Stocking Rate and Fertilization Influence Sustainability of Bermudagrass Pasture

By Monte Rouquette, Jr. and Maria Lucia Silveira

Long-term stocking of bermudagrass pastures provides for enhanced cycling of plant nutrients with minimal environmental concerns on sandy soils.

With high stocking rate, bermudagrass pasture integrity was better maintained with application of N fertilizer compared to relying solely on N fixation from clover.

Highest stocking rate pasture after 39 years of grazing. The originally planted Coastal bermudagrass has been displaced by less desirable and lower yielding bermudagrass ecotypes, as is indicated by the predominance of purple seed heads.

Lowest stocking rate pasture after 39 years of grazing. The originally planted Coastal bermudagrass remains dominant in the stand. The image shows some of the normal (brown) appearance of "pulled" stolons and leaf material that results from grazing.

Sustainable beef production is inseparably linked to sustainable forage and pasture production. In humid vegetation zones, bermudagrass [*Cynodon dactylon* (L) Pers.] is an important warm-season perennial grass for hay and pastures for cow-calf and stocker production. Bermudagrass occupies about 25 to 30 million acres in the U.S. (Taliaferro et al., 2004). Bermudagrass pastures may be overseeded with cool-season annual forages and exposed to an array of management strategies including various stocking rate and fertilization regimens (Rouquette, 2017). Early experiments with 'Coastal' bermudagrass in the 1950s and 60s determined that defoliation frequency and N fertilization rate were more important to stand maintenance than height of stubble after clipping or defoliation.

Because most soils contain limited amounts of one or more plant nutrients, pasture fertilization is an integral component of sustainable production of high quality forage. In general, soil-test results provide the basis for recommendations of P and K, while N fertilization is typically calculated based on expected yields. Although N usually has the most profound impact on forage dry matter (DM) and sustainability, P and K play an important role in pasture persistence, stand vigor, and resistance to pest and diseases.

Bermudagrass removes N, P_2O_5, K_2O in an approximate ratio of 4:1:3, and early fertilizer studies suggested that a ratio of 4:1:2 may be best when using high rates of N, and ratios of 3:1:2 may be appropriate with low rates of N (Burton, 1954). The importance of K and the N:K ratio for sustainability and DM production has been well documented. Some of the most profound demonstrations of the importance of K in bermudagrass stand maintenance have involved its effect on rhizome health and survival (Keisling et al., 1979; Keisling and Rouquette, 1981), and its impact on leaf diseases (Eichhorn, 1976; Matocha and Smith, 1980).

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; ppm = parts per million.

U.S. Roundtable for Sustainable Beef

A multi-stakeholder initiative, the U.S. Roundtable for Sustainable Beef, was developed to support sustainability of the U.S. beef value chain (USRSB, 2016). A collaborative group, Global Roundtable for Sustainable Beef (GRSB, 2017) defined "sustainable beef" as a socially responsible, environmentally sound, and economically viable product. They identified natural resources as a major factor associated with sustainable beef, and included objectives such as environmental stewardship, protect grasslands from degradation, efficient management of water resources, maintain or improve soil health, and other related components.

Long-Term East Texas Study

The long-term nutrient cycling experiment reported here was conducted at Texas A&M AgriLife Research and Extension Center near Overton in east Texas. In this study both Coastal and common bermudagrass pastures have been stocked at three levels of forage mass (stocking rates) with cows and calves from 1968 to current date (Rouquette et al., 2011). Pastures have been continuously stocked during February to September each year to achieve high, medium, and low herbage mass. The study is conducted on a Darco loamy fine sand. Before study establishment, limestone was applied to correct low soil pH, and has been applied an additional nine times since.

This is a unique study in that it is one of the few (if not the only) that addresses multiple aspects of bermudagrass management and subsequent impacts on soil properties, forage production and quality, and animal performance over the course of several decades. Long-term, large-scale field trials are essential to evaluate the risks and benefits of different grazing pressure and fertilization management strategies on bermudagrass responses.

Nutrient Cycling

In grazing conditions, unlike hay production, nutrient recycling is constantly occurring, and the impact on forage mass is dependent primarily on availability of soil plant nutrients, especially N, and stocking rate (Rouquette et al., 1973). From 1968 through 1984, all pastures in the Overton study received the same annual rates of fertilizer N, P, and K in split applications. A fertility regimen x stocking rate study was initiated in 1985 to compare N + overseeded annual ryegrass (*Lolium multiflorum Lam*) versus no N + overseeded clover (*Trifolium* sp). From 1985 to 1997 no P fertilizer was applied to the experiment; however, since 1998 P has been applied annually (**Table 1**).

