelengths and certain ratios of visible range to near-infrared range have been shown to be highly correlated with turfgrass quality (Trenholm et al., 1999a).

This research was conducted to determine the appropriate N fertilization levels and to verify the current UF fertilization recommendations for 'Pensacola' bahiagrass and 'Empire' zoysiagrass maintained as lawngrasses in central Florida.

Materials and Methods

'Empire' zoysiagrass and 'Pensacola' bahiagrass were sodded in separate experimental plots in Feb. 2001 at an off-production site at Schroeder–Manatee Ranch Sod Farm in Bradenton, FL. Research was conducted from 2001 through 2003; due to problems associated with insect and drought damage, data are only shown for 2001 and 2002. Fertilizer applications were initiated in Mar. 2001. Nitrogen was applied as ammonium sulfate (granular applications) at 0, 157, 294, or 447 kg·ha^{-1} (0, 3, 6, or 9 lb/1000 ft²) annually over the growing season. Nitrogen rates correspond to control, low (LN), medium (MN), or high (HN). Potassium (K) was applied as potassium chloride at 0, 157, 294 kg·ha^{-1} (0, 3, or 6 lb/1000 ft²) annually over the growing season. Treatments were applied in three equal applications throughout the growing season. The grass was mowed weekly or every other week at 10.2 cm (4 inches) with a rotary mower. Irrigation was applied when grass showed signs of drought stress. The grasses were maintained as "low-maintenance" lawns in terms of cultural practices and pesticide inputs.

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Visual quality, color, and density scores were taken throughout the growing season based on a scale from 1 to 9, where 1 = dead brown grass and 9 = optimal healthy green grass. A score of 6 was considered a minimally acceptable score for a home lawn.

Multispectral reflectance readings were taken every 2 months with a Cropscan MSR16 radiometer (Cropscan, Inc., Rochester, MN). The radiometer was fitted with filter wavelengths to measure reflectance at 450, 550, 660, 694, 710, 760, 810, and 930 nm. In addition, the following growth and stress indices were evaluated:

- NDVI (normalized difference vegetation index) growth index computed as $R_{930} – R_{660}/R_{930} + R_{660}$. Best = highest value.
- IR/R (leaf area index) growth index computed as R_{930}/R_{660}. Best = highest value.
- Stress1 index computed as R_{710}/R_{760}. Best = lowest value.
- Stress2 index computed as $R_{71}0/R_{810}$. Best = lowest value.

Experimental design for both experiments was a randomized complete-block design with three replications [3 m × 3 m (10 ft × 10 ft) replicates]. Data were analyzed with the ANOVA or GLM procedures in SAS (SAS, 2004). Significance was determined at the 0.05 probability level. Means were separated by Waller means separation at the 0.05 probability level. Since responses differed by year, data are presented separately by year.

Results and Discussion

‘Empire’ zoysiagrass. In 2001, quality, color, and density scores averaged over the season increased as N rate increased (Table 1). Quality at all N rates declined by September, primarily due to problems associated with the low maintenance regime and irrigation issues. Control plots did not maintain acceptable quality, color, or density when averaged over the season. Application of LN rates provided acceptable response in all categories when averaged over the growing season. There were no responses to K in ‘Empire’ for either year (data not shown).

Regression analysis for 2001 visual ratings indicated that there was a quadratic response to N rate for visual quality, color, and density (Fig. 1), although maximum values were not achieved within the range of rates used in this study. Regression indicated that acceptable quality scores would be met with N at 127.4 $kg·ha^{–1}$ (2.6 lb/1000 ft^2) annually, while color and density scores would both be met with N at 83.3 $kg·ha^{–1}$ (1.7 lb/1000 ft^2) annually.

In Spring 2002, quality in all plots was severely affected by hunting billbug (*Spenophorus venatus vestitus* Chitt.) damage and irrigation system problems in early summer. Quality scores did not differ due to N rate, although quality scores at all N rates were below an acceptable level (Table 1). Color scores were higher than quality, as this rating was based on color of the portion of the grass that was not affected by insect damage. Acceptable color scores were achieved with either MN or HN rates. Density scores were likewise acceptable with application of any N rate, although there were no differences in density due to N rate.

