

EVALUATION OF QUICKSTAND BERMUDAGRASS FERTILIZED WITH TWO
RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING
RATES IN A TEMPERATE ENVIRONMENT

by

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(ABSTRACT)

Two grazing trials and a feedlot trial were conducted with crossbred lambs to evaluate 'Quickstand' bermudagrass (*Cynodon dactylon* [L.] Pers.) in a cool temperate environment. Four stocking rates and two N fertilization rates (4 x 2 factorial) were replicated three times on .11-ha paddocks. Paddocks were continuously stocked with two, four, six, or eight lambs (light, moderate, heavy, and very heavy stocking rate, respectively) in grazing trial 1. Stocking rates were increased to 4, 8, 12, or 16 lambs per paddock, respectively, in grazing trial 2. In both grazing trials, paddocks were fertilized with 114 (low N) or 340 (high N) kg N ha⁻¹yr⁻¹ in split applications. The grazing season was 110 d and 112 d in grazing trials 1 and 2, respectively. After the termination of grazing trial 2, lambs were fed to slaughter weight (50 kg) on an all-concentrate diet. The feeding period was 110 d. In both grazing trials, ADG decreased ($P < .01$) as stocking rate increased. Animal production per hectare increased ($P < .001$) with increasing stocking rate in grazing trial 1, and was highest at the moderate stocking rate in grazing trial 2. In grazing trial 1, ADG was higher ($P < .05$) for lambs grazing high N fertilized bermudagrass. In grazing trial 2, ADG tended to be higher for lambs grazing high N fertilized bermudagrass at the light stocking rate and lower for lambs grazing at the heavy and very heavy stocking rates

(N x stocking rate interaction, $P < .05$). Canopy height and forage mass decreased linearly ($P < .01$) as stocking rate increased in both grazing trials. High N fertilization rate increased ($P < .05$) CP of bermudagrass for both grazing trials, and CP of forage tended to increase as stocking rate increased in grazing trial 2. In grazing trial 1, NDF was lower ($P < .05$) for high N fertilized bermudagrass. At the beginning and end of the grazing season in grazing trial 2, IVDMD increased ($P < .01$) as stocking rate increased. Lambs that had grazed at very heavy stocking rate had greater ($P < .01$) ADG and better ($P < .01$) feed efficiency in the feedlot as compared to lambs that had grazed at light stocking rate. 'Quickstand' bermudagrass persisted well under very heavy stocking rates and may have potential in some areas of the upper southern US. Key words: *Cynodon dactylon*, Bermudagrass, Stocking rate, Compensatory growth

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TABLE OF CONTENTS

ABSTRACT	
ACKNOWLEDGEMENTS.....	iv
TABLE OF CONTENTS.....	v
LIST OF TABLES.....	vi
LIST OF APPENDIX TABLES.....	ix
CHAPTER I. INTRODUCTION.....	1
CHAPTER II. REVIEW OF LITERATURE.....	3
Characteristics of Bermudagrass.....	3
Effects of Stocking Rate on Bermudagrass.....	6
Nitrogen Fertilization of Bermudagrass.....	10
Effect of Grazing Treatment on Subsequent Performance.....	13
CHAPTER III. EVALUATION OF 'QUICKSTAND' BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP IN A TEMPERATE ENVIRONMENT.....	17
Abstract.....	17
Introduction.....	18
Materials and Methods	
Grazing Trials.....	19
Trial 1.....	21
Trial 2.....	22
Feedlot Trial.....	23
Results	
Grazing Trials	
Trial 1.....	25
Trial 2.....	38
Feedlot Trial.....	54
Discussion.....	59
Implications.....	70
CHAPTER IV. LITERATURE CITED.....	72
APPENDIX.....	78
VITA.....	83

LIST OF TABLES

TABLE 1. PERIOD DAILY GAINS OF LAMBS GRAZING BERMUDAGRASS AT DIFFERENT STOCKING RATES AND NITROGEN FERTILIZATION RATES. TRIAL 1.....	26
TABLE 2. CUMULATIVE DAILY GAINS OF LAMBS GRAZING BERMUDAGRASS AT DIFFERENT STOCKING RATES AND NITROGEN FERTILIZATION RATES. TRIAL 1.....	27
TABLE 3. LAMB PRODUCTION AND LAMB GRAZING DAYS PER HECTARE IN GRAZING TRIALS 1 AND 2.....	29
TABLE 4. FORAGE MASS OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 1.....	30
TABLE 5. CANOPY HEIGHT OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 1.....	31
TABLE 6. CRUDE PROTEIN CONTENT OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 1.....	33
TABLE 7. NEUTRAL DETERGENT FIBER CONTENT OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 1.....	34
TABLE 8. ACID DETERGENT FIBER CONTENT OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 1.....	35
TABLE 9. LIGNIN CONTENT OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 1.....	36
TABLE 10. CELLULOSE CONTENT OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 1.....	37
TABLE 11. PERIOD DAILY GAINS OF LAMBS GRAZING BERMUDAGRASS AT DIFFERENT STOCKING RATES AND NITROGEN FERTILIZATION RATES. TRIAL 2.....	39
TABLE 12. CUMULATIVE DAILY GAINS OF LAMBS GRAZING BERMUDAGRASS AT DIFFERENT STOCKING RATES AND NITROGEN FERTILIZATION RATES. TRIAL 2.....	40

TABLE 13. FORAGE MASS OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 2.....	41
TABLE 14. CANOPY HEIGHT OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 2.....	43
TABLE 15. CRUDE PROTEIN CONTENT OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 2.....	44
TABLE 16. NEUTRAL DETERGENT FIBER CONTENT OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 2.....	45
TABLE 17. ACID DETERGENT FIBER CONTENT OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 2.....	47
TABLE 18. LIGNIN CONTENT OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 2.....	48
TABLE 19. CELLULOSE CONTENT OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 2.....	49
TABLE 20. IN VITRO DM DISAPPEARANCE OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 2.....	51
TABLE 21. PARASITE BURDENS OF SHEEP GRAZING BERMUDAGRASS AT DIFFERENT STOCKING RATES AND NITROGEN FERTILIZATION RATES. TRIAL 2.....	52
TABLE 22. SOIL CONSTITUENTS OF BERMUDAGRASS PASTURES AFTER TWO CONSECUTIVE YEARS OF GRAZING BY SHEEP AT DIFFERENT STOCKING RATES AND NITROGEN FERTILIZATION RATES.....	53
TABLE 23. PERCENTAGE OF GROUND AREA COVERED BY WEEDS. SPRING 1993.....	55
TABLE 24. PERIOD DAILY GAINS OF LAMBS IN THE FEEDLOT AFTER GRAZING BERMUDAGRASS AT DIFFERENT STOCKING RATES.....	56

TABLE 25. AVERAGE DRY MATTER INTAKE OF LAMBS BY PERIOD IN THE FEEDLOT AFTER GRAZING BERMUDAGRASS AT DIFFERENT STOCKING RATES.....	57
TABLE 26. DRY MATTER INTAKE OF LAMBS PER UNIT OF METABOLIC BODY SIZE IN THE FEEDLOT AFTER GRAZING BERMUDAGRASS AT DIFFERENT STOCKING RATES.....	58
TABLE 27. FEED EFFICIENCY OF LAMBS BY PERIOD IN THE FEEDLOT AFTER GRAZING BERMUDAGRASS AT DIFFERENT STOCKING RATES.....	60
TABLE 28. CARCASS CHARACTERISTICS OF LAMBS THAT HAD PREVIOUSLY GRAZED BERMUDAGRASS AT DIFFERENT STOCKING RATES.....	61

LIST OF APPENDIX A TABLES

TABLE 1. COMPOSITION OF STARTER DIET USED IN FEEDLOT TRIAL.....	78
TABLE 2. WEATHER DATA FOR GRAZING TRIALS 1 AND 2.....	79

Chapter I. INTRODUCTION

Forages are integral components of ruminant livestock production systems. Increasing utilization of forage resources in pasture-based production systems is a management strategy that can lower cost of production and hence, improve profitability. Cool season forage species predominate in pastures in cool temperate environments. These species exhibit a seasonal growth pattern with vigorous growth in spring and early summer but little growth in midsummer. Warm-season grasses may be valuable in alleviating this midsummer herbage deficit. Bermudagrass [*Cynodon dactylon* (L.) Pers.] is a warm season perennial grass that has potential to supplement cool season forage species.

Bermudagrass is drought tolerant and grows well on both acidic and saline soils. Bermudagrass responds well to N fertilization and produces large amounts of forage during the summer. Bermudagrass offers some advantages over other warm-season grasses in that it spreads quickly, forming a dense sod, responds well to N fertilization and tolerates close, continuous grazing.

The development of cold-hardy bermudagrass cultivars has extended the range of application into the mid- and upper-southern United States. A cultivar identified as 'Quickstand' has persisted in an Appalachian region where other cold-hardy cultivars may winterkill. Inclusion of warm season forage species in predominately cool season production systems is a management strategy that can increase utilization of forage resources. A warm-season grass that is long-lived, tolerant of a wide range of soil conditions and provides abundant forage during periods of limited cool season forage production would be advantageous.

Grazing trials were conducted with 'Quickstand' bermudagrass fertilized with two rates of nitrogen and grazed by sheep at different stocking rates in a temperate

environment. In addition, a feedlot trial was conducted to evaluate effects of grazing treatment on subsequent feedlot performance of lambs.

Chapter II. REVIEW OF LITERATURE

Characteristics of Bermudagrass

Distribution and Growing Conditions. Bermudagrass is a C₄ warm-season perennial grass that is widely distributed in the southern United States. It is best adapted to states south of a line connecting the southern boundaries of Virginia and Kansas (Burton and Hanna, 1985). Bermudagrass grows best when mean daily temperatures are above 24° C, with very little growth occurring at temperatures below 15° C. It grows on a wide variety of soils from heavy clay to deep sand, provided fertility and moisture are adequate, and tolerates both acidic and saline soils. Bermudagrass is a long-lived, drought-tolerant, sod-forming perennial which is propagated by seed, rhizomes, and stolons (Lundberg et al., 1977).

Bermudagrass is known to tolerate very acidic soil conditions. Several cultivars were shown to persist and yield well on acidic mine spoil material (pH 3.4 to 4.5) in an Appalachian region of the United States (Lundberg et al., 1977).

Bermudagrass is generally recognized as a "southern forage". However, development of winter-hardy cultivars such as 'Midland', and more recently 'Quickstand', has extended its range of application into the mid- and upper-southern United States. Mathias et al. (1973, 1978) reported that 'Midland' bermudagrass survived winters in an Appalachian region with temperatures reaching as low as -22° C when adequate N was applied. 'Quickstand' bermudagrass has been shown to persist in areas where other cold-hardy cultivars such as 'Midland' winterkill (Belesky et al., 1991).

Rainfall, air temperature, daylength, and soil moisture are known to affect bermudagrass productivity (Burton et al., 1988). The authors related the various

meteorological parameters to DM yield, and reported that daylength was the single most important variable associated with DM yield ($R^2 = .64$). The experiment was conducted in the southern region where mean maximum temperatures were always above 24° C and mean minimum temperatures were seldom below 15° C. Therefore, in upper southern regions, temperature may have a greater effect on bermudagrass productivity.

Stand persistence of bermudagrass in upper southern regions is dependent upon proper management and soil fertility (Gilbert and Davis, 1971). Bermudagrass is especially responsive to N fertilization, with yield increases in some scenarios when as much as 600 kg N/ha are applied (Burton and Hanna, 1985). 'Quickstand' bermudagrass was responsive to rates up to 448 kg N/ha when 225 kg P/ha were applied (Wright et al., 1984b). Furthermore, 'Quickstand' outyielded 'Midland' across all fertilization treatments by 60 to 230% (Wright et al., 1984b).

To simulate using bermudagrass as a complementary midsummer forage to cool-season pastures, Belesky et al. (1991) delayed initial harvest 2, 4, and 6 wk. All plots were clipped at 2 wk intervals after the initial harvest delay. In vitro DM digestibility and CP content of initial harvest forage were decreased 10 and 35%, respectively, as harvest delay increased from 2 to 6 wk. However, after the effect of maturity was removed, there were no differences in subsequent harvests, and DM yield was greater for the 6 wk delay than either the 2 or 4 wk delay.

Performance of Animals Grazing Bermudagrass. Animal performance on bermudagrass forage has been low, relative to other warm-season and cool-season species (Fribourg et al., 1979; Conrad et al., 1981). Fribourg et al. (1979) reported season-long ADG of .84 kg for steers grazing orchardgrass (*Dactylis glomerata* L.) and ladino clover (*Trifolium repens* L.), while performance of steers grazing 'Midland'

bermudagrass fertilized with 112, 224, or 448 kg N/ha ranged between .38 and .44 kg. Low values of IVDMD have been reported (Burton and Monson, 1972; Fribourg et al., 1979). Fribourg et al. (1979) observed a drastic decrease in IVDMD of bermudagrass forage over the grazing season, compared to orchardgrass-ladino clover forage.

The quality of bermudagrass forage has been improved through breeding. Burton and Monson (1972) determined IVDMD of 500 bermudagrass genotypes of 5-wk-old regrowth ranged from 40 to 69%, indicating the opportunity for genetic selection. Burton et al. (1967) increased DM digestibility from 53.5% to 60.1% by crossing 'Coastal' bermudagrass with a high-quality cultivar from Kenya. In a 3-yr grazing experiment using the F1 hybrid identified as 'Coastcross-1', Chapman et al. (1972) observed that steers grazing 'Coastcross-1' had 29% higher ADG, as compared to steers grazing 'Coastal'.

An attribute of bermudagrass pastures is high carrying capacity, relative to other forage species (Conrad et al., 1981; McLaren et al., 1983). Fribourg et al. (1979) used stocking rates of 3.7, 5.9, 8.7, 12.4, and 4.0 steers/ha on 'Midland' bermudagrass pastures fertilized with 0, 112, 224, 448 kg N/ha or orchardgrass-ladino clover, respectively. The high stocking rate used on the 'Midland' pastures fertilized with 448 kg N/ha was necessary to control excessive forage growth. McLaren et al. (1983) reported that 'Midland' bermudagrass pastures overseeded with tall fescue (*Festuca arundinacea* Schreb.) supported a stocking rate of 7.3 steers/ha, fescue plus clover pastures supported 5.0 steers/ha, and orchardgrass plus ladino clover pastures supported 4.0 steers/ha. Furthermore, while individual steer gains were lower on 'Midland' plus fescue pastures, compared to fescue plus clover pastures (.48 vs. .52 kg/d, respectively), beef production per hectare was higher for the 'Midland' plus fescue system (593 vs. 321 kg gain/ha). The study by McLaren et al. (1983) confirmed

previous results obtained by Fribourg and Overton (1979) that inclusion of tall fescue in bermudagrass pastures was feasible but required good forage management. The mixture extended the grazing season over that obtained with bermudagrass alone, and produced more forage than either species grown alone or in combination with clover.

