Review: Grazing stockpiled bermudagrass as an alternative to feeding harvested forage[1,2]

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Abstract

A large proportion of cow-calf enterprise costs are associated with hay feeding during late fall and early winter. Studies from different parts of the United States have demonstrated that management practices that extend grazing and reduce hay feeding improve cow-calf enterprise profitability. Bermudagrass has potential in many parts of the southern United States to be used in late summer stockpiling and fall/winter grazing programs. Fall bermudagrass forage accumulation is sensitive to forage variety, precipitation, temperature, nitrogen fertilization, and duration of the stockpiling period. Nitrogen fertilization increases crude protein concentration of stockpiled bermudagrass, and most studies indicate that fertilized forage maintains adequate crude protein concentration through February to sustain gestating beef cows. Dry matter digestibility during fall and winter is highly dependent on stage of maturity at the onset of dormancy. Digestibility generally declines through the winter months, and the extent and rate of this decline is highly dependent on environmental effects. Costs associated with a 100-d wintering period were evaluated for three systems: grazing stockpiled bermudagrass, grazing native tall grass prairie, and hay feeding. Pasture and feed costs associated with the stockpiled bermudagrass and tall grass prairie grazing systems were similar and averaged 57% of costs associated with hay feeding. The efficacy of a stockpiled bermudagrass grazing system seems to be most dependent on hay cost, fall forage production, and harvest efficiency, within a given year.

Key Words: Cynodon dactylon, Feed, Costs, Grazing, Forage, Stockpiling

Introduction

Extending grazing through fall and winter reduces the amount of harvested forage needed to maintain cow performance and can reduce production costs associated with winter feeding (D' Souza et al., 1990; Adams et al., 1994; Hitz and Russell, 1998). Grazing can be extended by different forage management practices, including the use of stockpiled forage (Matches and Burns, 1985). Stockpiling refers to the practice of allowing forage biomass to accumulate in the field until it is needed for grazing (Mays and Washko, 1960). Forages are generally stockpiled for use during the fall and winter, but they can be accumulated for use during any period of expected deficiency. Stockpiling forage for fall and(or) winter grazing has been practiced most extensively with the mixed native warm-season prairie grasses of the Great Plains and with tall fescue (*Festuca arundinaceae*) in the southeastern and south central states (Matches, 1979; Spooner and McGuire, 1979; Van Keuren and Stuedemann, 1979). The managed stockpiling of warm-season grasses, other than native species, for winter grazing is infrequently practiced, because the quality of the standing cured biomass is perceived as inadequate (Ball et al., 1996). Also, the practices of feeding hay and manufactured feeds during winter are strongly ingrained in the industry.

The feasibility of using stockpiled biomass of widely grown southern perennial grasses deserves additional research to elucidate the potential of this practice in reducing winter feeding costs. Bermudagrass (*Cynodon dactylon* [L.] Pers.) is a principal candidate species for this practice. It is grown on millions of hectares in the southern United States, where it serves as the base forage resource for cow-calf enterprises. This article is a review of the practice of stockpiling forage as a means of reducing winter feeding costs, with emphasis on the potential of bermudagrass for this purpose.

Discussion

Bermudagrass stands used for grazing or hay in the southern United States commonly serve as overwintering grounds for livestock, but the usual practice is to provide stored feed (i.e., hay) as the major source of nutrients. Accordingly, there is little information on the managed stockpiling of bermudagrass for the specific purposes of providing fall and winter grazing and thereby reducing winter feeding costs.

The attributes of bermudagrass that make it a widely used pasture grass in the South include high biomass production potential, ability to withstand sustained intense grazing pressure, acceptable palatability, absence of antiquality components, and tolerance to abiotic and biotic stress agents such as drought, insects, and diseases (Burton and Hanna, 1995). The ability of the species to respond to management practices influencing seasonal biomass production without jeopardizing stand health is an attribute contributing to its potential as a stockpiled forage. Current research has addressed the effects of variety, management, and climate on production and quality of forage during the growing season. However, little attention has been given to stockpiled bermudagrass systems. These variables are major determinants of the amount and quality of stockpiled bermudagrass and are thereby pertinent to this discussion.

