WHAT IS THE POTENTIAL OF SUBSTITUTING LEGUMES FOR SYNTHETIC NITROGEN IN WARM SEASON PERENNIAL GRASSES USED FOR STOCKER CATTLE GRAZING?

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Abstract

Stocker cattle grazing warm season perennial grasses is an important economic activity in the southern Great Plains. Substantial increases in the price of nitrogen fertilizer is negatively affecting forage producers' profitability. Two alternative nitrogen management systems that use annual and perennial legumes have been developed for bermudagrass pastures. The goal of the study is to determine if the legumes systems are more profitable than the conventional practice of applying synthetic sources of nitrogen. Enterprise budgeting techniques were employed to compare the economics of the legume systems relative to the common practice. Results of the two-year grazing study show that the legume systems could not compete economically with the common practice. The perennial legume system was most sensitive to the expected life of the stand and the number of grazing days.

Keywords: Bermudagrass, economics, grazing, legumes, nitrogen, stocker cattle

Subtheme: Farm Management

Stocker cattle grazing warm season perennial grasses is an important economic activity in the southern Great Plains. Synthetic sources of nitrogen (N) are commonly used to supply nitrogen fertilizer requirements to the introduced grass pastures common to the region. Typically, nitrogen fertilizer accounts for between 30 and 50 percent of the total cost of maintaining warm season perennial forages in the region. However, over the past several years, producer prices for synthetic sources of nitrogen have trended increasingly higher. In fact, the price for nitrogen fertilizer increased by 120 percent between 2000 and 2007 (USDA). These higher prices have weighed heavily on forage producers' farm profitability. With this strain on farm profitability, producers are searching for potential alternative strategies for managing nitrogen fertilizer requirements of their introduced warm season forages. Supplying nitrogen fertilizer requirements to warm season forages with nitrogen-fixing legume crops such as alfalfa and clover have been suggested as an alternative to using synthetic sources of nitrogen.

The use of legume crops to supply nitrogen needs for forage crops is not an innovative concept. In fact, a substantial amount of information currently exists regarding the various biological aspects of legume-grass pastures. For example, Baylor observed increases in forage yield, quality and a better distribution of available forage for grass pasture inter-seeded with legumes compared to only grass pastures (Baylor 1974). In 2007, Rao et al. reported that grass pea (*Lathyrus sativa* L. 'AC-Greenfix') inter-seeded into established stands of bermudagrass resulted in yields comparable to bermudagrass receiving 45 kg N ha^{-1} and that the content and in-vitro dry matter digestibility (IVDMD) was significantly higher than unfertilized bermudagrass (Rao et al. 2007). It was also reported that inter-seeded legumes increased forage relative feed value, supplied fixed nitrogen to the soil and decreased nitrogen fertilizer requirements (Hoveland 1989). Cassida et al. reported that bermudagrass inter-seeded with alfalfa produced a longer grazing period than alfalfa alone (Cassida et al. 2006). Moreover, they also reported that alfalfa produced a greater quantity of biomass early in spring while bermudagrass realized greater levels of biomass during the summer months, suggesting that a mix of cool season legume inter-seeded into established stands of bermudagrass may allow for a better distribution of high quality forage over a longer grazing period.

Mineral concentration of the forage is also important to sufficiently supply mineral requirements of grazing animals. Different ecotypes of white clover were shown to contain up to three times the amount of phosphorus, potassium, calcium, and manganese found in stands of bermudagrass (Kallem Abbasi et al. 2006). In addition, the quantities of calcium, phosphorus, and potassium in the soil increased by as much as 30 percent after one year in stands of white clover when compared to a control of warm season introduced grasses only. Incorporation of legumes into grasses has been shown to help maintain soil chemical characteristics. For example, a 25 year study of a continuous grass-legume mixed pasture led to substantial reduced soil pH compared to a grass-only pasture (Haynes 1983: Bolan et al. 1991). In contrast, it has been shown that grasses that obtain nitrogen requirements via synthetic sources of nitrogen tend to realize increases in soil pH (Boonman 1993).