Table 1. Fertilizer treatments to long-term grazing study in east Texas.

Time range	Years	N	P_2O5	K_2O
		- - - - - - - - - - - lbs/A/yr - - - - - - - - - - -		
1969 to 1984	16	193	90	89
		- - - - - - - - N + ryegrass - - - - - - - -		
1985 to 1989	5	412	0	0
1990 to 1997	8	249	0	0
1998 to 2004	7	303	104	102
		- - - - - - - No N + clover - - - - - - -		
1985 to 1989	5	0	0	104
1990 to 1997	8	0	0	100
1998 to 2004	7	0	104	102

Source: Rouquette and Smith (2010).

Nitrogen Fertilization and N-Fixation

Nitrogen is the nutrient most responsible for forage DM production for hay and/or grazing on the acidic, low fertility soils in the southeastern U.S. Under grazing conditions, bermudagrass overseeded with legumes without N fertilization has shown enhanced DM production (Rouquette and Smith, 2010; Han et al., 2012; Vendramini et al., 2014). Silveira et al. (2016) reported on soil properties (nitrate-N, pH, available K, Ca, and Mg) during 37 years (1968 to 2004) of stocked bermudagrass pastures at Overton. Pastures fertilized with ammonium nitrate in split-applications with annual rates averaging about 300 lb N/A had higher soil nitrate-N concentrations than non-N + clover pastures. Averaged across years, soil nitrate-N concentrations in the 0 to 6-inch depth were highest at about 14 ppm. The non-N fertilized + clover pastures were relatively constant across years at about 4 ppm and were about 72% less than N-fertilized bermudagrass.

Stocking rates did not affect soil nitrate-N levels in the 0 to 18-inch soil depth; however, high stocking rates at about 2.5 cow-calf pair per acre (1,500 lbs/pair) had less soil nitrate-N at the 18 to 48-inch depth compared to low (1 cow-calf pair/A) or medium (1.6 cow-calf pair/A) stocking rates. This is because the greater defoliation in the more intensive system (high stocking rate) required more nutrient uptake to regenerate shoot growth, resulting in less nitrate-N lower in the profile. Neither fertilization nor excreta represented a major contributor to excess soil nitrate-N during the more than 37 years stocking.

Soil Extractable K

Bermudagrass pastures receiving N fertilization but no K for 13 years (1985 to 1997) had lower soil extractable K than the no N + clover + K pastures. At the initiation of the fertility regimens imposed in fall 1984, the average soil extractable K concentration was about 48 ppm which was considered very low for bermudagrass production. These soil K levels were very low despite application of about 90 lb K_2O/A from 1968 through 1984 on the sandy Darco soil. This was likely due to the relatively low soil cation exchange capacity and limited capacity to retain K. It is possible that some K was lost via leaching and luxury consumption by the plant.

Stocking rate had no effect on soil K levels. Results suggested that nutrient cycling via animal excreta sustained soil K levels, particularly in the treatments receiving no K. Previous studies on these soils (Keisling et al., 1979; Nelson et al., 1983) at Overton showed that non-exchangeable K reserves can be efficiently converted to exchangeable forms, and in turn, represent a K source for deep-rooted bermudagrass. These pastures continue to receive 60 lb K_2O/A.

Soil P Distribution

The long-term impact of stocking and fertilization regimens on soil P distribution in overseeded bermudagrass pastures at Overton has been documented by Silveira et al. (2013). After 37 years of stocking, there was no significant effect on soil extractable P from bermudagrass fertilized with or without N. Franzluebbers et al. (2002) also showed no effect of inorganic fertilizer and clover treatments on extractable soil P. At high stocking rates, however, bermudagrass pastures receiving N had greater P concentrations in the 0 to 18-inch depth compared to pastures without N plus clover. On ungrazed plots that simulated hay production, Matocha et al. (1973) reported that P uptake by Coastal bermudagrass was enhanced by increased N rates. Bermudagrass grazed pastures that received P fertilization from 1968 through 1984 maintained plant available soil P concentrations for 13 years (1985 to 1997) without added P. Nutrient recycling via grazing and animal excreta maintained adequate soil P status for forage growth.