Grazing animals will select plant parts of higher nutritive value, provided herbage mass is not limiting (Roth et al., 1990). Canopy structure may help to explain the relatively poor animal performance associated with bermudagrass. The leaf, stem and dead fractions of bermudagrass remain integrated, and the preferred leaf fraction is not easily separated from the lower quality fractions (Burns et al., 1991; Fisher et al., 1991). Furthermore, Fisher et al. (1991) reported that the whole canopy of bermudagrass varied less in IVDMD than tall fescue, switchgrass (*Panicum virgatum* L.), or flaccidgrass (*Pennisetum flaccidum* Griseb.). Lack of variation among plant fractions in digestibility, integrated canopy structure and generally inferior quality clarify why animal performance has been relatively poor on bermudagrass forage (Fisher et al., 1991).

Effects of Stocking Rate on Bermudagrass

Relationship Between Stocking Rate and Animal Performance. The relationship between stocking rate and animal performance is of particular interest in developing grazing management systems. It has been demonstrated that as stocking rate increases individual animal performance decreases, but total animal production per hectare increases (Peterson et al., 1965; Conrad et al., 1981). At light stocking rates, amount of available forage is high, allowing for greater selectivity by grazing animals, which results in maximum gains per animal but reduced gains per hectare. Increasing stocking rate reduces the degree of grazing selectivity, which in turn, reduces

individual animal gains, but increases gain per hectare. Increasing stocking rate above a critical grazing pressure results in both reduced individual gain and reduced gain per hectare (Peterson et al., 1965; Jones and Sandland, 1974; Conrad et al., 1981). This was supported by Conrad et al. (1981) in a grazing study evaluating five cultivars of bermudagrass. Gain per animal decreased with each increase in grazing pressure. Gain per hectare was increased from the light to medium-light grazing pressure, but was not different at the medium-heavy or heavy grazing pressures. The increase in stocking rate did not compensate for the decrease in ADG at the heavier grazing pressures, and both individual and total animal production decreased. Forage availability would appear to be limiting ADG as well as animal production per hectare.

Increasing stocking rate also has been shown to increase the maintenance requirements of grazing animals (Young and Corbett, 1972ab; Sahlu et al., 1989). Sahlu et al. (1989) reported that heat production of wether lambs grazing at a heavy stocking rate was much higher, as compared to lambs grazing at a light stocking rate. Maintenance requirements of grazing lambs were estimated at approximately 1.5 times NRC (1975) for confinement-fed lambs, but were as high as 2.4 times NRC (1975) for lambs grazing at the heavy stocking rate, as available forage declined. As available forage declines in quality and quantity, sheep expend more energy grazing, maintenance requirements increase, and performance suffers (Jung and Sahlu, 1989). The energetic costs of grazing are high, and deteriorating pasture conditions dramatically increase these costs at the expense of animal performance (Sahlu et al., 1989).

Although stocking rate has been used as an experimental variable in grazing research, Guerrero et al. (1984) reported that the concept of stocking rate does not provide information on grazing pressure unless the actual amount of forage available to

the animal is known. Grazing pressure is defined as "the relationship between the number of animals and the weight of forage DM per unit area at any one time" while stocking rate is defined as "the relationship between the number of animals and the grazing management unit utilized over a specific time period" (FGTC, 1991).

Estimates of grazing pressure in stocking rate experiments are often accomplished using a put and take management system where a minimum number of "tester" animals are maintained on the pasture with additional animals added or removed to maintain the approximate levels of available forage corresponding to each grazing pressure (Conrad et al., 1981; Roth et al., 1990).

Peterson et al. (1965) reported a linear relationship between ADG and available forage up to maximum intake, after which increasing available forage had no effect on ADG. Hart et al. (1976) reported a strong, negative correlation between ADG and grazing pressure. Duple et al. (1971) suggested that digestibility of available forage as well as total amount of available forage influence animal performance.

Effects of Stocking Rate on Forage Characteristics. Stocking rate influences physical characteristics of the sward as well as chemical composition of the diet consumed by grazing animals. Increasing stocking rate decreases the amount of forage available to grazing animals (Conrad et al., 1981; Guerrero et al., 1984; Roth et al., 1990). If stocking rate becomes too heavy, forage intake will restrict animal performance.

The quality of the diet consumed by grazing animals will be affected by the number of animals grazing on a fixed area of land. Malechek and Leinweber (1972) compared the chemical composition and IVDMD of forage selected by Angora goats on heavily-stocked and lightly-stocked range. Diet samples were collected *via* esophageal cannulae. Forage consumed by goats on the lightly-stocked range was slightly lower in

NDF and slightly higher in IVDMD, compared to forage consumed by goats on the heavily-stocked range. However, the slight differences in composition and digestibility of diets consumed did not fully explain the difference in animal performance, and the authors attributed much of the difference in performance to restricted forage intake of goats on the heavily-stocked range.

Jung and Sahlu (1989) investigated effects of two stocking rates (15 or 30 lambs/ha) on intake and quality of diet selected. They reported that DM intake, quality of diet, and ADG were generally lower for lambs grazing at the heavier stocking rate, compared to lambs grazing at the lighter stocking rate. Results obtained on the two previous studies could be explained by increased opportunities for selective grazing at lighter stocking rates.

Roth et al. (1990) investigated effects of forage allowance on forage and dietary attributes of 'Coastal' bermudagrass. The primary effect of increasing grazing pressure was a reduction in the NDF content of the forage on the more heavily grazed pastures. The authors attributed the difference to the younger age of the forage on the heavily grazed pastures. Similarly, Guerrero et al. (1984) observed that forage grazed at heavier stocking rates was higher in IVDMD than forage grazed at lighter stocking rates. Although the quality of the forage may increase, at such heavy grazing pressures animal productivity generally is limited by the inability of the animal to harvest sufficient quantities of forage (Roth et al., 1990).

The apparent lack of consistency in results obtained on effects of increasing stocking rate on characteristics of the sward as well as the diet selected by animals illustrate the complexity of interactions occurring at the plant-animal interface. The total effect appears to be related to combined effects of increasing grazing pressure on

the quality of the forage coupled with the opportunities for animals to selectively graze (Roth et al., 1990).

Nitrogen Fertilization of Bermudagrass

Effects of N Fertilization on DM yield. Researchers have demonstrated consistent increases in DM yield with increasing levels of N fertilization of various bermudagrass cultivars (Burton et al., 1963; Hallock et al., 1965; Doss et al., 1966). Mathias et al. (1973) reported DM yield increases over the control (0 kg N/ha) of 70, 152, 206, and 266% on 'Midland' bermudagrass plots fertilized with 112, 224, 448, and 678 kg N/ha, respectively. Belesky et al. (1991) reported DM yield increases of 100% when 360 as compared to 60 kg N/ha were applied to 'Quickstand' bermudagrass plots. Belesky et al. (1991) reported DM yields were typically 3000 to 6000 kg/ha, which would contribute substantially to midsummer forage requirements in a region where mean daily maximum and minimum temperatures are often below what is considered optimal for bermudagrass productivity. Mathias et al. (1978) observed a decrease in DM yield of 'Midland' bermudagrass in the third year of a 3-yr experiment as N fertilization rate increased. The authors explained that the decrease in DM yield of bermudagrass was due largely to an increase in weed populations. The experiment was conducted in an Appalachian region where the high rates of N fertilization appear to have favored the native weed species.

Effects of N Fertilization on Forage Composition. The increase in CP content resulting from N fertilization of bermudagrass forage is well documented (Horn et al., 1976; Burton and Hanna, 1985; Belesky et al., 1991). Horn et al. (1976) reported CP contents of 10.7, 11.2, and 13.1%, DM basis, for bermudagrass fertilized with 17, 50,

and 150 kg N/ha, respectively. Similarly, Belesky et al. (1991) reported an increase in CP of 30% as N fertilization level increased from 60 to 360 kg N/ha.

There have been conflicting reports concerning the effect of N fertilization on IVDMD. Webster et al. (1965) found no increase in IVDMD of 'Midland' bermudagrass with N fertilization rates up to 1568 kg/ha. Taliaferro et al. (1975) also reported no effect of N fertilization on IVDMD. Conversely, Fribourg et al. (1971) observed an increase in IVDMD from 37 to 46% as N fertilization increased from 0 to 800 kg N/ha. Belesky et al. (1991) reported a 5 to 13% increase in IVDMD as level of N fertilization increased. Some controversy exists as to the accuracy of in vitro digestibility techniques developed with cool-season species to assess digestibility of warm-season species (Reid et al., 1988). Anderson and Matches (1983) concluded that IVDMD values for whole plant warm-season grasses may not adequately reflect the response of grazing animals, due either to selective grazing or poor correlation between IVDMD and in vivo DM digestibility. Nelson (1980) discussed the main sources of variability influencing in vivo/in vitro relationships in southern forages. These included forage species, sample preparation, microbial population of rumen inoculum, and laboratory procedures. Therefore, results obtained on warm-season grasses in different experiments should be interpreted carefully.

The effects of N fertilization on fiber levels are unclear as well. Belesky et al. (1991) observed that increasing N fertilization from 60 to 360 kg N/ha decreased ADF levels in 'Quickstand' bermudagrass. However, Stallcup et al. (1986) reported no effect of N fertilization rate (0, 57, 114, 170 or 226 kg N/ha) on NDF, ADF or lignin content of 'Hardie' bermudagrass hay.

Effects of N Fertilization on Cold Tolerance. Soil fertility, particularly N, P, and K, influences winter hardiness of plants (Gilbert and Davis, 1971). It has been

demonstrated that heavy application of N disproportionate to P and K decrease the resistance of bermudagrass to winter injury (Gilbert and Davis, 1971). Adams and Twersky (1960) determined that at high levels of N fertilization, winter hardiness was improved with increasing levels of K. Similarly, Gilbert and Davis (1971) observed that a balanced fertility program with emphasis on K late in the growing season improved the cold tolerance of two turf-type bermudagrass cultivars. Mathias et al. (1973) reported that 'Midland' bermudagrass survived three winters in an Appalachian region when greater than 112 kg N/ha as well as adequate rates of P and K were applied.

Effects of N Fertilization on Stand Persistence. Several authors have demonstrated good stand persistence of bermudagrass in upper southern regions (Mathias et al., 1978; McLaren et al., 1983; Belesky et al., 1991). However, Mathias et al. (1978) reported that at high levels of N fertilization (448 kg N/ha), DM yield of 'Midland' bermudagrass decreased due to increased weed encroachment. Jung et al. (1974) reported that persistence of 'Midland' was reduced on plots where 336 kg N/ha were applied, as compared to 168 kg N/ha, due to invasion of cool-season weed species. Belesky et al. (1991) reported good stand persistence of 'Quickstand' bermudagrass in an Appalachian region with no apparent detrimental effects of N fertilization. These results support previous results (Wright et al., 1984ab) that 'Quickstand' is more adapted to upper southern regions than 'Midland'.

Effects of N Fertilization on Animal Performance. Fribourg et al. (1979) observed that steers grazing 'Midland' bermudagrass fertilized with 448 kg N/ha had slightly higher ADG and produced more liveweight gain per hectare than steers grazing 'Midland' fertilized with 0, 112, or 224 kg N/ha. Much of the increase in liveweight

gain per hectare was attributed to the higher carrying capacity of the pastures fertilized with high levels of N.

Effect of Grazing Treatment on Subsequent Performance.

Compensatory Growth. The ability of growing animals to exhibit increased growth rates following a period of undernutrition has been reviewed extensively (Wilson and Osbourn, 1960; Allden, 1970; O'Donovan, 1984). However, many conflicting reports exist as to the exact cause of the phenomenon (Wright and Russel, 1991) as well as if compensatory growth really occurs (White et al., 1987). Among the suggested explanations for compensatory growth are reduced maintenance requirements (Ledger and Sayers, 1977), increased feed intake (Wright and Russel, 1986), and changes in the composition of gain (Fox et al., 1972; Baker et al., 1985).

It is difficult to separate the effects of changes in tissue gain from other possible causative factors, since in many experiments animals were fed at two or more levels and then given ad libitum access from a common date (Wright and Russel, 1991). According to Wright and Russel (1991), in these situations, the restricted animals are invariably lighter and hence have lower maintenance requirements. Therefore, the authors explained that at a similar level of intake, more energy will be available for growth.

It has been demonstrated that compensatory growth can occur without an increase in intake. Turgeon et al. (1986) reported that lambs gaining 32 g/d as compared to lambs gaining 135 g/d, exhibited compensatory growth not accompanied by an increase in intake. In support of the previous findings, Wright and Russel (1991)

observed that cattle gaining .45 kg/d as compared to cattle gaining .78 kg/d exhibited an increase in growth over and above that explained by the small increase in intake of the slower gaining cattle. The authors explained that while feed intake of compensating animals frequently increases, their results confirm previous observations (Thomson et al., 1982) that compensatory growth can occur independently of an increase in feed intake.

The apparent discrepancy of results obtained in compensatory growth research may be partially explained by the interpretation of compensatory growth. White et al. (1987) stated that no compensation occurred during the grazing season in cattle previously wintered on a restricted diet (losing .23 kg/d) as compared to cattle gaining .71 kg/d. However, the previously restricted cattle did gain faster during the subsequent grazing season (.54 vs. .37 kg/d), resulting in approximately 20% compensation in body weight. Other authors observed compensation rates of 35 to 40% (Baker et al., 1985) to 90% (Wright and Russel, 1986). The conflicting reports may be further explained by differences in experimental procedures and dietary treatments. Some trials were conducted at or below maintenance (White et al., 1987), while others were conducted at or above maintenance. Most research supports the hypothesis that compensatory growth does occur, but it is usually only a partial compensation, and is affected by variables such as feeding level, feeding period and the interpretation of the data.

Effects of Undernutrition During Grazing on Subsequent Feedlot Performance.

In grazing systems where animal production per hectare is maximized, there is a concomitant decrease in individual animal performance. Therefore, the concept of compensatory growth and how it relates to restricted growth during grazing is of interest (O'Donovan, 1984).