Despite the multitude of research studies that have been conducted to investigate the biological effects of using inter-seeded, nitrogen-fixing legumes in established stands of introduced perennial grasses, there remains limited information available regarding the economic potential of using such forage systems as a substitute for the common farmer practice of applying synthetic sources of nitrogen. To address this issue, two alternative nitrogen supply systems that utilize inter-seeded, nitrogen-fixing legumes in established stands of bermudagrass have been developed. The first system, a bermudagrass-clover mix (BG/C), requires inter-seeding a mix of annual legumes, including crimson clover (*Trifolium incarnatum*), arrowleaf clover (T. vesiculosum Savi) and hairy vetch (*Vicia villoso* Roth) into growing stands of bermudagrass (*Cynodon dactylon*). The second system, requires an inter-seeded establishment of perennial alfalfa (*Medicago sativa*) into growing stands of bermudagrass (BG/A). This system makes use of grazing-type alfalfa because of its high potential for grazing relative to varieties commonly used to produce hay crops (Smith and Bouton 1993; and Bouton and Gates 2003).

The objectives of the research reported here were (1) to determine the effects of nitrogen supply system on forage yield, forage quality and animal performance measures; and (2) to determine if the alternative legume systems are more profitable than the conventional nitrogen management strategies commonly used in the region. Given the expected increase in management intensity required to implement the alternative systems, estimates of the relative economic value of the two alternative systems is considered necessary to facilitate adoption by farmers. Economic information would also provide plant and soil and livestock scientists a better understanding of how the management practices should be adjusted in order to maximize the economic efficiency from the systems.

Materials and Methods

Site Description and Data Collection

The grazing experiment was conducted during the 2008 and 2009 production seasons via a complete randomized designed (CRD) experiment with three treatments and three replications. Treatments were the three nitrogen supply systems described above (BG/N, BG/C, and BG/A). This study site included a 12.75-hectare of established stands of bermudagrass partitioned into nine 1.41-hectare grazing paddocks located at the Samuel Roberts Noble Foundation's Pasture Research and Demonstration Farm in south-central Oklahoma. The land area used for this study site was planted to Midland bermudagrass in 1965 in an attempt to mitigate soil erosion resulting from continuous cropping activities commonly pursued in the region. Beginning in 1989 and continuing through the onset of this study, the land was used to demonstrate intensive rotational grazing practices for cow-calf and stocker enterprises. Further details about the site are reported by Dalrymple (1998).

Forage Management

A chronology of production and management activities for each of the nitrogen fertilizer management systems are reported in Table 1. Bermudagrass was hayed to a 7.62 cm stubble height in August 2007 to reduce residual herbage mass and enhance seedling competitiveness.

In October, 2007, an annual legume seed mix was no-till drilled into the existing bermudagrass sod in the BG/C paddocks in 19.05-cm rows with a no-till drill. The annual legume seed mix was 14.56 kg ha^{-1} pure-live seed (PLS) 'AU early cover' hairy vetch, 15.68 kg ha^{-1} PLS 'Dixie' crimson clover, and 10.08 kg ha^{-1} PLS 'Apache' arrowleaf clover. Vetch was drilled at 2.54 cm depth, while clovers were drilled at 0.635 cm depth.

'Bulldog 505' alfalfa (22.4 kg PLS ha^{-1}) was no-till drilled into the existing bermudagrass sod in the BG/A paddocks in 19.05 cm rows with a no-till drill in October 2007. Seeding depth for alfalfa was 0.635 cm depth. Stand failures of alfalfa resulted in alfalfa being drilled again in September 2008. This stand failure was attributed to poor soil contact of alfalfa drilled in 2007 due to a 1.27 cm layer of bermudagrass thatch.

In February, the BG/C and BG/A systems were sprayed with Raptor® at a rate of 0.362 L ha^{-1} to control broadleaf weeds, and glyphosate was applied to paddocks assigned to the BG/N system to control broadleaf weeds and cool-season annuals such as ryegrass and cheatgrass. In March, 112 kg N ha^{-1} (as urea; 46% N) was broadcast in March in the three paddocks assigned to the BG/N system. All paddocks received applications of phosphorus (P) and potassium (K) according to soil test recommendations.

Forage samples were collected at 14-day intervals during the grazing trial. Forage samples were analyzed for concentrations of crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF), total digestible nutrients (TDN), IVDMD, P, K, Ca, and Mg by near infra-red reflectance spectroscopy.

Cattle Management

Grazing experiments were carried out during the spring and summer in 2008 and 2009. Each year, crossbred male calves were purchased from local sale barns and preconditioned for 45 days. Preconditioning included individual identification, anthelmintic treatment, implant administration, vaccination, and surgical castration and dehorning as needed. During the receiving period calves were housed in a grass trap and fed a mineral supplement and ad-libitum rye hay. Following preconditioning, steers (238 kg) were randomly assigned to the experimental paddocks, weighed, and stocked at 1.45 steers ha^{-1}. Grazing was initiated in May and terminated in August. During the experimental grazing period, steers were weighed every 28 days. All steer body weights were recorded following a 16-h shrink in drylot, and steers had ad-libitum access to a loose mineral containing monensin during the experiment. In addition, steers in legume-containing paddocks had access to a pressed block containing poloxalene as a bloat preventative.