Factors Affecting Biomass Accumulation

Influence of Variety. Bermudagrass varieties differ greatly in total forage production potential and in seasonal production characteristics. The improved hybrid varieties have substantially higher forage yield potential than naturalized (common) bermudagrass strains that are prevalent across the South and used extensively as pasture. Popular hybrid varieties such as 'Coastal,' 'Midland,' and 'Tifton 44' typically produce 50 to 100% more dry matter on a total seasonal basis than common bermudagrasses under moderate to high management intensity (Burton, 1947; Holt and Lancaster, 1968; Eichhorn et al., 1983). Varieties vary in seasonal production characteristics, which influences the amount of forage accumulated during a stockpiling period. Important attributes of 'Coastal' bermudagrass are its ability to produce more biomass in the late summer and fall months and to maintain active growth later than common bermudagrass (Burton, 1947; Eichhorn et al., 1983). Data indicate that some varieties such as 'Coastcross 1' and seeded 'NK-37' (*C. dactylon* var. *aridus*) produce even more fall growth than 'Coastal' (Simpson, 1968; Eichhorn et al., 1983).

A detrimental factor in stockpiling is the lodging of biomass during and subsequent to the stockpiling period. In general, the tall-growing varieties such as 'Coastal,' 'Midland,' and 'Tifton 44' tend to lodge to a greater extent than the relatively lower-growing common varieties. However, substantial differences exist among the tall-growing productive types. For instance, 'Brazos' bermudagrass is more resistant to lodging than 'Coastal' (Eichhorn et al., 1984).

Influence of Temperature and Precipitation. Bermudagrass forage yield and quality is highly dependent on temperature, light, and availability of moisture (Jolliff et al., 1979; Henderson and Robinson, 1982). These factors are subject to considerable regional, seasonal, and yearly variation in the southern United States and, therefore, have implications regarding the potential success of stockpiled forage systems for fall and winter grazing. For example, the average date of first frost occurs approximately December 15 in the extreme South, compared with November 1 in the northern edge of the bermudagrass-producing areas of the United States (Ball et al., 1996). Because freezing serves to truncate bermudagrass forage accumulation, the average date of initiating the stockpiling period must be adjusted to allow adequate time for optimal forage accumulation and quality. Managers must also evaluate the probability of the occurrence of climatic events within microclimates that result in reduced forage accumulation. Rate of bermudagrass growth is considerably higher when the temperature is above 24°C, and very little growth occurs when the temperature is 15 to 18°C (Burton and Hanna, 1995). Consequently, less growth would be expected in years when autumn temperatures are cooler than normal and when frost occurs earlier than normal. Because bermudagrass yield is highly sensitive to the availability of moisture (Prine and Burton, 1956), the effects of temperature and date of first frost would be expected to interact with the timing and(or) amount of precipitation prior to and during the stockpiling period.

Influence of Rate and Date of Fertilizer. Response to additional N fertilization is highly variable due to the effects of variety, environment, management, and associated interactions. In a review by Wilkinson and Longdale (1974), biomass responses to N rate from 'Coastal,' common, 'Midland,' and other bermudagrasses were cited from numerous sources. Most citations indicate that biomass response to added N ranges from 25 to 60 kg forage/kg added N (Wilkinson and Longdale, 1974), and there was a linear relationship in biomass production up to 600 to 700 kg N/ha. Limited data are available to evaluate the effects of varying N rate and application date for the purpose of stockpiling bermudagrass forage during late summer and fall. In a 2-yr Georgia study, Hart et al. (1969) used three N fertilization rates (0, 56, and 112 kg/ha) and three final summer hay harvest dates (July 30, August 15, and September 1) to apply the fall N and begin the stockpiling period. Fall forage yield was determined on November 15 each year. Figure 1 shows the relationship between final summer hay harvest and N fertilization rates for forage yield. Longer stockpiling periods (earlier N application dates) combined with higher rates of N fertilization increased biomass yield. Averaged across both years, DM yield per kilogram of applied N for the 112 kg N/ha treatment was 32, 19, and 21 for the July, August, and September application dates, respectively. In recent work conducted in eastern Oklahoma, N fertilizer was applied during mid to late August before determining forage dry matter availability after the first killing frost each year (R. Woods, personal communication). Forage dry matter availability was 1,301, 1,947, 2,607, and 2,730 ± 132 kg/ha for 0, 56, 112, and 168 kg N/ha, respectively. Executing the same calculation for the 112 kg N/ha treatment, biomass yield averaged 11.7 kg DM/kg N. These values may be lower than values from previous citations due to inadequate moisture during the stockpiling period in 2 out of 3 yr (R. Woods, personal communication).