In two extensive reviews on the subject (Moran and Holmes, 1978; O'Donovan, 1984), the variability in results obtained were discussed. Moran and Holmes (1978) reported that, of the 27 trials reviewed, only nine trials showed that animals with lower gains during the grazing period compensated in the feedlot. Furthermore, in seven of the 27 trials, the feedlot performance was lower for animals that had grazed at a low plane of nutrition as compared to animals grazing at a high plane of nutrition.

Coleman et al. (1976) reported that, while pasture gains ranged from .38 kg/d for steers receiving no supplement, to .67 kg/d for steers receiving 4.1 to 4.5 kg supplemental grain, feedlot gains averaged .99 kg/d for both groups. In contrast, Perry et al. (1971, 1972) observed that, when high levels of supplemental grain were fed to grazing cattle (up to 8.8 kg), each additional kilogram of supplement fed during the grazing season resulted in a .2 to .29 kg/d suppression of gain during the subsequent feedlot phase.

Moran and Holmes (1978) listed six possible reasons for the discrepancies: 1) Age at commencement of grazing - feed restriction is more detrimental to younger animals and younger animals compensate less than older animals; 2) Severity of undernutrition; 3) Nature of undernutrition - animals appear to recover better following energy restrictions as compared to protein restrictions; 4) Liveweight at the commencement of refeeding; 5) Breed effects; and 6) Quality of the refeeding diet - higher quality diets allow for more compensation.

Effects of Compensatory Growth on Body Composition. Various reports have been published on changes in body composition of sheep that have undergone compensatory growth. The results include an increase in fat deposition (Wilson and Osbourn, 1960); an increase in protein deposition or decrease in fat deposition (Kabbali et al., 1992); and no change in body composition (Drouillard et al., 1991) of lambs,

relative to controls. Kabbali et al. (1992) indicated that the discrepancy may be related to length of recovery period, severity and duration of the restriction period, and age of the animal.

It has been demonstrated that compensatory growth occurs in two distinct stages: 1) early stage - increased rate of protein growth and 2) late stage - increased rate of fat growth (Fox et al., 1972; Turgeon et al., 1986; Wright and Russel, 1991). Kabbali et al. (1992) summarized the effects of compensatory growth on body composition. The authors stated that the extent to which body composition of refed lambs will be different from that of normally-fed lambs depends on how far the lambs have gone into the late stage of compensatory growth. If lambs are slaughtered at the end of the early stage of compensatory growth, they will be leaner. However, if lambs are slaughtered well into the late stage of compensatory growth, they may be similar in body composition to normally-fed lambs. This was supported by the findings of Turgeon et al. (1986), who reported that compensating lambs were leaner than unrestricted lambs when slaughtered at 30 kg BW but no difference was noted when lambs were slaughtered at 45 kg BW.

Chapter III.

EVALUATION OF QUICKSTAND BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES IN A TEMPERATE ENVIRONMENT

ABSTRACT: Two grazing trials and a feedlot trial were conducted with crossbred lambs to evaluate 'Quickstand' bermudagrass (*Cynodon dactylon* [L.] Pers.) in a cool temperate environment. Four stocking rates and two N fertilization levels (4 x 2 factorial) were replicated three times on .11-ha paddocks. Paddocks were continuously stocked with two, four, six, or eight lambs (light, moderate, heavy, and very heavy stocking rate, respectively) in grazing trial 1. Stocking rates were increased to 4, 8, 12, or 16 lambs per paddock, respectively, in grazing trial 2. In both grazing trials, paddocks were fertilized with 114 (low N) or 340 (high N) kg N ha⁻¹yr⁻¹ in split applications. The grazing season was 110 d and 112 d in grazing trials 1 and 2, respectively. After the termination of grazing trial 2, lambs were fed to slaughter weight (50 kg) on an all-concentrate diet. The feeding period was 110 d. In both grazing trials, ADG decreased ($P < .01$) as stocking rate increased. Animal production per hectare increased ($P < .001$) with increasing stocking rate in grazing trial 1, and was highest at the moderate stocking rate in grazing trial 2. In grazing trial 1, ADG was higher ($P < .05$) for lambs grazing high N fertilized bermudagrass. In grazing trial 2, ADG tended to be higher for lambs grazing high N fertilized bermudagrass at the light stocking rate and lower for lambs grazing at the heavy and very heavy stocking rates (N x stocking rate interaction, $P < .05$). Canopy height and forage mass

decreased ($P < .01$) linearly as stocking rate increased in both grazing trials. High N fertilization increased ($P < .05$) CP of bermudagrass for both grazing trials, and CP of forage tended to increase as stocking rate increased in grazing trial 2. In grazing trial 1, NDF was lower ($P < .05$) for high N fertilized bermudagrass. At the beginning and end of the grazing season in grazing trial 2, IVDMD increased ($P < .01$) as stocking rate increased. Lambs that had grazed at very heavy stocking rate had greater ($P < .01$) ADG and better ($P < .01$) feed efficiency in the feedlot as compared to lambs that had grazed at light stocking rate. 'Quickstand' bermudagrass persisted well under very heavy stocking rates and may have potential in some areas of the upper southern US. Key words: *Cynodon dactylon*, Bermudagrass, Stocking rate, Compensatory growth

Introduction

Pastures in cool, temperate environments are composed mainly of cool-season forage species. These species exhibit a seasonal growth pattern with very little growth in midsummer (Wright et al., 1984ab; Reid et al., 1988). Warm-season grasses could be utilized to fill this midsummer herbage deficit (Reid et al., 1988). Bermudagrass (*Cynodon dactylon* [L.] Pers.) is a warm-season perennial grass that is widely distributed throughout the southern US. It is drought resistant, tolerant of a wide range of soil conditions, and responds well to N fertilization (Burton and Hanna, 1985). The development of cold-hardy cultivars such as 'Midland' and more recently, 'Quickstand' has extended bermudagrass' range of application into the mid- and upper-southern US. 'Quickstand' has been shown to be more adapted to the cool, temperate zone as compared to 'Midland' (Wright et al., 1984ab; Belesky et al., 1991). No information is available on performance of animals grazing 'Quickstand' or response of 'Quickstand' to different grazing treatments.

The ability of animals to exhibit compensatory growth following a period of undernutrition has been reviewed extensively (Allden, 1970; O'Donovan, 1984). However, there have been conflicting reports concerning the effect of undernutrition during grazing on subsequent feedlot performance of cattle (Moran and Holmes, 1978). Wilkinson and Prescott (1970) and Coleman et al. (1976) reported no effect of rate of gain during the grazing season on subsequent feedlot performance, while Perry et al. (1971, 1972) reported that feeding supplemental energy to grazing cattle resulted in lower gains during the feedlot phase as compared to non-supplemented grazing cattle.

The objectives of this research were 1) to evaluate performance of lambs grazing 'Quickstand' bermudagrass at different stocking rates and N fertilization rates, 2) to assess changes in chemical composition of bermudagrass due to grazing treatment, and 3) to determine effect of grazing bermudagrass at different stocking rates on subsequent feedlot performance of lambs.

Materials and Methods

Grazing Trials

A bermudagrass [*Cynodon dactylon* (L.) Pers.] cultivar, 'Quickstand' (collected by Harold B. Rice, Univ. of KY, at Robinson Substation and USDA-SCS Quicksand Plant Materials Center, Quicksand, KY), was established on 2.64-ha in the spring of 1989 at the Southwest Virginia Research Station, Glade Spring (elevation 667 m). The experimental area was divided into three replicates of eight .11-ha paddocks (24 paddocks). The bermudagrass was propagated vegetatively in a tall fescue (*Festuca arundinacea*) sod killed with glyphosate. Bermudagrass sprigs were placed at 1.2 m intervals on 1.2 m rows. The Station is located in the Mountain-Valley region of southwest Virginia. The soil of the experimental area was of the Frederick series (silt loam, deep and well-drained). Soil samples were collected initially, and fertilizer

applied according to soil test recommendations. Specifically, 120 kg N, 54 kg P₂O₅ and 72 kg K₂O/ha were applied on May 26, 1989, and 134 kg N/ha was applied on July 21, 1989. Two grazing trials were conducted, one in 1991 (trial 1) and the other in 1992 (trial 2). The only fertilizer applied was the N treatment. Soil samples were collected at the termination of grazing in trial 2 to assess effects of grazing treatment on soil status. Mean daily maximum and minimum temperatures during both grazing trials were obtained at a site of similar elevation located 19 km from the research station. Total precipitation was recorded at a site located at the research station. No grazing was done in 1990 due to management problems of the bermudagrass stand.

The experiment was a 4 x 2 factorial representing four stocking rates and two rates of N fertilization with a split-plot experimental design. The four stocking rates (whole-plots) were allotted at random within each field replicate. Then, the two N rates (sub-plots) were allotted at random within each stocking rate.

Lambs were treated with Ivermectin (Ivomec, Merck and Co., Inc., NJ) every 28 d throughout the grazing season in both trials to control internal parasites. Lambs had ad libitum access to a medicated (lasalocid, 1,200 g/ton) trace mineralized salt mix and water. In April of 1993, paddocks were evaluated for percentage of ground area covered by weed species. Weeds were defined as any plant species other than bermudagrass.

For both trials, lambs were weighed every 14 d throughout the grazing season. For trial 1, forage was sampled for mass determination and chemical analysis every 28 d. Estimates of forage mass were obtained by mowing two strips (.54 m x 3 m) with a Honda mower in each paddock and collecting the forage in cloth bags. Samples of fresh forage were obtained from the forage mass strips for chemical analysis. Samples were dried at 60^o C for a minimum of 48 h. After drying, the samples for chemical

analysis were weighed and the amount added to the forage mass sample to estimate total forage mass. These samples were ground in a Wiley mill to pass a 1-mm screen. Samples were analyzed for NDF and ADF (Goering and Van Soest, 1970), lignin and cellulose (Van Soest and Wine, 1968). Crude protein was calculated as Kjeldahl N x 6.25 (AOAC, 1990). Canopy height was determined every 14 d. Measurements were taken at six random locations in each paddock using a disk meter. A plexiglass disk (51 cm x 51 cm) was lowered on a plastic pipe with gradations every cm from 4 cm to 60 cm. When all four corners of the disk came in contact with the forage, the height was read on the pipe and recorded. The six values were averaged to estimate canopy height.

For trial 2, the sampling interval was changed to 14 d to better evaluate seasonal fluctuation in forage growth and composition. In addition, IVDMD was determined on samples taken May 27, July 23, and September 17. In vitro DM disappearance was determined according to Tilley and Terry (1963) with the modifications of Barnes (1969). For IVDMD determinations, ruminal fluid was obtained from a cannulated steer fed orchardgrass (*Dactylis glomerata*) hay. Samples were incubated in duplicate with six blanks. Samples for all three dates were incubated in one run.

Trial 1. A total of 120 crossbred lambs (average initial weight, 33.5 kg) were used. Thirty-four lambs were 1/4 Hampshire, 1/4 Suffolk, 1/4 Dorset, 1/8 Finn, 1/8 Rambouillet; 21 lambs were 1/2 Suffolk, 1/4 Hampshire, 1/8 Finn, 1/8 Rambouillet; 8 lambs were 1/4 Finn, 1/4 Rambouillet, 1/2 Dorset; 1 lamb was 1/4 Finn, 1/4 Suffolk, 1/2 Rambouillet; 4 lambs were 1/4 Finn, 1/4 Rambouillet, 1/2 Suffolk; 46 lambs were undefined blackfaced crossbreds; and 6 lambs were undefined whitefaced crossbreds. Lambs were assigned to six blocks of 20 lambs each, based on sex, breeding and bodyweight, then were allotted at random to eight paddocks within each replicate.

Thus, two blocks were allotted to each replicate. The stocking rates were two, four, six, or eight lambs per paddock for the light, moderate, heavy, or very heavy stocking rates, respectively. The N treatments were 114 (low N) or 340 (high N) kg N ha⁻¹ yr⁻¹. The N source was NH₄NO₃. The paddocks were fertilized with N in split applications. The initial 50% was applied soon after grazing began, and the remaining 50% applied approximately midway through the grazing period. Grazing was initiated on May 31, 1991 and terminated on September 18 for a total grazing period of 110 d. All paddocks were clipped for weeds at approximately 10 cm during the week of June 23.

Trial 2. A total of 240 crossbred (1/4 Rambouillet, 1/4 Suffolk, 1/4 Finn, 1/4 Dorset) lambs were used in the same factorial arrangement of treatments as trial 1. The average initial BW was 25.3 kg. Stocking rates were increased to 4, 8, 12, or 16 lambs per paddock with the same treatment assigned to individual paddocks as in trial 1. Lambs were assigned to 12 blocks of 20 lambs each, based on sex and bodyweight. The lambs within each block were allotted at random to eight paddocks within each replicate. Thus, four blocks were allotted to each replicate. The N treatments remained the same as in trial 1. The initial 50% of nitrogen was applied 2 wk before grazing began, and the remaining 50% applied approximately midway through the grazing period. Grazing was initiated on May 27, 1992, and terminated on September 17, for a total grazing period of 112 d.

Lambs were removed from some paddocks at various times in the grazing season due to a shortage of forage. All lambs in a particular paddock were removed, weighed and placed in an adjacent, mostly fescue pasture. Lambs were returned to bermudagrass paddocks when it was determined sufficient forage mass was available.

Lambs were weighed before returning to the paddocks, and weight gains of lambs while grazing on the adjacent pasture were excluded from the analysis.

Some lambs began exhibiting foot problems early in the grazing period. The feet appeared tender and sore. The cause was unknown, but did not resemble foot rot. Beginning August 20, lambs were run through a foot bath containing a ZnSO₄ solution on each weigh day. Fecal samples were collected from four to six lambs in each paddock on one replication at two dates (August 20 and September 17) to assess parasite burdens.

Feedlot Trial

After termination of grazing trial 2, a total of 237 lambs were placed in a feedlot at the same research station. Three lambs died during the grazing trial, and the replacement lambs were not included in the feedlot trial. The high and low N treatments at each stocking rate were combined to provide 12 groups. The feeding area consisted of open sheds on the east and west sides of a pole-type barn. Groups of lambs were randomly assigned to pen locations (six pens on either side of the barn).

All lambs were weighed on two consecutive days at the end of the grazing season. The lambs were treated with levamisole hydrochloride (Tramisol, Cyanamid, Manati, Puerto Rico) to control internal parasites and placed in the feedlot. Lambs were vaccinated with Clostridium perfringens types C and D-Tetanus toxoid (Bar-Vac CD/T, Anchor, St. Joseph, MO) 2 wk prior to termination of grazing to prevent overeating disease.