Economics

The relative economic value for each of the nitrogen management systems was determined by calculating the revenues and costs associated with each of the production and management practices for each system. Only those costs that varied due to differences in production practices between systems were considered in the analysis. These costs include quantity of nitrogen and nitrogen

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application, seed cost, seed establishment costs, herbicide and herbicide application and opportunity cost of capital. Two-year average costs for each system were summed for each system and then subtracted from the expected revenue generated from marketing total kg gain ha^{-1} produced in each of the three systems. Note that establishment costs for the perennial alfalfa system were amortized over the expected life of the stand (five years). Oklahoma City futures prices were assigned to cattle in order to determine their beginning and ending values based on the observed on and off-dates for each system. In addition, expected prices for the 2010 production year were used for all inputs, including nitrogen fertilizer, herbicides and legume seeds and an annual percentage rate (APR) of 8.5% was used to calculate opportunity cost of capital and the amortized payment for the BG/A system. Custom rates for nitrogen application, no-till legume establishment, and herbicide application were taken from Doye and Sahs (2009). Input prices assumed in the study are reported in Table 2, and futures prices for cattle are reported in Table 5.

Statistical Model

Forage and animal performance data collected from the experiment and economic calculations (value of gain, gross revenue, cost, and net return) were analyzed using random-effects mixed models, with paddock (replication) and growing season (year) as random effects, and management treatment (system) as a fixed effect. The statistical models applied the autoregressive (AR1) spatial power covariance structure to help account for temporal autocorrelation in data collected across growing periods. Individual paddocks (replicates) were utilized as local subjects within all analyses, as they represented the units in the study that received the specified management practices (treatments) over the course of the study.

Results and Discussion

Forage Yield and Quality

Two-year average biomass yields for the three systems are depicted in Figure 1. Biomass yield of for the BG/N system was, on average, 2374 kg ha^{-1} and was significantly greater (P=0.05) than the 1523 and 1747 kg ha^{-1} of forage obtained in BG/A and BG/C systems, respectively. This difference translated into the production of a greater amount of animal gain ha^{-1} for the BG/N system compared to the two alternative bermudagrass-legume systems.

Two-year average measures of forage quality are reported in Table 3. Forage quality measures were mixed between systems. The average CP content of 16.9% measured in the forage produced in the BG/C system was significantly higher (P=0.05) than that measured in the forage produced in the BG/N and BG/A systems, respectively. In addition, the BG/C and BG/A systems realized greater percentages of ADF and IVDMD than that found in the BG/N system, and conversely they had significantly lower percentage levels of NDF and TDN compared to the BG/N system. This implies that the quality of the forage in the legumes systems were statistically better than for the synthetic nitrogen system; however, in absolute terms, these differences were not be large enough to influence large differences in animal performance between systems. We also found that BG/C system had greater percentages of P, Ca and K than the both the BG/N and BG/A systems. The BG/A system realized, on average, the lowest percentage of Mg concentration.

Animal Performance

Data reflecting animal management and observed performance measures are reported in Table 4. On average over the two years of the study cattle were placed on paddocks for BG/N, BG/C, and BG/A systems on 21-May, 29-April and 21-May, respectively. On weights of cattle were 588 (± 55), 571 (± 49), and 596 (± 45) kg ha^{-1} for BG/N, BG/C and BG/A systems, respectively. On average cattle grazing the

BG/N system realized a significantly greater number of days versus cattle grazing the BG/C and BG/A systems. In addition, off weights varied between the two systems. Cattle were coming off of the BG/N system weighted, on average, 11% and 8% more than cattle grazing the BG/C and BG/A systems, respectively. On average, cattle realized similar average daily gains (kg/hd/day) for all three systems. However, due to cattle realizing a greater number of grazing days on the BG/N system, the total gain ha^{-1} realized by cattle grazing the BG/N system was significantly greater (P=0.05) than the BG/C and BG/A systems. In fact, each ha of pasture in BG/N system realized approximately 75.04 kg ha^{-1} more than both of the legume systems. Based on the forage results, it appears that cattle grazing the BG/N system had more forage available to them for a longer period of time.