Our data indicated that long-term changes in extractable soil P under bermudagrass pastures were directly related to the

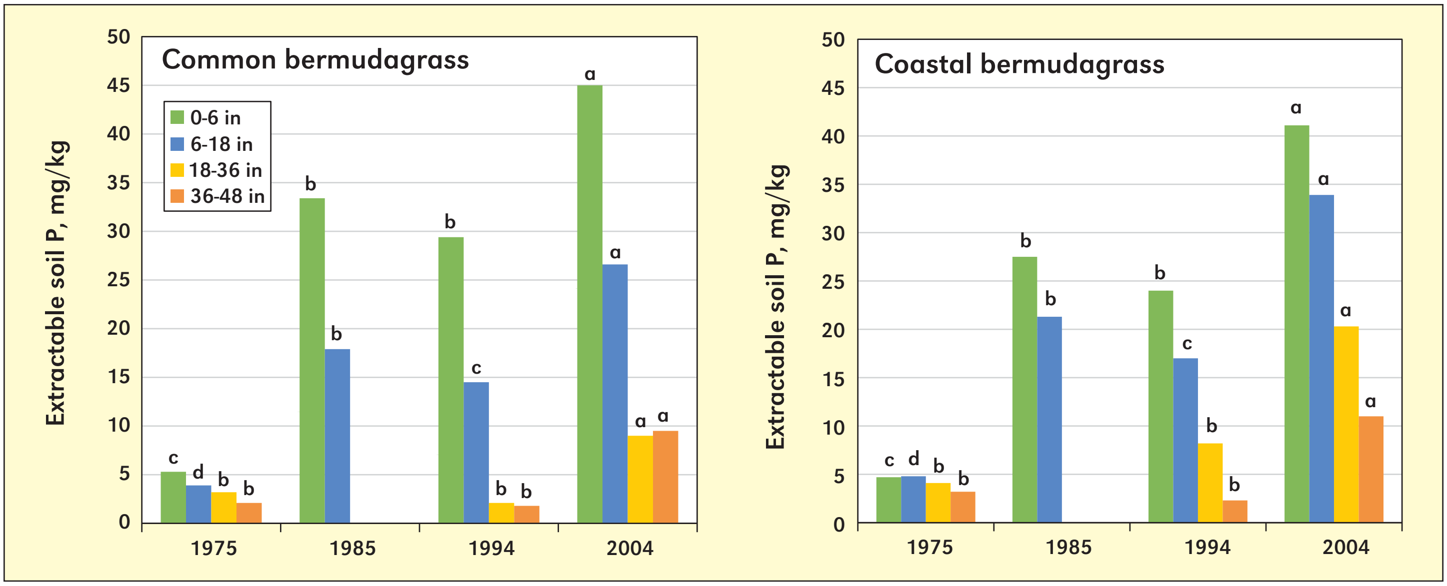

Figure 1. Changes in soil extractable P at the 0 to 48 in. depth in Common and Coastal bermudagrass pastures. Columns within series that have the same letters are not statistically different at $p \leq 0.05$.

application of P fertilizer intended to enhance soil fertility. For instance, annual application of 90 lb P_2O_5/A from 1975 to 1984 and 104 lb P_2O_5/A from 1998 to 2004 increased extractable soil P concentrations in common and Costal bermudagrass pastures (**Figure 1**). Despite the absence of P fertilization from 1985 through 1994, extractable soil P remained higher (particularly at depths >6 in.) compared to 1975 levels. Although P has been shown to be relatively immobile in the soil, on the sandy Darco soils in these pastures, P moved from the surface horizons and contributed to increased P in the subsurface depths. Ohno and Erich (1997) reported that organic acids present in animal excreta can potentially contribute to P leaching by competing with P for sorption sites in the soil. These well-managed and stocked bermudagrass pastures showed no accumulation of excessive P in soils after more than 37 years.

Bermudagrass Ecotype Diversity

After more than 38 years of continuous stocking of bermudagrass pastures during the active growth period (February to October) of overseeded cool-season annuals and bermudagrass, stands of both Coastal and common bermudagrass were negatively affected by high stocking rates, decreased herbage mass, and no N fertilization (Rouquette et al., 2011). Under low stocking rates (1 cow-calf pair/A), the originally established Coastal and common bermudagrass was still dominate, and made up about 70 to 75% of the stand (**Figures 2 and 3**). In the absence of N fertilizer (no N + clover) and under high stocking rates (2.5 cow-calf pair/A), only 20 to 27% of the original