Lambs had ad libitum access to grass hay for 1 d after removal from bermudagrass. On d 2, lambs were fed .45 kg/lamb of a starter ration (Appendix A Table 1) plus hay, free choice. The amount of starter ration was increased by .45 kg

per lamb on d 3, 4, and 5. On d 5, all hay was removed and lambs were given ad libitum access to the starter ration.

Lambs were given the finishing diet (85% shelled corn and 15% Tend-r-lamb protein supplement, Southern States Cooperative, Inc., Richmond, VA) when average pen weight was 36 kg. Groups of lambs that weighed greater than 36 kg at the end of the grazing season were fed the starter diet for 2 wk, after which they were given the finishing diet. The lambs were fed the finishing diet in the following proportions: 25, 50, 75, and 100% of the diet as the finishing diet. Lambs were fed each mixture for 2 d before switching to the next mixture. The total transition period from starter diet to finishing diet was 8 d.

Lambs were weighed every 14 d, and were removed from the experiment individually at 50 kg. The total feeding period was 110 d. Several lambs did not reach 50 kg BW by the end of the feeding period. Lambs had ad libitum access to the diets from self feeders and water from automatic waterers. Feed consumption was measured every 14 d starting with d 5. Slaughter weight, carcass weight, yield grade and quality grade were obtained on a limited number of lambs. Slaughter information was available for 13 lambs from light stocking rate, 12 lambs from moderate stocking rate, 3 lambs from heavy stocking rate, and 25 lambs from very heavy stocking rate. The mineral mix provided during the grazing trials was used for the feedlot trial.

Statistics

The General Linear Model procedure of SAS (1985) was used for all statistical analyses. Statistical models are given in Appendix B. Grazing data were analyzed using analysis of variance following a split-plot design. Paddocks were the experimental unit for forage measurements, soil constituents, lamb production/ha and lamb grazing days. Animals were the experimental unit for ADG and parasite burden

measurements. The final model for forage measurements included the effects of replicate, stocking rate, N, date, and all two-way interactions. Data were analyzed over the entire grazing trial and also within date. The final model for ADG included the effects of replicate, block within replicate, stocking rate, nitrogen, and the N x stocking rate interaction. Orthogonal contrasts were used to test for linear, quadratic and cubic effects of stocking rate.

Feedlot gain, feed efficiency and DM intake were analyzed using analysis of variance following a randomized block design. Pens were the experimental unit for DM intake and feed efficiency measurements, and animals were the experimental unit for ADG. The final model for DM intake and feed efficiency included the effects of period, replicate, stocking rate, and the period x stocking rate interaction. Data were analyzed over the entire feedlot trial and also within period. The final model for ADG included the effects of replicate, block within replicate and stocking rate. Orthogonal contrasts were used to test for linear, quadratic and cubic effects of stocking rate. All values presented in the tables are least square means. The pooled standard error of the mean was calculated, due to different sample sizes at each stocking rate, for the animal gain data in both grazing trials and the feedlot trial.

Results

Grazing Trial 1. Daily gains of lambs were not different during the first three periods (0 to 41 d) of the grazing season, except for a N x stocking rate interaction at the end of the second period (Tables 1 and 2). In the fourth period (41 to 55 d), lambs grazing high N fertilized bermudagrass gained more ($P < .01$) weight, with the exception of the light stocking rate where performance of lambs grazing high N

TABLE 1. PERIOD DAILY GAINS OF LAMBS GRAZING BERMUDAGRASS AT DIFFERENT STOCKING RATES AND NITROGEN FERTILIZATION RATES. TRIAL 1

Item	Stocking rates and N fertilization levels												SE
	Light		Moderate		Heavy		Very heavy		Low N		High N		
	Low N	High N	Low N	High N	Low N	High N	Low N	High N	Low N	High N	Low N	High N	
Initial wt.,kg	31.9	36.3	33.9	33.4	33.5	34.2	32.5	32.4	32.5	32.4	32.5	32.4	.98
Final wt.,kg ^{ab}	39.0	44.5	39.7	39.5	38.7	40.8	36.3	37.9	36.3	37.9	36.3	37.9	1.0
Daily gain, g	146	102	115	70	153	157	164	87	153	157	164	87	27.4
0-13d	-76	16	43	-45	-38	22	-31	15	-38	22	-31	15	23.0
13-27d ^c	-27	-11	-68	-9	-45	-63	-64	-38	-45	-63	-64	-38	21.0
27-41d	92	76	41	77	88	137	44	131	88	137	44	131	22.8
41-55d ^a	200	151	86	106	150	132	147	151	150	132	147	151	21.5
55-69d ^d	38	108	73	89	36	50	.34	7	36	50	.34	7	22.1
69-83d ^b	65	97	92	95	74	81	51	50	74	81	51	50	22.2
83-97d	81	49	38	29	-36	-32	-27	-7	-36	-32	-27	-7	30.4
97-110d ^b													

^aEffect of N level (P<.05)

^bLinear effect of stocking rate (P<.01)

^cN x stocking rate interaction (P<.05)

^dQuadratic effect of stocking rate (P<.01)

TABLE 2. CUMULATIVE DAILY GAINS OF LAMBS GRAZING BERMUDAGRASS AT DIFFERENT STOCKING RATES AND NITROGEN FERTILIZATION RATES. TRIAL 1

Period	Stocking rates and N fertilization levels											
	Light		Moderate			Heavy			Very heavy			SE
	Low N	High N	Low N	High N	Low N	High N	Low N	High N	Low N	High N		
13d	146	102	115	70	153	157	164	87	27.4			
27d ^a	31	57	78	11	54	87	62	50	17.3			
41d	11	34	28	4	20	36	19	20	13.0			
55d	32	45	31	23	38	61	26	48	10.1			
69d ^b	66	66	42	40	60	76	50	69	8.7			
83d ^b	61	73	48	48	56	71	42	59	7.7			
97d ^{bcd}	61	77	54	55	59	73	43	57	5.9			
110d ^{ce}	65	74	52	53	47	60	35	50	5.9			

^aN x stocking rate interaction (P<.05)
^bCubic effect of stocking rate (P<.05)
^cEffect of N level (P<.05)
^dLinear effect of stocking rate (P<.05)
^eLinear effect of stocking rate (P<.001)

fertilized bermudagrass tended to be lower (Table 1). For the period of 55 to 69 d, ADG decreased from light to moderate stocking rate, and was higher at the heavy and very heavy stocking rates (quadratic effect, $P < .01$). Daily gain decreased as stocking rate increased during the periods 69 to 83 d and 97 to 110 d (linear effect, $P < .01$). Over the entire grazing season (0 to 110 d), daily gains of lambs decreased ($P < .01$) as stocking rate increased (Table 2), and lambs grazing high N fertilized bermudagrass had higher ($P < .01$) ADG as compared to lambs grazing low N fertilized bermudagrass. The effects of stocking rate and N fertilization rate on daily gains of lambs during the grazing season resulted in differences ($P < .01$, $P < .05$, respectively) in final weights of lambs (Table 1).

Lamb production (kg lamb/ha) and actual lamb grazing days increased linearly ($P < .001$) as stocking rate increased (Table 3). There were no differences between theoretical and actual lamb grazing days, as all lambs were maintained on the paddocks the entire grazing season. There was a tendency ($P = .11$) for lambs grazing high N fertilized bermudagrass to produce more liveweight gain per hectare.

Forage mass was not affected by stocking rate or N rate in May or June (Table 4). In July, August and September, forage mass decreased linearly ($P < .01$) as stocking rate increased. There was no effect of N fertilization rate on forage mass. Forage mass decreased from May to July, then increased through the end of the grazing season (quadratic effect, $P < .001$).

Canopy height decreased linearly ($P < .01$) as stocking rate increased on all sampling dates (Table 5). No differences were detected due to N fertilization rate. Canopy height decreased from June 18 to July 11, increased through August 8, and then decreased through the end of the grazing season (cubic effect, $P < .001$).

TABLE 3. LAMB PRODUCTION AND LAMB GRAZING DAYS PER HECTARE IN GRAZING TRIALS 1 AND 2

Item	Stocking rates and N fertilization levels												SE
	Light			Moderate			Heavy			Very heavy			
	Low N	High N		Low N	High N		Low N	High N		Low N	High N		
Trial 1													
Liveweight gain, kg/ha ^a	129	148	210	214	284	361	301	398	28				
Grazing days													
Theoretical	2000	2000	4000	4000	6000	6000	8000	8000	8000				
Actual ^a	2000	2000	4000	4000	6000	6000	8000	8000	8000				
Trial 2													
Liveweight gain, kg/ha ^{b,c}	460	529	661	666	431	337	639	220	88				
Grazing days													
Theoretical	4073	4073	8146	8146	12218	12218	16291	16291	16291				
Actual ^a	4073	4073	7976	7976	11197	11197	13109	12470	748				

^aLinear effect of stocking rate (P<.001)

^bCubic effect of stocking rate (P<.05)

^cN x stocking rate interaction (P=.06)

TABLE 4. FORAGE MASS OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 1

Date ^a	Stocking rates and N fertilization levels												SE
	Light			Moderate			Heavy			Very heavy			
	Low N	High N	Avg ^b	Low N	High N	Avg ^b	Low N	High N	Avg ^b	Low N	High N	Avg ^b	
	-----DM, kg/ha-----												
May 31	6488	5926	5624	6032	5249	5086	6985	5828	5902	533			
June 27	4032	3381	3640	3974	3738	3635	3849	2651	3612	343			
July 25 ^c	4125	4932	3613	3488	3274	3225	2940	1813	3426	438			
Aug 22 ^c	6865	6295	6250	6161	5836	5734	4040	4598	5722	304			
Sept 18 ^c	7665	8047	6478	6649	4404	5404	5052	3780	5935	937			

^aDate x stocking rate interaction (P<.01)

^bQuadratic effect of date (P<.001)

^cLinear effect of stocking rate (P<.01)

TABLE 5. CANOPY HEIGHT^a OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 1

Date ^b	Stocking rates and N fertilization levels												Avg ^c	SE
	Light			Moderate			Heavy			Very heavy				
	Low N	High N	Low N	High N	Low N	High N	Low N	High N	Low N	High N	Low N	High N		
June 18 ^d	32	35	29	32	24	18	18	17	18	17	26	26	2.72	
June 27 ^d	30	29	23	26	21	18	18	15	16	15	22	22	2.33	
July 11 ^d	17	18	16	18	13	15	14	13	14	13	15	15	1.09	
July 25 ^d	25	25	20	22	17	18	15	16	15	16	20	20	.96	
Aug 8 ^d	30	30	24	28	20	22	17	17	17	17	24	24	.84	
Aug 22 ^d	30	29	23	23	19	20	16	16	16	16	22	22	1.00	
Sept 5 ^d	26	25	21	21	18	18	14	15	14	15	20	20	.75	
Sept 18 ^d	29	29	22	25	17	18	15	14	15	14	21	21	1.21	

^aMeasured with disk meter

^bDate x stocking rate interaction (P<.001)

^cCubic effect of date (P<.001)

^dLinear effect of stocking rate (P<.01)

Crude protein content of bermudagrass forage was not affected by grazing treatment in May (Table 6). In June, July, August and September, CP was higher ($P < .05$) in high N, compared to low N fertilized bermudagrass. In August and September, CP increased as stocking rate increased (linear effect, $P < .01$). Crude protein content of forage increased through July, was lower in August, then increased once again in September (quadratic effect, $P = .01$).

Neutral detergent fiber content was lower ($P < .05$) in bermudagrass fertilized at the high N rate in May, July, August and September (Table 7). No differences were detected in June. The NDF content of forage increased linearly ($P < .001$) with time. There were no effects of stocking rate on NDF at any time during the grazing season.

Few differences were observed in acid detergent fiber content of bermudagrass forage (Table 8). In September, ADF decreased linearly ($P < .01$) as stocking rate increased, and forage fertilized at the high N rate was lower ($P < .01$) in ADF, compared to forage fertilized at the low N rate. There were no effects of stocking rate or N fertilization rate on ADF content in May, June, July or August. The ADF of forage decreased from May to June, was higher in July, and decreased through the end of the grazing season (cubic effect, $P < .001$).

There were no differences in lignin content of bermudagrass forage due to stocking rate or N fertilization rate (Table 9). Lignin content decreased from May to June, was higher in July, and decreased through the end of the grazing season (cubic effect, $P < .001$).

Cellulose content of forage was not affected by stocking rate or N fertilization rate in May, June or July (Table 10). In August and September, cellulose decreased ($P < .01$) linearly as stocking rate increased, and in September, cellulose was lower ($P < .05$) in high N fertilized bermudagrass. Cellulose content increased from May to

TABLE 6. CRUDE PROTEIN CONTENT OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 1

Date ^a	Stocking rates and N fertilization levels												Avg ^b	SE	
	Light		Moderate		Heavy		Low N		High N		Very heavy				
	Low N	High N	Low N	High N	Low N	High N	Low N	High N	Low N	High N	Low N	High N			
May 31	12.0	12.7	12.3	13.5	11.6	14.0	12.0	11.8	12.5	12.5	11.8	12.0	11.8	12.5	.77
June 27 ^c	12.4	12.8	12.3	13.2	11.2	14.7	11.7	14.9	12.9	12.9	14.9	11.7	14.9	12.9	.76
July 25 ^c	12.2	13.5	11.7	13.9	12.2	14.9	13.3	14.2	13.2	13.2	14.2	13.3	14.2	13.2	1.02
Aug 22 ^{cd}	10.4	12.9	10.3	13.9	10.6	13.6	12.0	14.7	12.3	12.3	14.7	12.0	14.7	12.3	.44
Sept 18 ^{cd}	11.6	15.6	12.5	15.2	14.0	17.0	14.4	17.6	14.7	14.7	17.6	14.4	17.6	14.7	.66

-----%,DM basis-----

^aDate x N interaction (P<.05)

^bQuadratic effect of date (P=.01)

^cEffect of N level (P<.05)

^dLinear effect of stocking rate (P<.01)

TABLE 7. NEUTRAL DETERGENT FIBER CONTENT OF BERMU DAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 1

Date	Stocking rates and N fertilization levels												Avg ^a	SE
	Light			Moderate			Heavy			Very heavy				
	Low N	High N	Avg	Low N	High N	Avg	Low N	High N	Avg	Low N	High N	Avg		
May 31 ^b	73.2	72.8	74.0	71.4	74.6	71.3	73.2	73.6	73.0	73.0	73.0	73.0	.98	
June 27	73.7	75.1	75.0	74.7	76.3	74.3	75.3	73.1	74.7	74.7	74.7	74.7	.76	
July 25 ^b	77.3	75.5	76.6	76.3	76.8	75.7	76.6	73.7	76.0	76.0	76.0	76.0	.76	
Aug 22 ^b	77.3	76.1	77.4	75.9	77.2	75.6	77.3	75.4	76.5	76.5	76.5	76.5	.46	
Sept 18 ^b	76.7	74.2	77.4	75.4	76.6	75.4	75.7	74.5	75.7	75.7	75.7	75.7	.65	