Factors Affecting Forage Nutritive Value

Influence of Variety. Variation among bermudagrass varieties is greater for digestibility of dry matter than for protein concentration. Enhancing the dry matter digestibility of bermudagrass varieties has been a long-term plant breeding goal (Burton et al, 1967). Higher dry matter digestibility and associated animal performance has been attained in varieties such as 'Coastcross-1' (Burton, 1972), 'Tifton 44' (Burton and Monson, 1978), 'Tifton 68' (Burton and Monson, 1984), 'Tifton 78' (Burton and Monson, 1988), 'Brazos' (Eichhorn et al., 1984), 'Grazer' (Eichhorn et al., 1986), and 'Tifton 85' (Burton et al., 1993). Differences exist among these varieties in seasonal quality and production of forage. Daily steer gains in northern Louisiana were substantially higher on 'Grazer' (0.72 kg) than on 'Tifton 44' (0.46 kg), 'Brazos' (0.36 kg), or 'Coastal' (0.34 kg) during the latter part of the grazing season beginning in mid-August. Small differences are found among bermudagrass varieties in protein concentration, often as a consequence of confounding with growth maturity differences. In a 5-yr study, Eichhorn et al. (1983)

reported October crude protein percentages of 12.9, 14.0, 12.9, and 14.3 for 'Coastal,' 'Coastcross-1,' 'Alicia,' and common, respectively. Seasonal average (five samplings) protein concentrations closely matched the October averages of the varieties. Protein yields in October for 'Coastal,' 'Coastcross-1,' 'Alicia,' and common were 365, 532, 320, and 280 kg/ha. Although the differences in protein concentration were small, there was a substantial difference among the varieties in kilograms of protein yield per hectare.

Influence of Rate of Fertilizer. Nitrogen fertilization increases bermudagrass forage CP concentration (Burton and De Vane, 1952; Webster et al., 1965; Burton and Hanna, 1995). Most experiments have evaluated the influence of spring and summer applied N fertilizer on late spring and summer harvested forage CP concentration. However, few experiments have been published examining the influence of late summer applied N on fall and winter forage CP concentration. In a recent 2-yr Florida experiment using 'Tifton 85' bermudagrass, Johnson (1999) applied five N fertilization rates, each at five 28-d intervals, and harvested treatment plots on five 28-d intervals beginning in early June and ending in late September. In September, crude protein concentration was 10.4, 12.1, 14.6, 17.8 and 19.8% of DM for the 0, 39, 79, 118, and 157 kg/ha monthly N application treatments, respectively. Forage CP concentration increased 0.062 units for each additional unit of N (kg/ha) applied (r^2 = 0.99). A similar response was observed in June harvested samples, as shown by an increase of 0.057 percentage units of forage CP per unit of N (kg/ha) applied (r^2 = 0.99). In an Oklahoma study using 'Midland' bermudagrass, Webster et al. (1965) reported similar increases in forage CP concentration in response to increased N fertilizer across all harvest dates, ranging from May through early October. These data suggest that late summer accumulated forage CP concentration is increased with N fertilization, and that this response is similar to that when forage is grown and harvested earlier in the growing season. These responses were observed under experimental conditions in which late summer and fall moisture and temperature were apparently not limiting. Few experiments have evaluated the ability of bermudagrass forage to maintain higher CP concentration after frost and under varying dormant season environments. In a Georgia study, Hart et al. (1969) reported that the rate of late summer N application did not affect CP or dry matter digestibility of forage consumed after frost in mid-November. Alexander et al. (1961) fertilized 'Coastal' bermudagrass in Florida during late August and applied 56 or 112 kg N/ha. Bermudagrass forage was stockpiled through mid-October or early December, directly after a killing frost. When averaged across both harvest dates and years, forage contained 6.9 and 8.4% CP for 56 or 112 kg N/ha, respectively.

