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Performance of Meat Goats Control-Grazed on Winter Annual Grasses

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Summary

The performance of yearling replacement does and castrated male goats (*Capra hircus hircus*) controlled-grazed on cereal rye (CR; *Secale cereale* L.), annual ryegrass (RG; *Lolium multiflorum* L.) and triticale (TT; *Triticosecale rimpaui*) was evaluated during a 3-year study. Each year, 54 Boer and Boer-cross goats (avg initial age and BW: 8 mo to 10 mo and 30.4 kg, respectively) were assigned to nine plots (0.19 ha each) each containing six "tester" goats. Additional goats (put and take) were used to control forage growth. Forage species had no effect on ADG; however, castrated males gained more weight than does in year 2 (139 g/d vs. 94 g/d; $P < 0.003$) and during period 2 in year 3 (224 g/d vs. 146 g/d; $P < 0.0004$). Gain per ha was greater for RG than CR and TT (year 1: 514, 311, 293 kg, $P < 0.001$; year 2: 237, 144, 184 kg, $P < 0.004$; year 3: 528, 268, 149 kg, $P < 0.004$). In year 3, pH of ruminal fluid, ruminal ammonia and chilled-carcass yield from castrated males grazing RG, CR and TT was similar (avg: 6.67, 25.7 mg/dL and 51.3 percent, respectively), whereas plasma-urea nitrogen (16.4, 21.9, 24.1 mg/dL; $P < 0.024$), ruminal acetate (62.0, 60.7, 57.7 mM/100mM; $P < 0.017$), propionate (22.0, 25.2, 27.0 mM/100mM; $P < 0.006$) and acetate:propionate (2.83, 2.43, 2.22; $P < 0.017$) differed among forage species. Results indicated that yearling goats achieved satisfactory BW gains when fed only on these forages under controlled, rotational-grazing management, but that RG resulted in significantly greater BW gains per hectare.

Key Words: Annual Ryegrass, Cereal Rye, Meat Goat, Performance, Triticale

Introduction

In the Southeastern United States, meat goats (*Capra hircus hircus*) are becoming increasingly important contributors to the income of many small producers. Meat goats frequently obtain more than 50 percent of their daily ration from browse (Norton, 1984; Ball et al., 2007), but will perform well grazing cultivated pastures if grazing management practices are not in conflict with their grazing behavior. This "generalist" feeding behavior represents a clear advantage in the ability to utilize a variety of landscapes and plant communities. Furthermore, if managed to match goat-nutritional demands, these plant communities, represented by pasture and browse species, can provide an abundant, lost-cost, feed supply supplanting the need for expensive concentrates (Neuman et al., 1995). Nevertheless, few research data are available from the region specifically directed toward intensive grazing of cultivated pastures by goats reared for meat production. Muir (2006a) compared a range of stocking rates with crossbred-Boer doe kids grazed on cultivated, grass-legume winter pastures or examined the performance of crossbred-Boer doe kids grazing wheat (*Triticum aestivum* L.) pastures fertilized at different nitrogen (N) levels (Muir, 2006b). Lema et al. (2007) used continuous grazing and set stocking to evaluate the performance of weaned, crossbred-doe kids on tall fescue (*Schedonorus phoenix* [Scop.] Holub) cv. Kentucky 31 and two species of cereal grains, and Hart et al. (1993) examined the efficiency of high- and low-quality forage by three goat breeds. Our 3-year study was designed to evaluate the performance of replacement does and castrated males allowed to control-graze on cereal rye (*Secale cereale* L.) cv. Elbon (**CR**), annual ryegrass (*Lolium multiflorum* L.) cv. Marshall (**RG**) and triticale (*Triticosecale rimpaui*) cv. Resource Seeds 102 (**TT**).

Materials and Methods

Forage Establishment and Management

The 3-year study was conducted at North Carolina State University Field Research Station in Raleigh, N.C., located at approximately 35.8°N latitude and 78.7°W longitude. The climate is temperate, averaging 1,233 mm annual precipitation with annual maximum and minimum temperatures of 20.8°C and 10.1°C, respectively, during the periods of the study (NCSU, 2008-2011). Soils of the study area were Cecil Series (Clayey, Kaolinitic, Thermic, Typic Hapludults) on slopes ranging from 6 percent to 10 percent (USDA, 1970). The experimental area consisted of 1.7 ha divided into nine paddocks of 0.19 ha each. The experimental site, an old stand of tall fescue, was sprayed with glyphosate (Roundup, Monsanto Co., St. Louis, Mo.) approximately two weeks before each planting, and the remaining plant residue clipped a few days later. Forage species were no-till drilled (Marliss Soybean & Grain Drills, Jonesboro, Ark. [year 1 & 2]; Truax Co., Inc., New Hope, Minn. [year 3]) on 2 October (year 1), 26 September (year 2), and 2 October (year 3). In year 2, RG paddocks were replanted on 21 October. Seeding rates corrected for germination averaged 124 kg/ha, 35 kg/ha and 121 kg/ha for CR, RG and TT, respectively. Soil tests indicated the pH, P, and K were in the optimum range for plant growth; however, all forages were fertilized each year in November and February with ammonium nitrate at a rate of 56 kg N/ha.