-----%, DM basis-----

^aLinear effect of date (P<.001)

^bEffect of N level (P<.05)

TABLE 8. ACID DETERGENT FIBER CONTENT OF BERMU DAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 1

Date	Stocking rates and N fertilization levels												Avg ^a	SE
	Light			Moderate			Heavy			Very heavy				
	Low N	High N	Avg	Low N	High N	Avg	Low N	High N	Avg	Low N	High N	Avg		
May 31	36.9	36.1	36.8	34.9	37.2	34.3	37.0	37.4	36.3	37.0	37.4	36.3	1.05	
June 27	35.7	36.0	36.5	36.2	37.0	35.7	36.7	35.2	36.1	36.7	35.2	36.1	.65	
July 25	39.3	38.7	40.0	38.7	38.6	38.4	38.7	36.9	38.7	38.7	36.9	38.7	.73	
Aug 22	38.9	37.9	37.9	38.3	37.3	36.7	37.2	37.2	37.7	37.2	37.2	37.7	.59	
Sept 18 ^{bc}	37.1	35.5	36.4	36.1	35.5	35.4	35.6	33.7	35.7	35.6	33.7	35.7	.42	

^aLinear and cubic effects of date (P<.001)

^bLinear effect of stocking rate (P<.01)

^cEffect of N level (P<.01)

TABLE 9. LIGNIN CONTENT OF BERMU DAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 1

Date	Stocking rates and N fertilization levels												SE
	Light			Moderate			Heavy			Very heavy			
	Low N	High N	Avg ^a	Low N	High N	Avg ^a	Low N	High N	Avg ^a	Low N	High N	Avg ^a	
May 31	6.42	6.01	5.88	5.19	6.99	5.66	6.23	6.14	6.07	6.07	6.07	6.07	.50
June 27	4.66	5.06	5.24	4.78	5.10	4.84	5.55	5.11	5.04	5.04	5.04	5.04	.31
July 25	7.02	7.06	7.72	7.30	7.12	7.46	7.22	7.13	7.25	7.25	7.25	7.25	.32
Aug 22	7.28	7.27	7.00	8.02	7.13	7.03	7.12	7.60	7.31	7.31	7.31	7.31	.41
Sept 18	6.93	6.82	7.16	6.08	6.59	7.24	6.78	6.43	6.76	6.76	6.76	6.76	.55

-----%, DM basis-----

^aCubic effect of date (P<.001)

TABLE 10. CELLULOSE CONTENT OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 1

Date ^a	Stocking rates and N fertilization levels										Avg ^b	SE
	Light		Moderate		Heavy		Very heavy		Low N	High N		
	Low N	High N	Low N	High N	Low N	High N	Low N	High N				
May 31	27.9	28.3	28.0	28.1	27.9	26.8	28.7	29.1	28.1	28.1	.76	
June 27	29.2	29.0	28.4	29.4	30.1	28.4	29.3	28.1	29.0	29.0	.65	
July 25	30.1	29.5	29.3	29.1	29.2	28.7	29.1	27.8	29.1	29.1	.59	
Aug 22 ^c	29.2	28.8	28.6	28.3	27.8	27.4	27.2	26.7	28.0	28.0	.28	
Sept 18 ^{cd}	28.5	27.8	27.4	27.3	27.1	26.7	26.6	25.6	27.1	27.1	.25	

^aDate x stocking rate interaction (P=.01)

^bQuadratic effect of date (P<.001)

^cLinear effect of stocking rate (P<.01)

^dEffect of N level (P<.05)

July, and then decreased through the end of the grazing season (quadratic effect, $P < .001$).

Grazing Trial 2. Daily gains of lambs decreased ($P < .01$) linearly as stocking rate increased in all periods (Tables 11 and 12). From d 56 to 70, daily gains were greater for lambs grazing high N fertilized bermudagrass at the light and very heavy stocking rates, whereas performance was lower for lambs grazing high fertilized bermudagrass at the moderate and heavy stocking rates (N x stocking rate interaction, $P < .05$). In the last two periods (84 to 98 d and 98 to 112 d), daily gains were lower ($P < .05$) for lambs grazing high N fertilized bermudagrass (Table 11). For the entire grazing season (0 to 112 d), daily gains decreased linearly ($P < .01$) with increasing stocking rate. High N fertilization level improved ADG slightly at the light stocking rate, had no effect at the moderate stocking rate, and decreased ADG at the heavy and very heavy stocking rates (N x stocking rate interaction, $P < .05$). The effect of stocking rate on ADG during the grazing season resulted in a linear decrease ($P < .01$) in final weights of lambs (Table 11).

Lamb production per hectare (Table 3) increased from the light to moderate stocking rate, and decreased at the heavy and very heavy stocking rates (cubic effect, $P < .05$). Actual lamb grazing days increased linearly ($P < .001$) as stocking rate increased (Table 3). Actual grazing days were lower than theoretical grazing days at the moderate, heavy and very heavy stocking rates, due to removal of lambs at various times during the grazing season.

Increasing stocking rate decreased ($P < .01$) forage mass linearly in May and June (Table 13). Both linear and quadratic effects of stocking rate were significant ($P < .01$; $P < .05$, respectively) from July to the end of the grazing season, but the quadratic effect seemed to give a better fit. There was little difference in forage mass

TABLE 11. PERIOD DAILY GAINS OF LAMBS GRAZING BERMUDAGRASS AT DIFFERENT STOCKING RATES AND NITROGEN FERTILIZATION RATES. TRIAL 2

Item	Stocking rates and N fertilization levels												SE	
	Light			Moderate			Heavy			Very heavy				
	Low N	High N	Low N	High N	Low N	High N	Low N	High N	Low N	High N	Low N	High N		
Initial wt., kg	25.4	25.5	25.3	25.6	25.2	25.3	25.1	25.1	25.1	25.1	25.1	25.1	25.1	.13
Final wt., kg ^a	38.6	40.1	34.7	34.9	29.2	28.8	29.1	27.8	29.1	27.8	27.8	27.8	27.8	.44
Daily gain, g														
0-13 ^d	234	223	204	234	99	148	128	112	128	112	128	112	112	17.3
13-28 ^d	232	245	83	108	29	-22	55	9	29	-22	55	9	9	17.7
28-42 ^d	49	86	5	-62	-28	-49	-85	-83	-28	-49	-85	-83	-83	23.1
42-56 ^d	194	157	122	176	108	95	208	140	108	95	208	140	140	23.4
56-70 ^d	11	62	30	19	-12	-48	-99	-59	-12	-48	-99	-59	-59	16.4
70-84 ^d	92	135	38	50	-32	-.2	-54	-43	-32	-.2	-54	-43	-43	18.1
84-98 ^d	92	57	65	81	50	24	30	-50	50	24	30	-50	-50	15.4
98-112 ^d	69	74	66	27	92	78	383	190	92	78	383	190	190	32.6

^aLinear effect of stocking rate (P<.01)

^bN x stocking rate interaction (P<.05)

^cEffect of N level (P<.05)

TABLE 12. CUMULATIVE DAILY GAINS OF LAMBS GRAZING BERMUDAGRASS AT DIFFERENT STOCKING RATES AND NITROGEN FERTILIZATION RATES. TRIAL 2

Period	Stocking rates and N fertilization levels												
	Light		Moderate		Heavy		Very heavy		Low N		High N		SE
	Low N	High N	Low N	High N	Low N	High N	Low N	High N	Low N	High N	Low N	High N	
13d ^a	234	223	204	234	99	148	128	112	128	112	17.3		
28d ^{ab}	233	234	140	167	61	64	89	57	89	57	13.5		
42d ^a	172	185	102	107	57	52	50	32	50	32	10.2		
56d ^a	168	178	108	126	65	58	73	46	73	46	8.1		
70d ^{abc}	136	155	93	103	48	35	31	21	31	21	6.8		
84d ^{ab}	128	152	90	94	34	30	20	17	20	17	6.1		
98d ^{ac}	123	138	86	92	37	29	22	2	22	2	5.4		
112d ^{abc}	116	130	84	84	38	31	51	17	51	17	6.4		

^aLinear effect of stocking rate (P<.01)
^bQuadratic effect of stocking rate (P<.01)
^cN x stocking rate interaction (P<.05)

TABLE 13. FORAGE MASS OF BERMU DAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 2

Date ^a	Stocking rates and N fertilization levels								Avg ^b	SE
	Light		Moderate		Heavy		Very heavy			
	Low N	High N	Low N	High N	Low N	High N	Low N	High N		
May 27 ^c	4751	4397	3926	4192	3531	2981	1882	2021	3460	515
June 10 ^c	2505	2371	1609	1191	1217	810	626	326	1332	224
June 25 ^{cde}	1497	952	983	718	387	484	275	183	685	112
July 8 ^{cf}	1440	957	458	346	474	290	153	402	565	228
July 23 ^{cdf}	2026	1222	596	331	764	127	356	127	694	284
Aug 6 ^{cf}	2373	2464	586	580	285	285	255	219	881	292
Aug 20 ^{cf}	2683	2607	937	443	249	219	204	188	941	237
Sept 3 ^{cf}	2760	2831	794	484	234	316	204	158	972	150
Sept 17 ^{cf}	3915	3798	1471	871	300	382	351	224	1414	223

-----DM, kg/ha-----

^aDate x stocking rate interaction (P<.01)
^bQuadratic effect of date (P<.01)
^cLinear effect of stocking rate (P<.01)
^dEffect of N level (P<.05)
^eN x stocking rate interaction (P<.05)
^fQuadratic effect of stocking rate (P<.05)

between the heavy and very heavy stocking rates after June 25. On June 25 and July 23, the high N fertilization rate decreased ($P < .05$) forage mass, with the exception of the heavy stocking rate on June 25, when high N rate increased forage mass (N x stocking rate interaction, $P < .05$). Forage mass decreased from May to July 8, then increased through the end of the grazing season (quadratic effect, $P < .01$).

There were no effects of stocking rate or N fertilization rate on canopy height initially in May (Table 14). From June 10 through the end of the grazing season, canopy height decreased linearly ($P < .001$) as stocking rate increased. However, on June 10 and July 9 through the end of the grazing season, there was little difference in canopy height between the heavy and very heavy stocking rates. Therefore, the effect of stocking rate was better explained as quadratic ($P < .001$). On June 25, canopy height was lower ($P < .05$) on paddocks receiving high N fertilization. Canopy height decreased from May to June 25, remained constant through August 6, and increased slightly through the end of the grazing season (quadratic effect, $P < .01$).

Forage composition responses to stocking rate were variable. On May 27, June 10 and September 17, CP content of forage increased linearly ($P < .01$) as stocking rate increased (Table 15). However, on August 6, CP of forage decreased linearly ($P < .01$) as stocking rate increased. Bermudagrass fertilized at the high N rate was higher ($P < .05$) in CP on May 27, June 10, August 6 and September 17. Crude protein concentrations were quite variable over time, and both quadratic and cubic effects were evident ($P < .01$).

Neutral detergent fiber content of forage changed linearly and quadratically ($P < .05$) as stocking rate increased in May and June, with the quadratic effect giving the better fit (Table 16). On August 6, NDF increased linearly ($P < .05$) as stocking rate increased. High N fertilization rate decreased ($P < .01$) NDF content of

TABLE 14. CANOPY HEIGHT^a OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 2

Date ^b	Stocking rates and N fertilization levels												Avg ^c	SE	
	Light			Moderate			Heavy			Very heavy					
	Low N	High N	N	Low N	High N	N	Low N	High N	N	Low N	High N	N			
May 27	21	17	17	17	17	17	17	15	17	17	17	17	17	17	1.22
June 10 ^{de}	13	10	9	10	10	8	8	7	7	7	8	8	9	9	1.00
June 25 ^{df}	13	11	8	8	8	9	9	6	6	6	4	4	8	8	.95
July 9 ^{de}	13	12	9	8	8	8	8	7	7	7	7	7	9	9	.91
July 23 ^{de}	15	16	7	7	7	6	6	5	5	7	6	6	9	9	.85
Aug 6 ^{de}	18	17	9	8	8	6	6	5	5	6	5	5	9	9	.80
Aug 20 ^{de}	19	20	9	8	8	5	5	5	5	6	4	4	10	10	1.12
Sept 3 ^{de}	26	21	12	9	9	5	5	5	5	7	4	4	11	11	1.60
Sept 17 ^{de}	20	19	9	7	7	4	4	4	4	5	4	4	9	9	.80

^aMeasured with disk meter

^bDate x stocking rate interaction (P<.001)

^cQuadratic effect of date (P<.01)

^dLinear effect of stocking rate (P<.001)

^eQuadratic effect of stocking rate (P<.001)

^fEffect of N level (P<.05)

TABLE 15. CRUDE PROTEIN CONTENT OF BERMU DAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 2

Date ^a	Stocking rates and N fertilization levels												Avg ^b	SE
	Light		Moderate		Heavy		Very heavy		Low N		High N			
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High		
May 27 ^{cd}	16.1	21.1	17.2	21.1	17.2	21.1	17.2	21.1	21.6	23.6	19.9	19.9	.99	
June 10 ^{cd}	15.1	17.7	15.1	17.8	15.8	18.0	15.8	18.0	20.8	20.9	17.6	17.6	1.37	
June 25	17.3	19.0	14.7	16.0	14.8	14.7	14.8	14.7	16.9	15.3	16.1	16.1	1.44	
July 8	20.7	25.5	17.0	18.1	22.8	20.8	22.8	20.8	23.7	24.3	21.6	21.6	2.86	
July 23	18.3	19.1	19.9	19.0	21.3	17.4	21.3	17.4	20.2	19.8	19.4	19.4	1.71	
Aug 6 ^{cd}	16.3	21.9	18.7	20.7	15.4	15.4	15.4	15.4	16.0	17.9	17.7	17.7	1.05	
Aug 20	17.2	19.5	18.5	20.7	16.8	19.1	16.8	19.1	20.9	20.3	19.1	19.1	1.80	
Sept 3	17.1	18.6	18.9	19.3	17.5	18.6	17.5	18.6	18.2	21.3	18.7	18.7	1.70	
Sept 17 ^{cd}	16.8	19.3	18.5	22.8	18.1	22.4	18.1	22.4	20.0	21.6	19.9	19.9	.82	