Economic analysis

Mean cattle prices used to place initial and ending value on cattle, calculated value of gain, gross revenue, operating costs, total costs, and net returns are reported in Table 5. On prices (prices used to place value on cattle at the time they were placed on pasture at the beginning of the grazing period) represent Oklahoma City futures prices for preconditioned stocker steers for average weight and the dates reported. Off prices reflect Oklahoma City futures prices for average off weights and dates reported. Value of gain was calculated for cattle in each system and year as the difference between ending value of cattle (off price times off weight) and beginning value (on price times on weight) divided by total gain per head. Value of gain, on average, differed between systems within and between years. For example, value of gain for the BG/N system in 2008 ($0.26 kg^{-1}) was substantially different for BG/C ($0.29 kg^{-1}) and BG/A ($0.18 kg^{-1}) systems, respectively. Much of this difference is related to differences in initial weights, ending weights, and kg gain ha^{-1} between systems. Risk management practices used to hedge against price volatility may help reduce some variation in value of gain between systems. However, only a portion of the variation can be managed. Other parts of the variation are simply due to normal cyclical patterns in prices during a grazing period while other parts of variation are simply due to differences in total animal gain between systems.

The two-year average gross revenue ($ ha^{-1}) for the BG/N system was 32% and 45% greater (P=0.05) than the BG/C and BG/A systems, respectively. This is primarily the result of cattle in the BG/N system having access to a greater amount of forage for more days than the two bermudagrass-legume systems. Average two-year gross revenue for the bermudagrass-alfalfa system was lowest among systems, essentially due to a stand failure in the first year of the study. As a result, the bermudagrass forage did not receive a benefit from the nitrogen fixing legume, nor did cattle receive additional benefit from additional forage from legumes early in the grazing season. Consequently, the BG/A system was essentially comparable to a bermudagrass system receiving a zero-level of nitrogen fertilizer. Forage allowance from legumes was also lower in BG/C system in the first year of production, which effectively reduced the revenue generated from this system. Even though the BG/C system did produce a partial stand in the initial production year, low levels of precipitation following the seed establishment in September of 2007 negatively affected growth of legumes during the early spring. Legume stands for the BG/C system were significantly better in the second growing season. Gross revenue realized from the BG/A system was more than double in the second year of the study compared to the first. This is the result of a successful stand establishment in the second year, and hence adequate forage for cattle to graze in the cool season months before the bermudagrass responded to warmer temperatures. It is important to note that the variation in growing conditions (rainfall) in the region is present in both years of the study. As such, the data reflect the typical risks associated with growing condition common to the region.

When the cost ($ ha^{-1}) of establishing alfalfa (seed and seed establishment expenses) was amortized over the expected 5 year life of the of stand, the total cost of the BG/A system was 9% and 38% lower

(P=0.05) than the BG/N and BG/C systems, respectively. The establishment cost of the alfalfa system would have been half as much, but due to stand failure in the first year the cost of establishing alfalfa had to be accounted for twice in the analysis. It is worth reemphasizing that that establishment failures of perennial crops like alfalfa remain a real risk that producers face in the region, and hence the two-year cost is likely a better measure of the expected costs associated with this system. The opportunity costs associated with owning the steers during the grazing period and the herbicide expenses for broadleaf weed management were considered to be annual expenses and therefore were not amortized in the analysis. Herbicide management is necessary to control for broadleaf weeds and to help control other perennial grasses such as crabgrass, which can effectively choke out legumes if not managed properly. Development of inexpensive alternative herbicide practices would further reduce the cost of using the perennial alfalfa.

Overall, profitability favoured the conventional system of applying synthetic nitrogen on bermudagrass. The average two-year net return for the BG/N system was \$180.31 ha^{-1} greater (P=0.05) then the BG/C and BG/A systems, respectively. Forage gleaned from pastures assigned to the BG/C system realized a greater amount of gain in the second compared to the first (i.e., 258.72 versus 123.20 kg ha^{-1}); however, the influence of the market played a substantial role in reducing the profitability of the BG/C system in the second year compared to the first. That is, cattle prices were \$0.0226 kg^{-1} less in the second year than the first. This also illustrates the existence of different levels of market risk between systems and years due to the variations in market prices for cattle at both the time of placement and the time cattle are removed and marketed for each system.