There were differences in multispectral reflectance values due to N rate when averaged over the season, with optimal reflectance values occurring in either the HN (450 and 550 nm) or HN and MN treated plots (660 and 694 nm and all indices) (Table 2). This is a common response to N rate in most warm-season grasses, including seashore paspalum (Trenholm et al., 2001), bermudagrass (Trenholm and Unruh, 2005; Trenholm et al., 2001), and St. Augustinegrass (Trenholm and Unruh, 2007).

Similar multispectral reflectance responses were seen in 2002, except that LN rates were often also included in the highest values (660 and 694 nm and LAI, Stress1, and Stress2). Lowest values occurred in the untreated control plots.

These data would indicate that a good quality ‘Empire’ zoysiagrass lawn could be maintained with N at approximately 147 $kg·ha^{–1}$ (3 lb/1000 ft^2) with proper cultural practices and appropriate pest management. Where less than optimal cultural practices exist, even HN rates may not provide acceptable quality. Over time, ‘Empire’ zoysiagrass exhibited fewer differences in response to N rate, indicating that lower N rates may be used in combination with good cultural practices to maintain a good quality lawn.

‘Pensacola’ bahiagrass. Visual quality and density ratings were not influenced by N rate in 2001 when averaged over the growing season (Table 3). None of the N rates produced an acceptable quality or density score of 6. On the June evaluation date, control plots had significantly lower quality than any of the treated plots, but no differences in quality or density due to N rate were observed on any other evaluation date (data not shown). Color

Table 1. Seasonal averages for visual turf quality, color and density scores of ‘Empire’ zoysiagrass for 2001–02 in Bradenton, FL. Visual ratings are from 1 to 9, where 1 = dead, brown grass and 9= perfect green grass. Means are averages of multiple rating events.

Year	Nitrogen ($kg·ha^{–2}$)	Seasonal quality	Seasonal color	Seasonal density
2001	447 (HN)[z]	7.0 a[y]	7.4 a	7.4 a
	298 (MN)	6.6 b	7.0 b	7.0 b
	149 (LN)	6.2 c	6.5 c	6.6 c
	0	5.2 d	5.4 d	5.5 d
P-value		***	***	***
2002	447 (HN)	4.0 a	6.3 a	6.5 a
	298 (MN)	3.2 a	6.1 a	6.2 a
	149 (LN)	3.7 a	5.7 a	6.3 a
	0	3.7 a	5.5 a	5.6 a
P-value		NS	NS	NS

[z]HN = high nitrogen; MN = medium nitrogen; LN = low nitrogen
[y]Means separation within a column by Waller’s multiple range test, 5% level.
[NS, ***]Nonsignificant or significant at the 0.001 probability level, respectively.

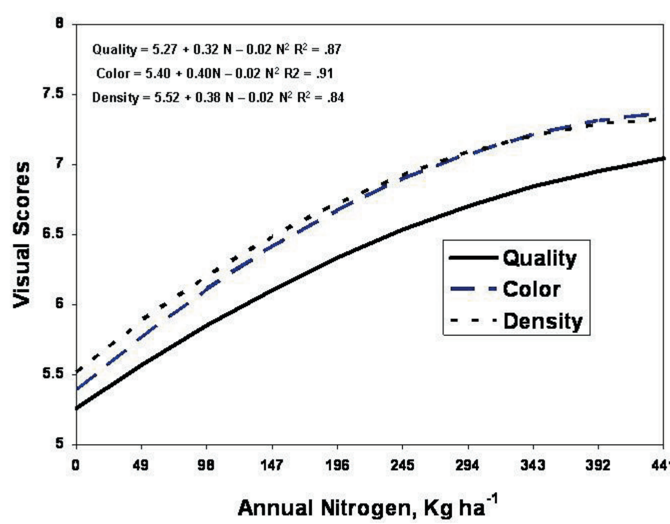

Fig. 1. Predicted visual scores of quality, color, and density in ‘Empire’ zoysiagrass in response to annual nitrogen (N) rates in 2001. A score of 6 is considered minimal acceptance for a home lawn in all categories.