-----%, DM basis-----

^aDate x stocking rate interaction (P<.05)

^bQuadratic and cubic effects of date (P<.01)

^cEffect of N level (P<.05)

^dLinear effect of stocking rate (P<.01)

TABLE 16. NEUTRAL DETERGENT FIBER CONTENT OF BERMU DAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 2

Date ^a	Stocking rates and N fertilization levels												SE
	Light			Moderate			Heavy			Very heavy			
	Low N	High N	N	Low N	High N	N	Low N	High N	N	Low N	High N	N	
May 27 ^{cd}	70.7	69.1	69.2	68.4	68.4	68.7	68.4	57.8	58.4	66.3	1.99		
June 10 ^{cd}	72.1	72.3	73.3	72.6	72.7	72.7	72.1	67.7	70.2	71.6	1.22		
June 25 ^{cd}	71.9	72.1	74.8	76.3	75.4	76.2	76.2	70.9	73.3	73.9	1.52		
July 8	65.9	64.1	71.0	70.7	65.1	67.3	64.8	62.5	66.4	3.20			
July 23	72.5	72.7	72.0	73.6	71.4	75.3	71.8	72.0	72.7	1.42			
Aug 6 ^c	72.1	67.7	71.9	69.1	76.0	76.5	73.6	74.1	72.7	2.00			
Aug 20	74.0	71.4	71.9	68.9	76.2	72.4	70.1	72.2	72.2	2.20			
Sept 3	74.2	73.7	71.7	72.5	74.4	75.3	73.8	76.6	74.0	2.20			
Sept 17 ^{ef}	73.9	72.8	73.9	69.2	76.4	75.0	73.1	70.1	73.1	1.05			

^aDate x stocking rate interaction (P<.001)

^bQuadratic and cubic effects of date (P<.001)

^cLinear effect of stocking rate (P<.05)

^dQuadratic effect of stocking rate (P<.05)

^eCubic effect of stocking rate (P<.001)

^fEffect of N level (P<.01)

bermudagrass on September 17. The NDF decreased from light to moderate stocking rate, was highest at heavy stocking rate, and decreased at the very heavy stocking rate (cubic effect, $P < .001$). No consistent patterns were discerned for NDF over time, even though quadratic and cubic effects ($P < .001$) were detected.

Few differences were observed in ADF content of bermudagrass due to stocking rate (Table 17). Acid detergent fiber decreased linearly ($P < .05$) as stocking rate increased on May 27 and September 17, but increased linearly ($P < .05$) and quadratically ($P = .05$) as stocking rate increased on August 6. There was little difference in ADF between the heavy and very heavy stocking rates on August 6, explaining the quadratic effect. There were no effects of N rate on ADF content of bermudagrass. Forage ADF averaged over stocking rate and N fertilization rate, increased from May through June, was lower on July 8, increased through September 3, and was lower on September 17 (linear and quadratic effects, $P < .01$).

Lignin content decreased linearly ($P < .05$) on May 27 and increased linearly ($P < .05$) on September 3 as stocking rate increased (Table 18). Lignin increased linearly ($P < .05$) and quadratically ($P < .05$) on August 6, and increased quadratically ($P < .05$) on August 20. On July 23, bermudagrass fertilized at the high N rate was higher ($P < .05$) in lignin, and tended to be higher ($P = .08$) on May 27 and June 25. Once again, averaged over treatments, no consistent patterns were observed for lignin over time, despite the presence of quadratic and cubic effects ($P < .01$).

There were small linear and quadratic ($P < .05$) effects of stocking rate on cellulose content of forage on May 27, July 8 and September 17 (Table 19). On May 27 and June 10, bermudagrass receiving the high N fertilization rate was lower ($P < .05$) in cellulose, compared to low N fertilized bermudagrass. Averaged over treatments, cellulose increased through June 25, decreased on July 8, was highest on

TABLE 17. ACID DETERGENT FIBER CONTENT OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 2

Date ^a	Stocking rates and N fertilization levels												Avg ^b	SE
	Light			Moderate			Heavy			Very heavy				
	Low N	High N	Avg	Low N	High N	Avg	Low N	High N	Avg	Low N	High N	Avg		
May 27 ^c	37.3	35.5	36.2	36.0	35.4	34.9	30.4	31.0	34.6	30.4	31.0	34.6	.94	
June 10	39.4	39.0	39.6	39.7	39.4	39.0	36.1	38.5	38.8	36.1	38.5	38.8	1.74	
June 25	36.6	37.1	39.8	40.4	40.2	40.9	38.8	40.6	39.3	38.8	40.6	39.3	1.78	
July 8	29.8	28.1	35.6	36.7	30.8	33.5	31.4	28.6	31.7	31.4	28.6	31.7	2.84	
July 23	33.8	34.1	34.0	38.3	33.9	38.9	32.6	35.7	35.2	32.6	35.7	35.2	2.26	
Aug 6 ^{cd}	34.6	31.5	35.8	34.9	40.2	41.7	38.0	37.3	36.9	38.0	37.3	36.9	1.90	
Aug 20	34.8	34.0	36.0	35.6	39.6	38.2	33.6	36.4	36.0	33.6	36.4	36.0	2.20	
Sept 3	35.1	35.4	36.7	36.7	40.4	40.4	36.9	38.1	37.5	36.9	38.1	37.5	2.45	
Sept 17 ^c	34.9	34.1	34.5	31.6	33.7	31.9	31.4	31.6	33.0	31.4	31.6	33.0	.99	

-----%,DM basis-----

^aDate x stocking rate interaction (P<.01)
^bLinear and quadratic effects of date (P<.01)
^cLinear effect of stocking rate (P<.05)
^dQuadratic effect of stocking rate (P=.05)

TABLE 18. LIGNIN CONTENT OF BERMU DAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 2

Date ^a	Stocking rates and N fertilization levels												Avg ^b	SE
	Light			Moderate			Heavy			Very heavy				
	Low N	High N	Low N	High N	Low N	High N	Low N	High N	Low N	High N	Low N	High N		
May 27 ^{cd}	9.9	10.1	8.2	9.8	7.8	8.6	5.4	6.7	8.3	6.7	5.4	6.7	8.3	.70
June 10	9.6	11.1	10.1	11.1	10.1	10.7	8.6	10.9	10.3	10.9	8.6	10.9	10.3	1.44
June 25 ^d	9.0	11.2	11.2	12.8	10.9	12.9	11.9	13.1	11.6	13.1	11.9	13.1	11.6	1.31
July 8	5.7	5.7	8.8	10.0	6.5	9.4	8.1	7.0	7.7	7.0	8.1	7.0	7.7	1.43
July 23 ^e	6.2	6.7	7.4	10.3	7.4	11.1	6.0	8.8	8.0	8.8	6.0	8.8	8.0	1.44
Aug 6 ^{cf}	6.7	4.9	8.7	8.7	10.9	13.5	9.7	9.7	9.1	9.7	9.7	9.7	9.1	1.30
Aug 20 ^f	6.7	7.1	8.2	9.0	11.2	10.7	7.2	8.9	8.5	8.9	7.2	8.9	8.5	1.30
Sept 3 ^c	8.0	8.3	9.6	9.7	12.9	11.8	10.1	11.3	10.2	11.3	10.1	11.3	10.2	1.38
Sept 17	7.7	7.7	8.4	7.5	9.1	7.3	6.5	7.1	7.7	7.1	6.5	7.1	7.7	.61

-----%, DM basis-----

^aDate x stocking rate interaction (P<.01)
^bQuadratic and cubic effects of date (P<.01)
^cLinear effect of stocking rate (P<.05)
^dEffect of N level (P=.08)
^eEffect of N level (P<.05)
^fQuadratic effect of stocking rate (P<.05)

TABLE 19. CELLULOSE CONTENT OF BERMU DAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 2

Date ^a	Stocking rates and N fertilization levels												Avg ^b	SE
	Light			Moderate			Heavy			Very heavy				
	Low N	High N	Low N	High N	Low N	High N	Low N	High N	Low N	High N	Low N	High N		
May 27 ^{cde}	24.7	22.4	24.8	23.5	24.8	23.6	22.5	22.0	23.6	22.5	22.0	23.6	23.6	.48
June 10 ^e	26.6	25.3	26.9	24.9	26.1	24.8	24.8	24.4	25.5	24.8	24.4	25.5	25.5	.61
June 25	25.6	23.8	26.1	25.2	26.4	25.4	24.3	24.6	25.2	24.3	24.6	25.2	25.2	.62
July 8 ^{cd}	22.8	21.3	25.3	24.8	23.0	22.6	20.6	19.8	22.5	20.6	19.8	22.5	22.5	1.37
July 23	26.5	26.7	25.5	26.8	25.6	26.3	25.7	25.4	26.1	25.7	25.4	26.1	26.1	.71
Aug 6	26.0	24.8	25.0	24.0	26.9	25.1	25.4	24.7	25.3	25.4	24.7	25.3	25.3	.92
Aug 20	26.1	25.2	25.7	24.3	25.7	25.1	24.1	25.0	25.2	24.1	25.0	25.2	25.2	1.00
Sept 3	24.9	25.2	24.6	24.6	25.0	25.6	24.1	24.2	24.8	24.1	24.2	24.8	24.8	1.08
Sept 17 ^{cd}	24.7	24.2	23.9	21.8	23.2	22.6	22.7	22.1	23.2	22.7	22.1	23.2	23.2	.54

-----%, DM basis-----

^aDate x stocking rate interaction (P=.05)
^bQuadratic effect of date (P<.001)
^cLinear effect of stocking rate (P<.05)
^dQuadratic effect of stocking rate (P<.05)
^eEffect of N level (P<.05)

July 23, and decreased through the end of the grazing season (quadratic effect, $P < .001$).

In vitro DM disappearance (Table 20) increased linearly ($P < .01$) as stocking rate increased on May 27 and September 17 (beginning and end of the grazing season, respectively). Bermudagrass fertilized at the high N rate had higher ($P = .05$) IVDMD than forage fertilized at the low N rate on September 17. On July 23 (middle of the grazing season), there was no effect of stocking rate or N fertilization rate on IVDMD. In vitro DM disappearance decreased from the beginning to the middle of the grazing season, and was higher at the end of the grazing season (quadratic effect, $P < .01$).

On August 20, tricho-strongyl eggs in the feces of sheep increased linearly ($P < .01$) as stocking rate increased, but there were no effects of stocking rate or N fertilization rate on September 17 (Table 21). Coccidia oocytes per gram of feces increased linearly ($P < .05$) as stocking rate increased on August 20, and coccidia numbers tended to be higher for lambs that grazed at the heavy and very heavy stocking on September 17 (quadratic effect, $P = .10$).

The effects of two consecutive years of grazing by sheep on soil status are presented in Table 22. Soil in paddocks fertilized at the high N rate had a lower ($P < .001$) pH than soil in paddocks fertilized at the low N rate. Soil pH decreased from the light to heavy stocking rate, and was slightly higher in soil of paddocks grazed at the very stocking rate (quadratic effect, $P < .05$). Organic matter content of soil decreased from the light to moderate stocking rate, and was higher in soil of paddocks grazed at the heavy and very heavy stocking rates (quadratic effect, $P < .05$). Soil fertilized at the high N rate was lower ($P < .05$) in Ca and Mg than soil fertilized at the low N rate. There were no effects of stocking rate or N rate on P or K concentrations in the soil.

TABLE 20. IN VITRO DRY MATTER DISAPPEARANCE OF BERMUDAGRASS FERTILIZED WITH TWO RATES OF NITROGEN AND GRAZED BY SHEEP AT DIFFERENT STOCKING RATES. TRIAL 2

Date	Stocking rates and N fertilization levels								Avg ^a	SE
	Light		Moderate		Heavy		Very heavy			
	Low N	High N	Low N	High N	Low N	High N	Low N	High N		
May 27 ^b	51.8	47.8	60.2	51.0	54.5	55.6	68.1	63.8	56.6	3.21
July 23	50.2	55.1	51.5	46.1	55.5	40.1	52.3	47.0	49.7	4.63
Sept 17 ^{bc}	46.6	48.1	50.6	55.5	53.7	56.9	55.8	59.8	53.4	2.34

-----%, DM basis-----

^aQuadratic effect of date (P<.01)

^bLinear effect of stocking rate (P<.01)

^cEffect of N level (P=.05)

TABLE 21. PARASITE BURDENS OF SHEEP GRAZING BERMUDAGRASS AT DIFFERENT STOCKING RATES AND NITROGEN FERTILIZATION RATES. TRIAL 2

Item	Stocking rates and N fertilization levels								SE	
	Light		Moderate		Heavy		Very heavy			
	Low N	High N	Low N	High N	Low N	High N	Low N	High N		
Aug 20										
Tricho-Strongyl, epg ^a	0	0	70	30	38	129	767	305	149	
Coccidia, opg ^b	342	306	315	850	817	1479	1763	1485	581	
Sept 17										
Tricho-Strongyl, epg	0	0	0	0	0	0	4	0	1.7	
Coccidia, opg ^c	725	850	400	531	920	417	1046	1529	380	

^aLinear effect of stocking rate (P<.01)

^bLinear effect of stocking rate (P<.05)

^cQuadratic effect of stocking rate (P=.10)

TABLE 22. SOIL CONSTITUENTS OF BERMU DAGRASS PASTURES AFTER TWO CONSECUTIVE YEARS OF GRAZING BY SHEEP AT DIFFERENT STOCKING RATES AND NITROGEN FERTILIZATION RATES

Item	Stocking rates and N fertilization levels												SE
	Light			Moderate			Heavy			Very heavy			
	Low N	High N	N	Low N	High N	N	Low N	High N	N	Low N	High N	N	
pH ^{ab}	5.40	4.67	5.27	4.63	4.93	4.50	5.17	4.63	5.17	4.63	5.17	4.63	.09
OM, % ^b	3.77	3.77	3.50	3.40	3.63	3.53	3.83	3.60	3.83	3.60	3.83	3.60	.11
P, ppm	29	30	26	26	29	34	33	27	33	27	33	27	4.52
K, ppm	58	61	68	68	94	81	94	68	94	68	94	68	11.04
Ca, ppm ^c	635	522	613	490	514	443	622	498	622	498	622	498	57.6
Mg, ppm ^c	103	87	103	80	85	69	106	78	106	78	106	78	13.16

^aEffect of N level (P<.001)

^bQuadratic effect of stocking rate (P<.05)

^cEffect of N level (P<.05)

The percentage of ground area covered by weeds in the spring of 1993 after 2 yr of grazing increased linearly ($P < .001$) as stocking rate increased (Table 23).