Based on the two-year finding of this study, it does appear that the two legumes systems are not economically competitive with the conventional practice of supplying synthetic sources of nitrogen to growing stands of bermudagrass, at least at the current market price of \$0.204 kg^{-1} of actual nitrogen (46% urea). Further analysis indicates the breakeven price of nitrogen is \$0.308 kg^{-1}. At that rate the BG/N system would realize zero profits, holding all other variables constant. Results for the legumes systems are most sensitive to the length of the grazing period which translates into a greater amount of total animal gain ha^{-1}.

A primary limitation of this research is the limited number of years of data. Conducting the grazing study over more years would allow for better understanding the variation in forage production, and hence livestock performance between years. More years of the study would also allow researchers to obtain a better feel for what can be expected regarding the life of the alfalfa stand and corresponding quantity and quality of forage that it will produce. An additional limitation of the study is that it was only conducted at one site within the region. Replication of the study at additional sites would provide better information about how result can be expected to vary under different soil types and weather conditions.

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Table 1. Chronology of Production and Management Activities for the Conventional Nitrogen Fertilizer and Two Alternative Legume Grazing Systems

Bermudagrass fertilized with nitrogen fertilizer (BG/N)

Month	Production Activity
August	Mow off excess bermudagrass forage to initiate the study
February	Apply herbicide glyphosate at a rate of 4.7 L ha^{-1} to control broadleaf weeds
March	Broadcast 112 kg N ha of actual (46-0-0)
May	Stock pastures with preconditioned steers weighing on average 588 kg ha^{-1}
September	Remove and market stocker cattle

Bermudagrass interseeded with a mix of annually established legumes system (BG/C)

Month	Production Activity
August	Mow off excess bermudagrass forage to initiate the study
September	No-till drill mixtures (40 kg PLS ha^{-1}) of hairy vetch (15 kg PLS ha^{-1}), crimson (16 kg PLS ha^{-1}) and arrowleaf (10 kg PLS ha^{-1}) clovers into bermudagrass
February	Apply herbicide Raptor at a rate of 0.36 L ha^{-1} and crop oil at 2.33 L ha^{-1} pints per acre to control broadleaf weeds
April	Stock pastures with preconditioned steers weighing on average 588 kg ha^{-1}
July	Remove and market stocker cattle

Bermudagrass interseeded with perennial alfalfa system (BG/A)

Month	Production Activity
August	Mow off excess bermudagrass forage to initiate the study
September	No-till drill alfalfa seed at a rate 22 kg PLS ha^{-1} per acre into bermudagrass
February	Apply herbicide Raptor at a rate of 0.36 L ha^{-1} and crop oil at 2.33 L ha^{-1} pints per acre to control broadleaf weeds
April	Stock pastures with preconditioned steers weighing on average 588 kg ha^{-1}
July	Remove and market stocker cattle

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Table 2. Prices for Nitrogen Fertilizer, Herbicides, Legumes Seeds and Custom Rates for Nitrogen and Herbicide Application and No-till Drilling

Input Description	Price
Urea (46-0-0) ($ kg^{-1})	0.20
Glyphosate ($ L^{-1})	7.91
Raptor ($ L^{-1})	141.37
Crop oil ($ L^{-1})	1.94
Crimson clover seed ($ Kg^{-1} PLS)	0.64
Arrowleaf clover seed ($ kg^{-1} PLS)	1.33
Hairy vetch seed ($ kg^{-1} PLS)	0.83
Alfalfa seed ($ kg^{-1} PLS)	1.68
Custom N application rate ($ ha^{-1})	14.82
Custom herbicide application rate ($ ha^{-1})	14.82
Custom no-till drilling legumes seeds ($ ha^{-1})	29.64

Note that prices for nitrogen, herbicides and legume seeds were obtained from local farm input suppliers, and custom rates taken from Doye and Sahs 2009.

Table 3. Mean forage nutrient concentration of bermudagrass either fertilized with synthetic nitrogen (BG/N), inter-seeded clover (BG/C), amd inter-seeded alfalfa (BG/A).

	System		
Nutrient, % DM	BG/N	BG/C	BG/A
Crude Protein	14.6b	16.9a	14.4b
Acid Detergent Fibre	33.3b	34.9a	34.3a
Neutral Detergent Fibre	61.8a	55.3c	57.7b
Total Digestible Nutrients	62.9a	61.7b	62.2b
In Vitro Dry Matter Digestibility	69.4c	73.7a	71.9b
Phosphorus	0.21c	0.27a	0.21b
Potassium	1.96b	2.13a	1.76c
Calcium	0.58c	0.94a	0.73b
Magnesium	0.34a	0.33a	0.28b

Note that letters that differ across systems are significantly different at a 95% level of confidence.