Table 2. Average spectral reflectance values of 'Empire' Zoysiagrass in response to nitrogen (N), 2001–02. Optimal responses are in bold. Means are averages of multiple rating events.

Year	Nitrogen (kg·ha^{-2})	Wavelength (nm) or index 450	550	660	694	NDVI	LAI	Stress1	Stress2
2001	447 (HN)[z]	**5.54 d**[y]	**10.15 d**	**6.82 c**	**7.14 c**	**0.77 a**	**8.37 a**	**0.33 c**	**0.31 c**
	298 (MN)	5.87 c	10.74 c	**7.25 c**	**7.58 c**	**0.75 a**	**7.83 a**	**0.35 c**	**0.32 c**
	147 (LN)	6.40 b	11.96 b	8.36 b	8.83 b	0.18 b	6.62 b	0.37 b	0.37 b
	0	7.51 a	13.63 a	10.66 a	11.08 a	0.65 c	5.10 c	0.47 a	0.45 a
P-value		***	***	***	***	***	***	***	***
2002	447 (HN)	**4.90 c**	**8.84 c**	**6.05 b**	**7.59 b**	0.75 a	**8.85 a**	**0.38 b**	**0.36 b**
	298 (MN)	**5.15 bc**	**9.28 c**	**6.38 b**	**8.13 b**	0.74 a	**7.59 ab**	**0.40 ab**	**0.38 b**
	147 (LN)	5.89 b	10.28 b	**7.43 b**	**9.28 b**	0.70 a	**6.44 ab**	**0.44 ab**	**0.42 ab**
	0	7.44 a	13.41 a	9.63 a	12.14 a	0.65 a	4.92 b	0.51 a	0.49 a
P-value		***	***	**	**	NS	**	**	**

[z]HN = high nitrogen; MN = medium nitrogen; LN = low nitrogen
[y]Means separation within a column by Waller's multiple range test, 5% level.
NS, **, ***Nonsignificant or significant at the 0.01 or 0.001 probability levels, respectively.

Table 3. Average visual turf quality, color and density scores of 'Pensacola' bahiagrass for 2001–02 in Bradenton, FL. Visual ratings are from 1 to 9, where 1 = dead, brown grass and 9 = perfect green grass. Means are averages of multiple rating events.

Year	Nitrogen (kg·ha^{-2})	Seasonal quality	Seasonal color	Seasonal density
2001	447 (HN)[z]	5.2 a[y]	5.8 a	5.4 a
	298 (MN)	5.3 a	5.8 a	5.4 a
	149 (LN)	5.4 a	5.6 ab	5.3 a
	0	5.3 a	5.4 b	5.4 a
P-value		NS	**	NS
2002	447 (HN)	5.6 a	6.3 a	6.0 a
	298 (MN)	5.6 a	6.2 a	5.9 a
	149 (LN)	5.5 a	5.7 a	5.5 a
	0	3.9 b	4.2 b	4.0 b
P-value		**	**	**

[z]HN = high nitrogen; MN = medium nitrogen; LN = low nitrogen.
[y]Means separation within a column by Waller's multiple range test, 5% level.
NS, **Nonsignificant or significant at the 0.01 probability level, respectively.

scores increased as N rate increased, with highest color scores from either MN or HN treatments when averaged over the season. Regression analysis indicated that color had a quadratic response to N rate in bahiagrass. Maximum color of 5.82 was achieved with N at 407 kg·ha^{-1} (8.3 lb/1000 ft^2) (Fig. 2). Quality and color scores did not fit a regression model. There were no differences due to K in bahiagrass for either year (data not shown).

In 2002, plots receiving any rate of N had higher visual quality, color, and density ratings compared to the untreated control plots, although there were no response differences between treated plots (Table 3). Average quality scores did not reach an acceptable level at any N rate. Color scores were >6 with application of MN or HN and density reached a score of 6 at HN rates.