Animals and Grazing Management

Each year 54, eight- to ten-month-old, growing, purebred Boer and Boer X Landrace (brush or wood) goats (year 1: four purebred Boer and two halfbred Boer/plot, initial BW 28.2 kg ± 0.6 kg; year 2: six halfbred Boer/plot, initial BW 31.0 kg ± 0.4 kg; year 3: one purebred, four three-quarter and one halfbred Boer/plot, initial BW 32.0 ± 0.4 kg) were stratified by BW, placed into six groups of nine animals with similar BW, assigned randomly to one of nine plots (three field replicates per forage species), and managed using controlled rotational grazing with electronetting (Premier1 Supplies, Washington, Iowa). Each year, the study was initiated based on multiple criteria, including mean-forage-canopy height (8 cm to 15 cm) and estimated-herbage mass (500 kg/ha to 1,000 kg/ha) based on calibrated-disk-meter values (Vartha and Matches, 1977). In year 1, all paddocks were stocked with six goats from start to finish, whereas in year 2 paddocks first were stocked with only three goats (Table 4). In year 3, variable stocking was used in December to January (Period 1) due to environmental conditions unfavorable to forage growth. Grazing resumed with six goats per paddock from the end of February until the termination of the study (Period 2). In the spring, these annual forages shift from vegetative to reproductive growth, in which forage quality declines rapidly and herbage production becomes sensitive to periods of dry weather. Therefore, each year, the study was terminated when forage quality was judged insufficient to support animal performance goals, based on a visual estimate of leaf-to-stem ratio (< 0.5), and quantity (canopy height < 5 cm and < 500 kg/ha), based on calibrated-disk-meter values.

In year 1 all six tester goats were females, whereas in years 2 and 3 two of the six tester goats per plot were castrated males. Goats were born and raised at the Small Ruminant Educational Unit of North Carolina State University in compliance with the North Carolina State University Institutional Animal Care and Use Committee regulations. Each goat was treated for elimination of gastrointestinal parasites (Ivermectin, 0.4 mg/kg BW; Merial, Division of Merck and Co., Rahway, N.J.) at the start of the trial. Goats were moved to a fresh strip of grass three to four times weekly depending on forage availability, and were excluded from the previously grazed strips to promote forage regrowth. Variable-stocking management was used with additional goats (2 to 14 goats/plot) available as put-and-take animals to control forage availability. Goats had free-choice access to water and movable shelters (Polydome, Litchfield, Minn.). Water was provided using underground, polyvinyl chloride (PVC) lines branching off at regular intervals with risers and valves (Kenkove Farm Fence, Blairsville, Penn.). Portable, UV-resistant, water troughs equipped with automatic float valves were tied to the underground water system using garden hoses fitted with quick couplings. This system allowed water troughs to be moved along with the animals with a minimum of effort and provided maximum, controlled-grazing flexibility. Goats were fed

approximately 20 g/goat loose minerals (SSC557-55001; Southern State Cooperative, Inc., Richmond, Va.) three times weekly and were weighed on-site every two to three weeks using an electronic scale (Tru-Test Inc., San Antonio, Texas).

Forage Measurements and Sampling

During the grazing season, forage measurements were taken at two-week intervals to characterize forage availability (Chamblee and Green, 1995). Height and mass of the forage were quantified during a random walk through each paddock using the average of 15 canopy heights and 15 compressed, bulk heights measurements of the forage (Vartha and Matches, 1977) using a falling-plate disk meter (area = 0.22 m^2, weight = 1.1 kg). The compressed, bulk-height readings were used to predict herbage mass based on a regression equation developed from paired sampling of quadrats from three short, three medium, and three tall forage samples. A compressed-height reading was taken from each quadrat, immediately followed by cutting the forage within the nine 0.25 m^2-quadrats. The forage was cut within 1 cm of ground level. Samples were then dried in a forced-air oven (BlueM - Lunaire Ltd., Williamsport, Penn.) at 55°C for 48 to 72 h, and weighed to determine herbage mass. Additional forage samples were hand-plucked as an estimate of the forage selected by the goats. Plucked samples were dried at 55°C as previously described, ground in a forage grinder (Wiley Mill, Thomas Scientific, Swedesboro, N.J.) to pass through a 1-mm screen, and stored in sealed, plastic bags until they were analyzed to determine chemical composition and *in vitro* true DM digestibility (IVTDMD).