In recent years, interest has grown in further characterizing forage CP in order to better match forages and supplemental feeds to animal requirements. Forage or feed N is divided into nonprotein nitrogen (fraction A), true protein (fraction B), and insoluble or cell-wall-bound N (fraction C) (Sniffen et al., 1992; Licitra et al., 1996; NRC, 1996). The B fraction is further divided into B_1, B_2, and B_3 fractions, representing fast, medium, and slow rates of rumen degradability, respectively. An estimate of fluid and particulate passage rate from the rumen is necessary to estimate the quantity of true protein that passes from the rumen undegraded. Rogers et al. (1996) reported bermudagrass forage (70.6% NDF, 14.7% CP) to contain 32.3, 4.2, 13.8, 36.6, and 13.1% of CP as A, B_1, B_2, B_3, and C, respectively. Using the methodology described by Licitra et al. (1996), Johnson (1999) found that bermudagrass N fractions (A, B_1, B_2, B_3, and C) were increased by 136, 84, 109, 38, and 53%, respectively, when 157 kg N/ha (18% CP) was applied monthly, compared to the 0 kg N/ha control (9.9% CP). These data indicate that the protein fractions with rapid and moderate rates of degradation, including nonprotein nitrogen, are increased to a greater extent than the slowly degraded and indigestible protein fractions when a higher rate of N fertilization is used. Highly soluble N sources in cured standing forage would presumably be more susceptible to leaching during extended periods of grazing deferral and(or) with high levels of precipitation.

Bermudagrass digestibility is not significantly altered in response to different levels of N fertilization when in vivo or in vitro methods are used and treatment groups are harvested at similar time intervals (Alexander et al., 1961; Hart et al., 1969; Johnson, 1999).

Influence of Forage Maturity. The influence of plant maturity on bermudagrass nutritive value has been extensively studied since the 1950s. In general, advancing plant maturity is associated with decreasing protein concentration and DM digestibility (Knox et al., 1958; Burton et al., 1963; Wilkinson et al., 1970). Several have shown a decline in IVDMD with advanced plant maturity created by less frequent defoliation (Jolliff et al., 1979; Henderson and Robinson, 1982; Monson and Burton, 1982). Holt and Conrad (1986) reported that IVDMD declined about 2 g/kg with each advancing day of age (r^2 = 0.90). Similarly, as harvested forage maturity increases, animal performance and in vivo digestibility decline (Chambliss et al., 1999).

One of the contributing factors to declining protein concentration and forage digestibility with advancing maturity is the decrease in the proportion of leaves associated with advancing age. Prine and Burton (1956) harvested bermudagrass forage at 2-, 3-, 4-, 6-, and 8-wk intervals and reported average leaf percentages of 85.6, 81.2, 75.7, 62.5, and 56.3, respectively. Similarly, Holt and Conrad (1986) evaluated various bermudagrass varieties and observed average percentage of leaves of 65, 60, 50, and 47 when harvested at 2-, 4-, 6-, and 8-wk intervals, respectively. Structural characteristics that limit digestibility are highly lignified support tissues such as sclerenchyma and xylem (Akin, 1989). It is not known whether increased cell wall constituents complex a greater proportion of plant protein. This would cause more protein to escape ruminal degradation, and perhaps digestion altogether. These studies indicate that stage of maturity at the onset of dormancy is an important factor determining the forage nutritive value of stockpiled bermudagrass. Forage accumulated over a shorter time period would have higher nutritive value than forage accumulated over longer time periods. Consequently, decisions relative to the timing of stockpiling initiation must consider forage maturity as an important variable.