In 2001, where differences in reflectance scores occurred due to N treatment, optimal reflectance values were at either HN (660 nm) or HN and MN rates (550 and 694 nm and Stress1 and Stress2) (Table 4). These responses were similar to those seen in the 'Empire' trial. In 2002, treatment differences only occurred at 550 nm, again with optimal responses from MN or HN rates (Table 4).

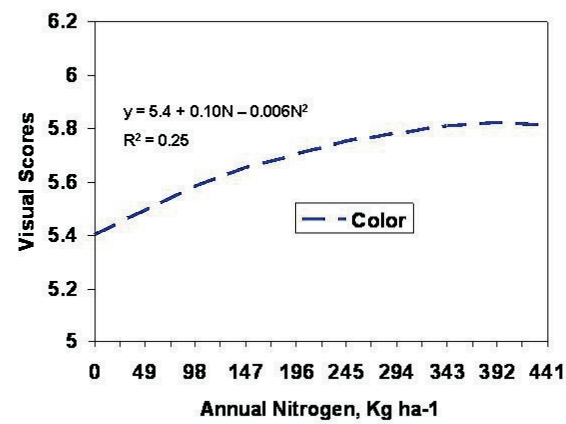

Fig. 2. Predicted visual color scores 'Pensacola' bahiagrass in response to annual nitrogen (N) rates in 2001. A score of 6 is considered minimal acceptance for a home lawn in all categories.

In this research, bahiagrass did not follow typical turfgrass quality or density responses to N. Color scores increased as N rates increased, although scores remained low at very high N rates. Due to the lack of response to N, it would be wise to limit annual N applications to bahiagrass to a minimal amount. For central Florida, N at 98 kg·ha^{-1} (2 lb/1000 ft^2) should produce a lawn that is acceptable, although in this study, a score of 6 was seldom reached for bahiagrass quality.

Based on the results of this research, recommendations for central Florida N rates for 'Empire' zoysiagrass would be 98–196 kg·ha^{-1} (2–4 lb/1000 ft^2) annually and 98 kg·ha^{-1} (2 lb/1000 ft^2) for bahiagrass. Although responses to K were not seen in either grass in this research, increased turf visual scores and reflectance values (Trenholm and Unruh, 2007; Trenholm et al., 2001) are not typically reported in response to K.

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Table 4. Average spectral reflectance values of 'Pensacola' bahiagrass in response to nitrogen (N), 2001–02. Optimal responses are in bold. Means are averages of multiple rating events.

Year	Nitrogen (kg·ha^{-2})	Wavelength (nm) or index							
		450	550	660	694	NDVI	LAI	Stress1	Stress2
2001	447 (HN)[z]	4.0 a[y]	**7.4 b**	**6.7 c**	**7.1 b**	0.68 a	5.48 a	**0.44 b**	**0.40 b**
	298 (MN)	4.0 a	**7.5 b**	6.8 b	**7.2 b**	0.68 a	5.36 a	**0.45 ab**	**0.41 ab**
	149 (LN)	4.4 a	7.9 a	7.5 a	7.8 a	0.65 a	4.94 a	0.48 a	0.44 a
	0	4.3 a	7.9 a	7.4 ab	7.8 a	0.66 a	4.94 a	0.48 a	0.44 a
P-value		NS	***	*	**	NS	NS	**	**
2002	447 (HN)	3.9 a	**8.0 b**	6.5 a	8.2 a	0.72 a	6.4 a	0.41 a	0.38 a
	298 (MN)	3.9 a	**8.0 b**	6.5 a	8.0 a	0.71 a	6.3 a	0.41 a	0.38 a
	149 (LN)	4.1 a	**8.3 ab**	7.0 a	8.7 a	0.70 a	5.9 a	0.44 a	0.41 a
	0	4.3 a	8.7 a	7.0 a	8.8 a	0.71 a	6.1 a	0.44 a	0.40 a
P-value		NS	**	NS	NS	NS	NS	NS	NS

[z]HN = high nitrogen; MN = medium nitrogen; LN = low nitrogen.
[y]Means separation within a column by Waller's multiple range test, 5% level.
[NS, *, **, ***]Nonsignificant or significant at the 0.05, 0.01, or 0.001 probability levels, respectively.

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