Table 4. Mean Statistics for Animal Management and Performance Measures for Alternative Systems that Supply Nitrogen Requirement to Bermudagrass (BG/N, BG/C and BG/A) for 2008, 2009 and the Two-Year Average

	2008			2009			Two-Year Average		
Measure	BG/N	BG/C	BG/A	BG/N	BG/C	BG/A	BG/N	BG/C	BG/A
Cattle on-date	23-May	24-Apr	23-May	19-May	5-May	19-May	21-May	29-Apr	21-May
Cattle off-date	15-Aug	4-Jul	18-Jul	22-Sep	14-Jul	25-Aug	3-Sep	9-Jul	6-Aug
Cattle on-weight (kg hd^{-1})	220	209	232	256	253	241	239[a]	231[a]	241[a]
	(23)	(18)	(18)	(21)	(22)	(18)	(22)	(20)	(18)
Cattle off-weight (kg hd^{-1})	294	266	279	346	304	309	320[a]	285[b]	294[b]
	(38)	(27)	(25)	(35)	(29)	(22)	(37)	(28)	(24)
Steer grazing days	34	26	22	67	34	47	50[a]	30[b]	34[b]
		(5)			(7)	(15)		(6)	(15)
Average daily gain (kg hd^{-1} d^{-1})	0.89	0.86	0.83	0.71	0.77	0.68	0.80[a]	0.82[a]	0.76[a]
	(0.02)	(0.19)	(0.17)	(0.15)	(0.26)	(0.21)	(0.19)	(0.22)	(0.19)
Gain (kg ha^{-1})	161	123	101	259	147	170	209[a]	134[b]	136[b]
	(43)	(37)	(20)	(54)	(69)	(62)	(48)	(53)	(40)

Note that letters that differ are statistically significant at a 95% level of confidence. Numbers in parenthesis are standard deviations.

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Table 5. On Price, Off Price, Value of Gain, Gross Revenue, Establishment and Maintenance Costs, Total Cost and Net Returns for Alternative Systems for Supplying Nitrogen to Growing Bermudagrass (BG/N, BG/C and BG/A) for 2008, 2009 and the Two-Year Average

	2008			2009			Two-Year Average		
Economic Variable	BG/N	BG/C	BG/A	BG/N	BG/C	BG/A	BG/N	BG/C	BG/A
On price ($ kg^{-1})	0.54	0.55	0.54	0.50	0.50	0.50	0.52	0.52	0.52
Off price ($ kg^{-1})	0.46	0.49	0.47	0.44	0.47	0.45	0.45	0.48	0.46
Value of gain ($ kg^{-1})	0.26	0.29	0.18	0.24	0.22	0.22	0.25[a]	0.25[a]	0.20[b]
	(0.06)	(0.05)	(0.06)	(0.03)	(0.06)	(0.06)	(0.04)	(0.05)	(0.06)
Gross revenue ($ ha^{-1})	213	177	92	305	173	197	259[a]	175[b]	144[c]
	(98)	(77)	(46)	(93)	(128)	(105)	(95)	(103)	(75)
Nitrogen and nitrogen application expenses ($ ha^{-1})	126	------	------	126	------	------	126	------	------
Herbicide and herbicide application expenses ($ ha^{-1})	20	42	42	20	42	42	20	42	42
Seed and seed establishment expenses ($ ha^{-1})	------	146	173	------	146	173	------	146	173
Seed and seed establishment expenses amortized at 8.5% over five years ($ ha^{-1})	------	------	44	------	------	44	------	------	44
Opportunity cost of capital and steer ownership at 8.5% (APR)	27	21	17	57	30	37	42	26	27
Total cost ($ ha^{-1})	173	209	104	203	219	123	188[b]	214[c]	113[a]
	(3)	(5)	(1)	(4)	(7)	(13)	(3)	(6)	(7)
Net return ($ ha^{-1})	41	-32	-12	102	-45	73	71[a]	-39[c]	31[b]
	(97)	(74)	(45)	(91)	(126)	(105)	(94)	(100)	(75)

Note that letters that differ are statistically significant at a 95% level of confidence. Numbers in parenthesis are standard deviations.

Figure 1. Two-year average biomass yield for bermudagrass receiving nitrogen and two alternative bermudagrass legume systems. Bars with letters that differ are statistically different at a 95% level of confidence.