Feedlot Trial. The effect of stocking rate during the grazing trial resulted in a linear ($P < .01$) decrease in initial weight of lambs going into the feedlot (Table 24). For d 5 to 14 and d 40 to 54 of the feeding period, lambs that had grazed at the heavy and very heavy stocking rates gained more weight than lambs that had grazed at the light and moderate stocking rates (linear and quadratic effects, $P < .05$). For 14 to 28 d, a linear increase ($P < .01$) in rate of gain with increased stocking rate was observed. For the period 96 to 110 d, feedlot daily gains increased from light to moderate, were lower for lambs at the heavy stocking rate, and highest for lambs that had grazed at the very heavy stocking rate during the grazing trial (cubic effect, $P < .05$). For the entire 110 d feeding period, daily gains were higher (linear effect, $P < .01$) for lambs that had grazed at the very heavy stocking rate, with little difference between the light, moderate and heavy stocking rates.

Daily DM intake of lambs decreased from the light to the heavy stocking rate, and was higher for lambs at the very heavy stocking rate (quadratic effect, $P < .01$, Table 25). There was also an effect of previous stocking rate on DM intake expressed on a metabolic body size basis ($BW^{.75}$, Table 26). There was a tendency for lambs that had grazed at the very heavy stocking rate to consume more DM per unit of metabolic body size during most periods. For the period, 82 to 96 d, DM intake increased linearly ($P = .05$) as previous stocking rate increased, and over the 110 d feeding period, DM intake was the same for lambs that had grazed at the light and moderate stocking rate, and higher for lambs that had grazed at the heavy and very heavy stocking rates (quadratic effect, $P < .01$).

TABLE 23. PERCENTAGE OF GROUND AREA COVERED BY WEEDS. SPRING 1993^a

Item	Stocking rates and N fertilization levels													
	Light			Moderate			Heavy			Very heavy				
	Low	N	High	Low	N	High	Low	N	High	Low	N	High	N	SE
Ground area, % ^b	3.3		2.0	7.7		31.7	28.3		45.0	71.7		76.7		11.87

^aPaddocks visually evaluated in April 1993

^bLinear effect of stocking rate (P<.001)

TABLE 24. PERIOD DAILY GAINS OF LAMBS IN THE FEEDLOT AFTER GRAZING BERMUDAGRASS AT DIFFERENT STOCKING RATES^a

Item	Stocking rate				SE
	Light	Moderate	Heavy	Very heavy	
Initial wt., kg ^b	39.5	34.8	29.0	28.5	.26
Daily gain, g					
5-14d ^c	3	101	275	237	17
14-28d ^b	158	213	222	299	15
28-40d	284	193	27	166	20
40-54d ^c	144	125	175	270	18
54-68d	153	201	174	148	16
68-82d	147	122	110	171	15
82-96d	190	167	123	123	17
96-110d ^d	184	219	158	235	18
0-110d ^b	163	174	167	223	7

^aTrial conducted at the termination of grazing trial 2

^bLinear effect of stocking rate (P<.01)

^cLinear and quadratic effects of stocking rate (P<.05)

^dCubic effect of stocking rate (P<.05)

TABLE 25. AVERAGE DRY MATTER INTAKE OF LAMBS BY PERIOD IN THE FEEDLOT AFTER GRAZING BERMUDAGRASS AT DIFFERENT STOCKING RATES^a

Period	Stocking rate				SE
	Light	Moderate	Heavy	Very heavy	
	-----kg/d-----				
5-14d	1.61	1.45	1.30	1.46	.14
14-28d	1.87	1.87	1.63	1.76	.08
28-40d	1.58	1.50	1.32	1.66	.11
40-54d	1.46	1.30	1.19	1.66	.14
54-68d	1.30	1.11	1.09	1.29	.11
68-82d	1.11	1.25	.98	1.23	.11
82-96d	.79	.98	.89	1.06	.09
96-110d	1.20	1.04	.92	1.05	.13
0-110d ^b	1.36	1.31	1.17	1.40	.04

^aTrial conducted at the termination of grazing trial 2

^bQuadratic effect of stocking rate (P<.01)

TABLE 26. DRY MATTER INTAKE OF LAMBS PER UNIT OF METABOLIC BODY SIZE IN THE FEEDLOT AFTER GRAZING BERMUDAGRASS AT DIFFERENT STOCKING RATES^a

Period	Stocking rate				SE
	Light	Moderate	Heavy	Very heavy	
	-----g DM/kg BW ^{.75} -----				
5-14d	101.8	97.9	95.0	109.3	8.22
14-28d	113.9	118.9	110.8	119.9	3.11
28-40d	90.3	91.7	89.1	108.4	5.48
40-54d	82.8	77.8	76.6	100.6	7.27
54-68d	73.7	63.4	67.2	76.5	5.29
68-82d	61.6	70.7	59.6	71.4	6.61
82-96d ^b	43.1	55.1	53.3	61.6	5.01
96-110d	65.6	57.3	53.2	58.8	7.10
0-110d ^c	79.1	79.1	75.6	88.3	2.26

^aTrial conducted at the termination of grazing trial 2

^bLinear effect of stocking rate (P=.05)

^cQuadratic effect of stocking rate (P<.01)

In the initial 14 d of the feedlot trial (Table 27), lambs that had grazed at the heavy and very heavy stocking rates were more efficient in feed conversion than lambs that had grazed at the light and moderate stocking rates (linear and quadratic effects, $P < .05$). For the period of 14 to 28 d and over the entire feeding period, feed efficiency of lambs increased linearly ($P < .01$) as previous stocking rate increased.

There were no effects of previous stocking rate on carcass characteristics of lambs (Table 28). Quality grade was Choice for all carcasses.

Discussion

Grazing Trials. The relationship between stocking rate and animal performance has been examined by several investigators (Peterson et al., 1965; Jones and Sandland, 1974). The reduction in daily gains of lambs with increasing stocking rate observed in both grazing trials is in general agreement with other studies (Hart et al., 1976; Conrad et al., 1981). Conrad et al. (1981) reported that gain per animal decreased with each increase in grazing pressure, and Hart et al. (1976) reported that ADG was strongly and negatively correlated with grazing pressure.

Increasing stocking rate decreased individual animal performance but increased total animal production per hectare. Increasing stocking rate above a critical grazing pressure results in both reduced gain per animal and per hectare (Peterson et al., 1965; Jones and Sandland, 1974). In grazing trial 1, lamb production increased with increasing stocking rate, whereas in grazing trial 2, lamb production was highest at the moderate stocking rate. The results of trial 2 support the findings of Conrad et al. (1981). The authors reported that gain per hectare was reduced at the very heavy grazing pressures, due to a significant reduction in gain per animal that was not compensated for by the increase in stocking rate. The stocking rates used in grazing

TABLE 27. FEED EFFICIENCY OF LAMBS BY PERIOD IN THE FEEDLOT AFTER GRAZING BERMUDAGRASS AT DIFFERENT STOCKING RATES^a

Period	Stocking rate				SE
	Light	Moderate	Heavy	Very heavy	
	-----g gain/kg DM-----				
5-14d ^b	-6	78	211	164	26
14-28d ^c	84	114	137	170	16
28-40d	174	129	49	93	59
40-54d	100	91	147	166	32
54-68d	106	182	159	118	24
68-82d	125	103	111	134	17
82-96d	261	176	141	126	40
96-110d	141	217	176	224	26
0-110d ^c	104	125	140	152	2

^aTrial conducted at the termination of grazing trial 2

^bLinear and quadratic effects of stocking rate (P<.05)

^cLinear effect of stocking rate (P<.01)

TABLE 28. CARCASS CHARACTERISTICS OF LAMBS THAT HAD PREVIOUSLY GRAZED BERMUDAGRASS AT DIFFERENT STOCKING RATES^a

Item	Stocking rate				SE
	Light	Moderate	Heavy	Very heavy	
Slaughter wt., kg	52.2	51.9	51.8	51.5	.53
Carcass wt., kg	25.4	25.6	26.3	24.6	.34
Yield grade	2.08	2.0	1.33	1.92	.16

^aQuality grade was Choice for all carcasses

trial 2 were high enough to rise above the critical grazing pressure referred to in previous studies.

Lamb grazing days increased with increasing stocking rate in both grazing trials. Although it was necessary to remove lambs from paddocks due to insufficient forage mass in trial 2, season-long carrying capacity still increased linearly with increasing stocking rate. Carrying capacity in the present study was high. These findings support those of Fribourg et al. (1979) and McLaren et al. (1983), who reported high carrying capacity of bermudagrass pastures, relative to cool-season pastures.

The differences in ADG among stocking rates in grazing trial 1 were numerically smaller than for grazing trial 2. There was not a shortage of forage at any stocking rate and few differences were detected in forage composition during trial 1. Therefore, stocking rates were doubled in grazing trial 2 in an attempt to stress the bermudagrass and determine what level of grazing pressure the stand would tolerate. Bermudagrass tolerated the heavy grazing pressures as shown by the good growth in the spring of 1993. However, under the conditions of grazing trial 2, the heavy and very heavy stocking rates may have been too high for animal performance, as evidenced by the low per animal and per hectare performance. Another factor that may have contributed to low animal performance at heavier stocking rates is parasite burdens. Gruner and Cabaret (1985) stated that, while parasitism of sheep on pasture is affected by variables such as age and physiological status of sheep, anthelmintic program and grazing management, as a general rule high stocking rates are associated with high levels of parasitism. Worm counts generally increased as stocking rate increased, however, there was no difference among stocking rates in tricho-strongyl egg numbers on September 17. Therefore, the extent to which parasite burdens impacted lamb performance in trial 2 cannot be determined.

The moderate and very heavy stocking rates in trial 1 corresponded to the light and moderate stocking rates in trial 2 in terms of lambs grazing per paddock. Forage mass and canopy height were higher in trial 1 on the respective paddocks than for trial 2. The differences in available forage and canopy height between trials may be partially explained by differences in ambient temperature (Appendix A, Table 2). Maximum and minimum daily temperatures during May were 5^o and 3^o C cooler, respectively, in trial 2 compared to trial 1. Bermudagrass is a warm-season grass, and exhibits its best growth around 24^oC (Burton and Hanna, 1985). In May of trial 1, maximum daily temperature was 27^oC, whereas in trial 2, maximum daily temperature was 22^oC. Perhaps in trial 1, bermudagrass growth was more vigorous, resulting in more forage and advanced maturity. This advanced maturity may help to explain the differences in ADG and forage measurements at equal relative stocking rates between years.

Forage mass and canopy height decreased with increasing stocking rate in both grazing trials. This is consistent with the findings of Conrad et al. (1981) and Roth et al. (1990). In trial 2, the decrease in forage mass and canopy height with increasing stocking rate was more severe, and at times, it is likely forage intake was limiting animal performance.

In both trials, forage mass decreased until July, then increased through the remainder of the grazing season. This corresponded to changes in daily temperature. Maximum and minimum temperatures were higher during July, August and September. High temperature favors bermudagrass growth, and temperatures recorded during the second half of the grazing season are more typical of optimal warm-season grass growing conditions.

There was no effect of stocking rate on NDF, and few differences were detected in other cell wall components in trial 1. Forage composition responses to stocking rate in trial 2 were inconsistent. Fiber levels decreased and CP increased as stocking rate increased on May 27 and September 17, but fiber levels increased and CP decreased with increasing stocking rate on August 6. Obtaining samples for chemical analyses became increasingly difficult due to a lack of forage at the heavier stocking rates. This may have resulted in erroneous estimates of forage quality. Roth et al. (1990) reported that increasing grazing pressure reduced the NDF content of available forage as well as diets selected by grazing animals. The authors attributed the decrease in NDF to decreased maturity of the canopy due to heavy grazing pressure. In contrast, Malechek and Leinweber (1972) and Jung and Sahlu (1989) reported the quality of diet selected decreased with increasing stocking rate. Increasing grazing pressure may increase the quality of available forage (Guerrero et al., 1984; Roth et al., 1990), but the quality of diet selected often decreases because of decreased opportunities for selective grazing and restricted intake at heavy grazing pressures (Malechek and Leinweber, 1972; Jung and Sahlu, 1989).

Stocking rates used in trial 1 may not have been high enough to consistently detect differences in forage composition, and in trial 2, stocking rates were too high to allow good comparisons of forage response to different grazing pressures.

In vitro DM disappearance of bermudagrass increased as stocking rate increased at the beginning and end of the grazing season in trial 2. This is in agreement with results obtained by Guerrero et al. (1984), who reported that IVDMD of bermudagrass increased as grazing pressure increased. The increased IVDMD in the present study was associated with a decrease in fiber levels and an increase in CP of forage.

Weed cover in the spring of 1993 increased with increasing stocking rate. Paddocks were evaluated while the bermudagrass was still dormant. The predominant weeds were cool-season annuals. It is likely the heavy thatch present on the lighter stocking rate paddocks prevented the encroachment of weeds, explaining the relatively small area covered by weeds on these paddocks.

High N fertilization improved animal performance in grazing trial 1 and was inconsistent in grazing trial 2. In trial 2, it appeared that the high N level had a positive effect at the light stocking rate, no effect at the moderate stocking rate, and a negative effect at the heavy and very heavy stocking rates (N x stocking rate interaction). Fribourg et al. (1979) reported that N fertilization of bermudagrass increased beef production per hectare but had little influence on gain per animal. Much of the improvement was attributed to increased carrying capacity.

The improvement of ADG for lambs grazing high N fertilized bermudagrass in trial 1 may be related to changes in forage composition. Bermudagrass fertilized with high N was higher in CP and lower in NDF. It is generally accepted that digestibility of available forage will influence animal performance (Duble et al., 1971; Guerrero et al., 1984). Estimates of digestibility were not obtained in trial 1, but lower fiber levels and higher CP contents would indicate that bermudagrass fertilized at high N level was more digestible.

The negative effects of high N fertilization on animal performance at the heavy and very heavy stocking rates in trial 2 may be related to timing of N application. The initial 50% of N was applied earlier in trial 2 than trial 1. The cooler weather during May of trial 2 likely delayed growth of bermudagrass. The early application of N coupled with the high grazing pressure at the heavy and very heavy stocking rates may have compromised forage growth and, consequently, decreased available forage.