Influence of Dormant Season Environment. In systems in which forage is stockpiled for fall and winter grazing, the rate and extent of forage deterioration due to environmental factors is a major concern. Alexander et al. (1961) reported reduced in vivo digestibility, forage intake, and daily weight gains for cattle fed stockpiled forage harvested after frost (early December), compared with cattle fed forage harvested before frost (mid-October). Both forages had received 56 kg N/ha prior to stockpiling. When pastures received 112 kg N/ha, no differences in apparent digestibility or animal performance were observed among harvest dates. Hart et al. (1969) found that stockpiled bermudagrass forage DM digestibility declined from November through February. These workers concluded that digestibility declined faster during warm, wet weather and that the effect of weather was greater on younger forage (shorter stockpiling period). Taliaferro et al. (1987) evaluated selected cultivars of bermudagrass for nutritive value when stockpiled for deferred grazing until post-frost conditions. The experiments were conducted over 2 yr and at two (yr 1) and six (yr 2) locations. In each experiment, IVDMD declined from November through March and CP concentration decreased during the same time period in one of the two experiments. The authors suggested that the occurrence, extent, and rate of decline in nutritive value are highly dependent on environmental conditions. In more recent work, Coblentz et al. (1999) reported that predicted TDN of stockpiled bermudagrass forage declined from 63% in October to 57% in January. Crude protein concentration did not change significantly over time and ranged from 11.9 to 13.4% of DM; however, protein degradability declined from October through January (Scarbrough et al., 2000).

Nutritive value of forage is best reflected through studies evaluating animal performance, but few experiments are available evaluating animal performance and(or) economical supplementation strategies to enhance use of stockpiled bermudagrass forage. McCroskey et al. (1969) measured the effects of increasing amounts of cottonseed meal (**CSM**, 41% CP) on cow performance while grazing bermudagrass during the winter. Cows were fed daily either 0.45, 0.91, or 1.4 kg of CSM from December to April. Pastures were fertilized with 56 kg/ha of N, P, and K in the spring followed by two applications of 56 kg/ha of N in mid and late summer. Cow weight loss through calving decreased with each increased amount of CSM. However, the authors suggested that 0.45 kg of CSM daily was sufficient for adequate cow performance.

In a recent 2-yr experiment, Wheeler (1999) applied 56 kg N/ha in late August to bermudagrass pasture and initiated grazing during early November. In both of these experiments, the first killing frost occurred during the 1st wk of November. Unsupplemented, gestating beef cows gained weight during the month of November in both years and lost (yr 1) or maintained (yr 2) weight and body condition from December through late January or early February, respectively. In both experiments, cows receiving the equivalent of 1.4 kg supplement lost less (yr 1) or gained more (yr 2) weight and body condition than did cows receiving no supplement. Increasing supplement CP concentration above that of the energy control (12% CP) did not influence cow weight or body condition change.

From these experiments, it is evident that stockpiled bermudagrass forage quality declines through the fall and winter. When forage enters the dormant stage in an immature state with a high proportion of soluble nutrients, the rate of decline is faster than it is for forage entering the dormant stage in a more mature state. Additionally, rate of decline in forage quality is faster in regions with higher fall and winter precipitation. Finally, within a single location, stockpiled bermudagrass forage quality declines at variable rates, depending on the occurrence of extreme environmental conditions.