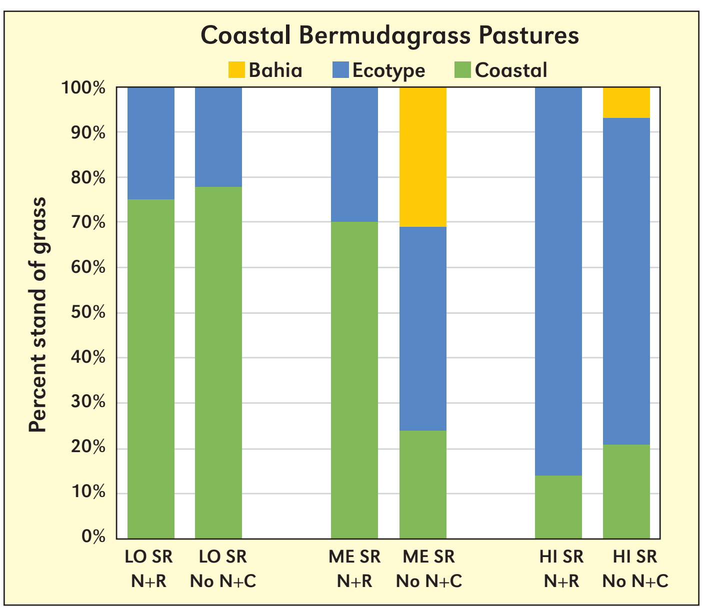

Figure 2. Invasive bermudagrass ecotypes and bahiagrass in Coastal bermudagrass pastures under long-term (>38 years) stocking rates (LO, ME, HI) and fertility regimens (N + Ryegrass vs. no N + Clover)

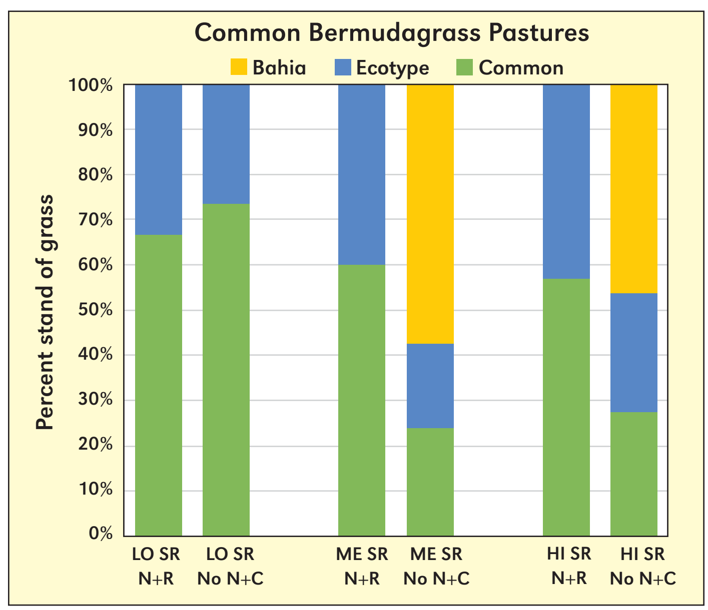

Figure 3. Invasive bermudagrass ecotypes and bahiagrass in Common bermudagrass pastures under long-term (>38 years) stocking rates (LO, ME, HI) and fertility regimens (N + Ryegrass vs. no N + Clover)

Coastal and common bermudagrass remained. In general, at the higher stocking rates the N+ryegrass treatment maintained stand integrity over time better than the no N+clover treatment.

Invading species included other bermudagrass ecotypes which maintained ground cover; thus, soil-exposed areas were minimum to non-existent (**see images**). The primary invading species on non-N fertilized common bermudagrass was bahiagrass (*Paspalum notatum* Flugge). After more than 40 years of stocking bermudagrass pastures, stocking rates of 1 cow-calf pair/A allowed for sufficient forage mass to promote stand maintenance and sustainable pastures. The high stocking rates of 2.5 cow-calf pair/A did not eradicate the invading, persistent bermudagrass ecotypes; however, these higher stocking rates during a 40-yr period practically eliminated the originally-planted, higher yielding and more desirable Coastal and common bermudagrass. The impact of long term continuous high stocking rates on bermudagrass pastures, therefore, is reduction in carrying capacity and animal gains per acre.

Conclusions

Although high stocking rates practically eliminated the original bermudagrass species, bermudagrasses are sustainable for pastures in the southeast U.S. under a wide range of less severe management strategies. This long-term grazing study documented the importance of N-fixation by clovers, which sustained bermudagrass pastures when stocked at low stocking rates of about 1 cow-calf/A. Silveira et al. (2014) summarized that recommendations for pasture fertilization are often based on soil tests; however, N fertilization rates have traditionally been based on management strategies for the desired level of dry matter yield and economic expectations. These management strategies generally do not account for residual soil N when preparing for hay and/or stocking rate. BC

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