Blood and Ruminal Fluid Collection

At the completion of the study in year 3, blood samples were collected by jugular venipuncture from the castrated males using 20-gauge, 2.54-cm needles and 10-mL vacutainer tubes containing K_2 EDTA solution as an anticoagulant (Becton Dickinson Vacutainer Systems, Franklin Lakes, N.J.). Blood samples were placed on ice for transport to the laboratory, centrifuged at 10,000 rpm for 10 minutes, and the plasma was frozen until analyzed. Ruminal fluid samples were taken from the same animals by stomach tube and ruminal pH was determined immediately using a Cardy Twin pH meter (Spectrum Technologies, Inc., Plainfield, Ill.). Ruminal fluid samples were then placed in a crushed ice and water solution to stop fermentation and then frozen until they were thawed in preparation for analysis. The castrated males then were harvested at a USDA-inspected, commercial facility.

Chemical Analyses

Hand-plucked forage samples were analyzed for DM and Kjeldahl N according to AOAC (1999). Kjeldahl N was multiplied by 6.25 to estimate crude protein (CP). Neutral-detergent fiber (NDF), acid-detergent fiber (ADF), and 72-percent, sulfuric-acid lignin (ADL) were determined sequentially according to Van Soest et al. (1991), as modified by Komarek et al. (1994), but without the addition of amylase and urea for starch removal. Cellulose was calculated as the difference between ADF and ADL plus ash, and hemicellulose as the difference between NDF and ADF concentrations. Acid-detergent lignin (ADL) was corrected for mineral matter by ashing the ADL residue in a muffle furnace at 400°C. In vitro true DM digestibility was determined using a 48-h incubation period in a batch fermenter (Ankom Technology, Fairport, N.Y.) with steer ruminal inoculum and buffer (Tilley and Terry, 1963) and NDF termination.

Blood plasma samples were thawed and plasma urea N (PUN) was determined colorimetrically by an automated diacetyl-monoxime method (Marsh et al., 1965). Ruminal-fluid samples were thawed and centrifuged at 3,600 rpm for 10 min. Eight milliliters of supernatant were mixed with 2 mL of 25-percent metaphosphoric acid. The mixture was covered, held at room temperature for 30 min, centrifuged again at 3,600 rpm for 10 min, and analyzed for ammonia and VFA. Ruminal VFA concentrations were determined on a Varian 3,800 gas chromatograph (Varian Chromatography Systems, Walnut Creek, Calif.) using a Nikol-fused, silica-capillary column (15 m; 0.53 mm i.d.; 0.5 μm film thickness; Supelco, Bellefonte, Penn.). Ruminal ammonia (RUA) was determined by the colorimetric procedure used for Kjeldahl N (AOAC, 1999).

Statistical Analyses

Data were subjected to ANOVA for a randomized complete block design with three field replicates (Steel et al., 1997) using the GLM procedure of SAS (2003) for the model Y = μ + replicate + forage species + replicate x forage species + residual. The interaction replicate x forage species was used as error term to test for forage species effects. In years 2 and 3, ADG data were analyzed for sex effects using the model Y = μ + replicate + forage species + sex + forage species x sex + residual. The residual was used as an error term to test for sex and forage species x sex effects. Forage means were examined using pre-planned, orthogonal contrasts (Steel et al., 1997). Average daily gain for each goat was estimated by linear regression of BW as a function of days on study using the REG procedure of SAS (2003).

Results and Discussion

Planting

Adverse weather conditions delayed planting 11 d to 17 d beyond the optimum planting dates in all three years (Table 1). In year 1, wet conditions in late summer delayed the building of fences and water lines followed on 6

Table 1. Planting season monthly cumulative precipitation during the 3-year study and 20-year average (mm), Raleigh, N.C., USA[a].

Month	Year 1	Year 2	Year 3	20-year avg
August	80	35	83	109
September	330	71	654	106
October	102	73	99	104

[a] NCSU (2008-2011).

September by a hurricane with wind gusts of 129 km/h and more than 211 mm of rain in 6 h to 7 h. Excessively wet conditions in year 3 again delayed planting as 220 mm and 197 mm of rain fell on the experimental site due to a tropical storm on 5 and 6 September and a hurricane on 15 and 16 September, respectively. In year 2, planting was delayed because of excessively dry conditions. In Piedmont of North Carolina, the best dates to plant winter annual grasses are between 25 August and 15 September, with possible planting dates extending from 20 August to 31 October (Green et al., 1995).