Colby et al. (1965) suggested that N fertilization stimulates the utilization of storage reserves in the plant, and in combination with frequent removal of topgrowth, can weaken the plant. This was supported by the work of George et al. (1989), who observed that N fertilization reduced the total nonstructural carbohydrate concentration of switchgrass defoliated under moderate or severe intensity. Adegbola and McKell (1966) reported that excessive rates of previous N fertilization (> 848 kg/ha) reduced the subsequent regrowth potential of 'Coastal' bermudagrass compared to a rate of 565 kg/ha. Forage mass was frequently numerically lower for the high N fertilized bermudagrass, compared to the low N fertilized bermudagrass at the heavy and very heavy stocking rates. This may partially explain the decrease in ADG of lambs grazing high N fertilized bermudagrass at the heavier stocking rates in trial 2.

There was no effect of N application rate on forage mass or canopy height in trial 1, and forage mass was lower for high N fertilized bermudagrass on June 25 and July 23 in trial 2. These results were unexpected, as the response of bermudagrass to N fertilization is well documented (Mathias et al., 1973; Fribourg et al., 1979; Belesky et al., 1991). Mathias et al. (1978) observed a decrease in DM yield of 'Midland' bermudagrass fertilized with 448 kg N/ha in an appalachian region, and attributed the decrease to an invasion of cool-season weed species. The experiments of Wright et al. (1984ab) and Belesky et al. (1991) examined 'Quickstand' bermudagrass, whereas previous studies (Mathias et al., 1973, 1978; Jung et al., 1974) evaluated 'Midland'. Results indicate that 'Quickstand' is more adapted to cool, temperate environments than 'Midland'. No explanation is apparent for the lack of a N effect in trial 1. The apparent negative effect of high N fertilization in trial 2 may be related to timing of N application as discussed previously.

Crude protein content was higher in bermudagrass fertilized with high N in both grazing trials. These results are consistent with the findings of several earlier studies (Horn et al., 1976; Wright et al., 1984b; Belesky et al., 1991).

In trial 1, NDF was consistently lower in bermudagrass fertilized with high N. The effects of N fertilization on the other cell wall components were much less consistent for both trials. In September of trial 1, ADF and cellulose were lower in high N bermudagrass, but there was no effect of N on ADF, lignin or cellulose during any other month. Results were more variable in trial 2, with lower NDF in high N fertilized bermudagrass on September 17, no effect of N on ADF, and increased lignin in high N fertilized bermudagrass on July 23. Previous findings have been inconsistent as well. Belesky et al. (1991) reported lower levels of ADF in bermudagrass fertilized with 360 kg N/ha compared to 60 kg N/ha, while Stallcup et al. (1986) reported no effect of N fertilization on NDF, ADF or lignin content of bermudagrass hay.

High N fertilization increased IVDMD of bermudagrass on September 17. While not statistically significant, high N fertilization generally decreased IVDMD of bermudagrass on May 27 and July 23. In earlier reports, N fertilization effects on IVDMD of bermudagrass have been mixed. Webster et al. (1965) and Taliaferro et al. (1975) reported no effect of N fertilization on IVDMD, whereas Fribourg et al. (1971) and Belesky et al. (1991) observed an increase in IVDMD with N fertilization. The accuracy of standard in vitro digestibility techniques developed with cool-season forage species has been questioned (Anderson and Matches, 1983; Reid et al., 1988). The conflicting reports in the present study and inconsistencies of previous findings demonstrate the need for further evaluation of standard in vitro techniques.

The reduction in soil pH at high N fertilization is consistent with earlier studies (Adams et al., 1967; Rasmussen and Rohde, 1989). Bermudagrass has been shown to

tolerate low pH soils (Lundberg et al., 1977), but Burton and Hanna (1985) reported that addition of lime to soils with a pH below 5.5 was beneficial for bermudagrass growth. In support of this, Lundberg et al. (1977) reported that various bermudagrass cultivars grown in low pH soils responded with yield increases to lime rates up to 6.7 t/ha.

High N fertilization was also associated with a reduction in soil Ca and Mg, compared to low N fertilization. Adams et al. (1967) reported that high N fertilization of 'Coastal' bermudagrass and the subsequent drop in soil pH resulted in the downward movement of exchangeable Ca and Mg below 30 cm in the soil profile. The soil samples in the present study were to a depth of approximately 30 cm. The results of Adams et al. (1967) support the findings of this experiment.

Feedlot Trial. Lambs that had grazed at the very heavy stocking rate had higher daily gains, and were more efficient in converting feed to gain compared to lambs that grazed at the light, moderate and heavy stocking rates. Lambs that grazed at the heavy stocking rate did not compensate to any great extent in the feedlot. It was anticipated these lambs would perform similarly to the lambs at the very heavy stocking rate, because the restriction during grazing was similar. Dry matter intake in the feedlot was lowest for the heavy stocking rate lambs. Feed efficiency was better for these lambs, but ADG was only slightly better than for the light stocking rate lambs. No explanation is apparent for these results.

The results obtained for the very heavy stocking rate lambs are in agreement with those of Perry et al. (1971, 1972) but in contrast to Wilkinson and Prescott (1970) and Coleman et al. (1976). Perry et al. (1971, 1972) observed that, for each additional kilogram gained by cattle during the grazing season, they gained .2 kg less on the same amount of concentrate in the feedlot. In contrast, Coleman et al. (1976) and Wilkinson

and Prescott (1970) reported no effects of grazing gains on subsequent feedlot performance, while Lake et al. (1974) observed that cattle supplemented during the grazing season actually maintained a slight advantage in gain during the feedlot phase.

A possible explanation for the inability of researchers to consistently demonstrate compensation following undernutrition during grazing is the relatively mild level of restriction observed on pasture (O'Donovan, 1984). Wilkinson and Prescott (1970) reported no effect of grazing pressure on subsequent feedlot performance of cattle. However, the heavily-stocked cattle gained only .3 kg/d less than the lightly-stocked cattle (.59 compared to .89 kg/d, respectively). In the present study, lambs grazing at the heavy and very heavy stocking rate were under a relatively severe level of restriction (gaining 34 g/d) and, during several periods, lost weight. This level of restriction is more typical of studies in which compensation is observed (Turgeon et al., 1986; White et al., 1987).

The effects of compensatory growth on intake are inconclusive. Reports include no increase in total intake (Kabbali et al., 1992), no increase in intake per unit of metabolic body size (Drew and Reid, 1975), and increased intake (Graham and Searle, 1975; Wright and Russel, 1986) for compensating animals, compared to controls. In this experiment, lambs that grazed at the very heavy stocking rate consumed more total dry matter and more DM per unit of metabolic body size in the feedlot. If animals are lighter and consume more DM relative to body size, more energy will be available for growth (Wright and Russel, 1991). Lambs were lighter and did consume more DM relative to body size. Therefore, these lambs had more energy available for growth, partially explaining the increase in ADG.

Lambs that grazed at the very heavy stocking rate were 32% more efficient in converting feed to gain compared to the lightly-stocked lambs. These results are

consistent with those of Turgeon et al. (1986) and Kabbali et al. (1992). Reasons given for improved feed efficiency during compensatory growth include increased efficiency of energy utilization (Meyer and Clawson, 1964), lower maintenance requirements (Ledger and Sayers, 1977), and lower basal metabolic rate coupled with higher DM intake (Graham and Searle, 1975).

It appears the improvement in ADG for the heavily-stocked lambs resulted from a combination of increased intake and an improvement in efficiency of gain. Although heavily-stocked lambs did exhibit compensatory growth, the compensation was not complete. At the end of the 110 d feeding period, all lambs that grazed at the light stocking rate had reached 50 kg, whereas only 86, 49, and 69% of lambs that grazed at the moderate, heavy and very heavy stocking rates, respectively, had reached 50 kg. Furthermore, average time on feed for those lambs that reached 50 kg were 76, 90, 99 and 89 d for the light, moderate, heavy and very heavy stocking rates, respectively. The restriction of gain during the grazing season was too severe at the heavy and very heavy stocking rates to be fully compensated for within the 110 d feeding period. More research is needed concerning the level of restriction during the grazing season that can be compensated for in subsequent feeding periods.

Implications

Increasing stocking rate reduced gain per animal in both grazing trials, but total animal production per hectare increased as stocking rate increased in trial 1, and was highest at the moderate stocking rate in trial 2. Crude protein was higher in high N fertilized bermudagrass. Lambs that grazed at the very heavy stocking rate gained faster and were more efficient in the feedlot, but this compensation was not complete.

Bermudagrass appears to have persisted well in this climate. Carrying capacity of bermudagrass pastures is high, and 'Quickstand' bermudagrass may have potential as a forage resource in cool, temperate environments. More research is needed on the management and utilization of 'Quickstand' for optimal animal and forage productivity.

Chapter IV. LITERATURE CITED

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APPENDIX A

TABLE 1. COMPOSITION OF STARTER DIET^a USED IN FEEDLOT TRIAL

Ingredient	% of DM
Soybean hulls	46.77
Corn	40.91
SBM, 44%	8.19
Bentonite	1.66
TM Salt	.45
NH ₄ chloride ^b	.45
Fat	.45
Limestone	.42
Dicalcium phosphate	.43
Urea	.21
Vitamin mix ^c	.06

^aLasalocid included to provide 33 g per t of diet

^bIncluded to prevent urinary calculi

^cContributed the following per kg of diet: 1103 IU Vit A, 138 IU Vit D, 28 IU Vit E

APPENDIX A

TABLE 2. WEATHER DATA FOR GRAZING TRIALS 1 AND 2

Item	Mean temp. ^a		Total precipitation ^b
	Max	Min	
	-----°C-----		-----mm-----
Grazing trial 1			
May 1-30	27	12	105
May 31-June 26	27	14	123
June 27-July 24	31	16	78
July 25-Aug 21	28	15	86
Aug 22-Sept 18	<u>29</u>	<u>15</u>	<u>46</u>
Season avg.	28	14	Total 438
Grazing trial 2			
May 1-May 26	22	9	58
May 27-June 9	22	13	85
June 10-June 24	25	14	22
June 25-July 7	27	16	48
July 8-July 22	29	18	66
July 23-Aug 5	27	16	69
Aug 6-Aug 19	26	16	34
Aug 20-Sept 2	26	14	43
Sept 3-Sept 17	<u>27</u>	<u>13</u>	<u>27</u>
Season avg.	26	14	Total 452

^aData collected from location 19 km from research station

^bData collected from site located on research station

APPENDIX B

STATISTICAL MODELS

1. To test for differences in ADG of lambs during the grazing trials, the following model was used:

$$Y_{ijkl} = u + R_i + B_j + S_k + N_l + (SN)_{kl} + e_{ijkl}$$

Y_{ijkl} = the $ijkl$ th animal mean, u = the general mean, R_i = the effect of the i th replicate ($i = 1,2,3$), B_j = the effect of the j th block within the i th replicate ($j = 1,2,3,4$), S_k = the effect of the k th stocking rate ($k = 1,2,3,4$), N_l = the effect of the l th N rate ($l = 1,2$), $(SN)_{kl}$ = the interaction between the k th stocking rate and the l th N rate, and e_{ijkl} = residual error term.

2. To test for differences in forage mass, canopy height, and chemical composition within date, and soil constituents, lamb production and actual lamb grazing days per hectare, the following model was used:

$$Y_{ijk} = u + R_i + S_j + N_k + (SN)_{jk} + e_{ijk}$$

Y_{ijk} = the ijk th paddock mean, u = the general mean, R_i = the effect of the i th replicate ($i = 1,2,3$), S_j = the effect of the j th stocking rate ($j = 1,2,3,4$), N_k = the effect of the k th N rate ($k = 1,2$), $(SN)_{jk}$ = the interaction between the j th stocking rate and the k th N rate, and e_{ijk} = the residual error term.

3. To test for differences in forage mass, canopy height and chemical composition over all dates, the following model was used:

$$Y_{ijkl} = u + R_i + D_j + S_k + N_l + (SN)_{kl} + (DS)_{jk} + (DN)_{jl} + e_{ijkl}$$

Y_{ijkl} = the $ijkl$ th paddock mean, u = the general mean, R_i = the effect of the i th replicate ($i = 1,2,3$), D_j = the effect of the j th date ($j = 1,2,3,4,5$ in trial 1 and $j = 1,2,3,4,5,6,7,8,9$ in trial 2), S_k = the effect of the k th stocking rate ($k = 1,2,3,4$), N_l = the effect of the l th N rate ($l = 1,2$), $(SN)_{kl}$ = the interaction between the k th stocking rate and the l th N rate, $(DS)_{jk}$ = the interaction between the j th date and the k th stocking rate, $(DN)_{jl}$ = the interaction between the j th date and the l th N rate, and e_{ijkl} = the residual error term.

4. To test for differences in ADG of lambs in the feedlot, the following model was used:

$$Y_{ijk} = u + R_i + B_j + S_k + e_{ijk}$$

Y_{ijk} = the ijk th animal mean, u = the general mean, R_i = the effect of the i th replicate ($i = 1,2,3$), B_j = the effect of the j th block within the i th replicate ($j = 1,2,3,4$), S_k = the effect of the k th stocking rate ($k = 1,2,3,4$), e_{ijk} = the residual error term.

5. To test for differences in DM intake and feed efficiency of lambs in the feedlot within period, the following model was used:

$$Y_{ij} = u + R_i + S_j + e_{ij}$$

Y_{ij} = the ij th pen mean, u = the general mean, R_i = the effect of the i th replicate ($i = 1,2,3$), S_j = the effect of the j th stocking rate ($j = 1,2,3,4$), and e_{ij} = the residual error term.

6. To test for differences in DM intake and feed efficiency of lambs in the feedlot over all periods, the following model was used:

$$Y_{ijk} = \mu + P_i + R_j + S_k + (PS)_{ik} + e_{ijk}$$

Y_{ijk} = the ijk th pen mean, μ = the general mean, P_i = the effect of the i th period ($i = 1, 2, 3, 4, 5, 6, 7, 8$), R_j = the effect of the j th replicate ($j = 1, 2, 3$), S_k = the effect of the k th stocking rate ($k = 1, 2, 3, 4$), $(PS)_{ik}$ = the interaction between the i th period and the k th stocking rate, and e_{ijk} = the residual error term.

VITA

Scott Medford Baker, son of James A. and Yvonne R. Baker, was born October 24, 1968 in Scranton, PA. He graduated from Wyoming Valley West High School in Plymouth, PA. in June, 1986. He attended Lycoming College in Williamsport, PA. for 2 yr and received a Bachelor of Science in Animal Science from Cornell University in May, 1990. He married Jeanette Elizabeth Roycroft on June 1, 1991. In August of 1991, he entered a Master of Science program in Animal Science (Ruminant Nutrition) at Virginia Polytechnic Institute and State University.

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