Winter Feeding System Economics

Harvested forage costs range from 18 to 24% of the total cost per weaned calf (Adams et al., 1994). Therefore, by concurrently maintaining cow-calf production and reducing harvested forage use, enterprise profitability should be increased. D' Souza et al. (1990) suggested that more dependence on cows rather than machines to harvest forage is one method to reduce winter feed costs. Our group has recently conducted experiments to compare animal performance while grazing stockpiled bermudagrass (**SB**) or stockpiled native tall grass prairie (**TGP**) during fall and early winter (our unpublished observations). In each of 2 yr, spring-calving beef cows grazed SB or TGP from late October through early February. Bermudagrass pastures were grazed or clipped during late August to remove existing forage and 56 kg of N/ha was applied. Grazing in TGP pastures was completely deferred from February through October. Cows grazing TGP were continuously grazed and received 0.91 kg daily of a 38% protein supplement. Cows grazing SB pasture were given sequential access to fresh forage at weekly intervals by moving a temporary fence. Cows grazing the SB pasture received 0.91 kg daily of a 25% protein supplement. Set stocking rate was 1.21 animal units (**AU**)/ha for native pasture, and variable stocking rate was 1.58 ± 0.24 AU/ha for bermudagrass pasture. Harvest efficiency for SB pasture was 62.1 ± 1.9%. Weight change and body condition score change did not differ ($P > 0.1$) among pasture types.

Economic simulation and sensitivity analyses were conducted comparing three 100-d systems: SB, TGP, and bermudagrass hay (**HAY**). All systems were assumed to achieve equal animal performance and hay was assumed to provide adequate protein and energy (when fed alone) to meet animal requirements. Harvest efficiency, stocking density, N fertilization, and supplemental feed type and amount were taken from those observed in the experiment described above. Average fall forage availability (3,089 kg/ha) was taken from Wheeler (1999) and Johnson et al. (2000), representing three consecutive years of forage data from two locations each year. Pasture rental costs, N fertilizer price, hay price, and feed prices were consistent with fall 1999 and winter 2000 costs in central Oklahoma (NASS, 2000). Bermudagrass pasture rental rate was $44.48/ha annually, and rental costs were allocated to 120 d of summer grazing and 100 d of fall and winter grazing (October 24 through February 1). Total cost for the stockpiled bermudagrass pasture was $49.86/ha for the winter grazing phase. Medium protein supplement (25% CP) was priced at $157.82/t, and the supplemental feeding period was 70 d. Native pasture rent was $24.71/ha, with an annual stocking rate of 4 ha/cow. High-protein supplement (38% CP) was priced at $206.37/t, and the supplemental feeding period was 75 d. Hay feeding waste was 15% of DMI and hay was valued at $55/t.

Sensitivity of input variables for the SB system was determined by changing one variable while holding all other variables constant until the total cost for the 100-d period equaled that of the hay system. Sensitivity was considered to be the difference in percentage change for each input variable required to reach the cost of the hay system. Total feed and forage costs/cow for the 100-d period were $39.61, $42.80, and $71.88 for SB, TGP, and HAY, respectively. Percentage of change required for SB system costs to equal HAY system costs was 46, 51, 51, 179, 261, 354, 355, and 355 for hay price, forage production, harvest efficiency, nitrogen cost per kilogram, fall and winter period pasture rental cost per hectare, days of supplemental feeding, amount of supplement fed per day, and supplemental feed price, respectively. In other words, if the price of hay declined by 46% from $66.63 to $30.07/t, with all other prices and production coefficients unchanged, the cost of the hay system would be equal to the cost of the SB system. Similarly, pasture rental costs for the fall and winter period could increase from the budgeted $20/ha to $73/ha before the HAY system would be more economical than the SB system.

A second sensitivity analysis was conducted to determine the influence of varying hay prices and forage accumulation on the difference in cost of these two systems over a 100-d period (Table 1). In this analysis, it was assumed that 1,300 kg biomass/ha was available at the initiation of fall grazing (800 kg available on September 1 and 500 kg produced through October 24) and that stockpiled bermudagrass pastures were grazed to a constant 1,000 kg/ha biomass residual (harvest efficiency varied with level of biomass accumulation). All other variables used in the analysis were as described in the previous analysis. These data demonstrate that N fertilization reduces the cost of the stockpiling system because fewer acres are required per animal, and that this effect is magnified with higher forage response to N fertilization (more optimal growing conditions during the stockpiling period). When hay prices are low, growing conditions must be near ideal to achieve significant savings. Alternatively, when hay prices are high, considerable savings can be achieved by grazing stockpiled forage rather than feeding hay, even in the presence of limiting climatic conditions.

Implications

Stockpiling bermudagrass forage for fall and winter grazing has the potential to reduce cow-calf production costs. Late summer and fall forage yield is variable, depending on variety, precipitation, temperature, duration of stockpiling period, and the date and rate of N fertilization. Forage digestibility and protein concentrations are also variable but are usually adequate to meet the requirements of spring-calving beef cows during the first few weeks after frost. Forage nutritive values decline through the winter and are sensitive to environmental and managerial effects. Cost per animal for stockpiled bermudagrass systems is affected more by forage accumulation and(or) harvest efficiency than by nitrogen fertilizer, pasture rental, or supplementation costs. Future research is necessary to determine optimal grazing management and supplementation strategies. Further research is also necessary to quantify the variability in forage yield within different regions of the southern United States.

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Notes

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Table 1. Difference in cost of stockpiled bermudagrass system and hay feeding system at various hay prices and fall forage availabilities ($/cow)[a]

Forage availability, kg/ha[b]	Hay price, $/t				
	33	44	55	66	77
0 kg N/ha					
1,300	–42.30	–27.92	–13.55	.83	15.20
56 kg N/ha					
3,540	11.76	26.13	40.51	54.88	69.26
2,980	5.46	19.83	34.21	48.58	62.96
2,420	–5.80	8.58	22.95	37.33	51.70
1,860	–31.76	–17.38	–3.01	11.37	25.74

[a]Values in the table were calculated as cost of hay feeding system minus cost of stockpiled bermudagrass wintering system, each for 100-d periods.

[b]Forage availability was determined assuming 800 kg/ha residual forage at initiation of stockpiling period and 500 kg/ha accumulation with 0 kg N/ha fertilizer applied in late summer. Remaining values in the range were calculated by using 40, 30, 20, or 10 kg biomass accumulation/kg N fertilizer and adding forage available when 0 kg N/ha was applied (1,300 kg/ha).

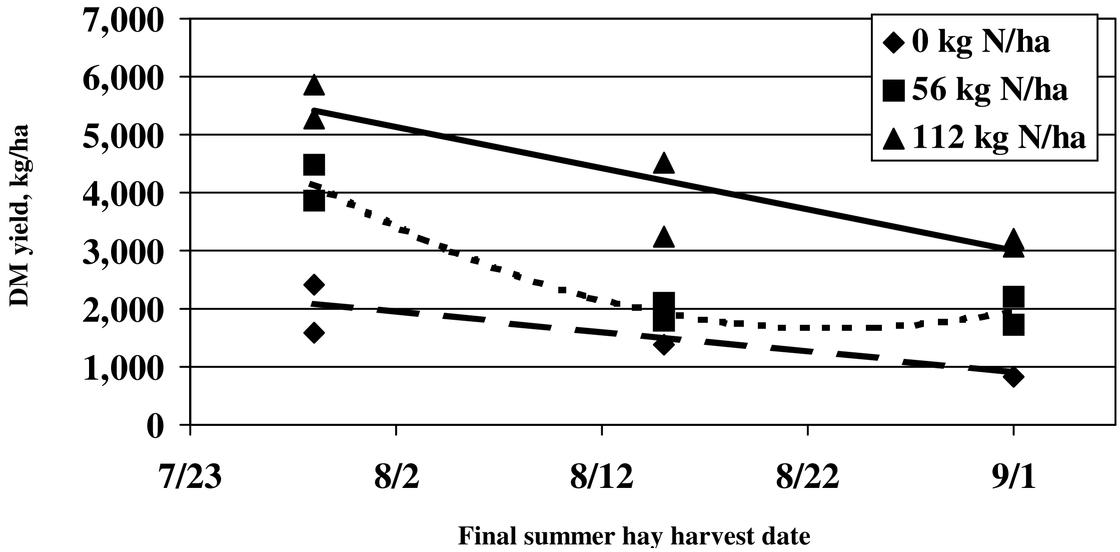

Figure 1. Relationship of stockpiled bermudagrass dry matter yield to final summer hay harvest date and nitrogen fertilization rate (Hart et al., 1969).