Herbage Quality

Concentrations of NDF, ADF, CELL and ADL in year 1, CP in year 2 and ADF and CELL in year 3 were lower in RG ($P < 0.002$ to $P < 0.04$) compared to CR and TT (Table 2). Differences between CR and TT ($P < 0.012$ to $P < 0.037$) were observed in year 1 for CELL and year 3 for NDF, ADF, HEMI and CELL. The IVTDMD did not differ among forage species, averaging 93.0 percent in year 1, 92.6 percent in year 2, and 94.7 percent in year 3. In addition, CP concentrations ranged from 25.0 percent to 14.1 percent, 26.0 percent to 16.4 percent and 26.6 percent to 12.6 percent for RG, CR and TT, respectively, in year 1, 24.4 percent to 10.7 percent, 27.5 percent to 16.4 percent, and 28.0 percent to 15.9 percent in year 2, and 32.0 percent to 18.9 percent, 32.6 percent to 23.9 percent and 33.4 percent to 24.0 percent in year 3 (data not shown). The lower CP concentrations resulted from stem elongation and head formation resulting in significant decreases in leaf-to-stem ratios at the end of the grazing season. Nevertheless, the chemical composition attested to the high quality of the grazeable forage, the CP concentrations and IVTDMD values observed being well above the nutritional requirements for actively growing or lactating meat goats (NRC, 2007). Comparable CP concentrations and decline in quality as the grazing season or the maturity of the herbage progressed were reported by Muir (2006b) for soft white wheat fertilized twice a year with 56 kg N/ha, as in the present study. Similar results were obtained by Short and Segelquist (1975) for CR cv. Elbon, Edmisten et al. (1998) for CR, wheat, oat (*Avena sativa* L.) and barley (*Hordeum vulgare* L.), and by Coblentz and Walgenbach (2010) for wheat, oat and TT cultivars. The latter authors reported slightly lower average IVTDMD values. Concentrations of CP reported by Lema et al. (2004; 2007) for two CR or several TT cultivars were either similar to or lower than those reported in the present study. Conversely, the NDF and ADF concentrations reported by the same authors were either higher (Lema et al., 2004) than those reported herein, or lower for NDF and higher for ADF (Lema et al., 2007). Finally, in an over-wintering study conducted from late November until mid-April with Angora does, Hart and Sahlu (1995) reported CP and ADF concentrations averaging 17.2 percent and 24.8 percent, respectively, for a pasture consisting of a mixture of ryegrass, cv. Marshall, and wheat.

Table 2. Chemical composition and *in vitro* true DM digestibility (DM basis, %) of annual ryegrass, cereal rye and triticale grazed as winter annual forages by meat goats, Raleigh, N.C., USA.

					Treatment Contrasts *P-value*	
Item[a]	RG[b]	CR[c]	TT[d]	SE[e]	RG vs CR + TT	CR vs TT
Year 1						
CP	18.54	20.81	19.07	0.99	0.31	0.28
NDF	42.11	43.65	45.01	0.55	0.029	0.15
ADF	20.37	21.56	22.77	0.37	0.018	0.09
HEMI	21.73	22.10	22.25	0.21	0.16	0.63
CELL	18.94	19.46	21.26	0.29	0.016	0.012
ADL	1.50	2.28	1.75	0.14	0.04	0.055
IVTDMD	92.21	93.60	93.17	0.43	0.09	0.52
Year 2						
CP	19.28	21.38	21.35	0.23	0.002	0.91
NDF	40.94	42.46	42.49	1.11	0.32	0.99
ADF	19.65	19.47	20.46	0.53	0.66	0.26
HEMI	21.29	22.99	22.03	0.62	0.18	0.33
CELL	17.68	17.06	18.28	0.59	0.99	0.22
ADL	1.53	1.98	1.92	0.13	0.054	0.77
IVTDMD	92.54	92.99	92.20	0.56	0.94	0.37
Year 3						
CP	26.73	27.58	28.59	0.44	0.066	0.18
NDF	37.78	40.63	37.87	0.57	0.10	0.026
ADF	17.99	19.22	18.50	0.17	0.012	0.037
HEMI	19.80	21.41	19.37	0.40	0.295	0.023
CELL	16.57	17.44	16.91	0.10	0.008	0.021
ADL	1.38	1.76	1.64	0.13	0.11	0.53
IVTDMD	94.79	94.98	94.35	0.20	0.63	0.095

[a] CP = crude protein; NDF= neutral detergent fiber; ADF = acid detergent fiber; HEMI = hemicellulose; CELL = cellulose; ADL = acid detergent lignin; IVTDMD = *in vitro* true DM digestibility.
[b] RG = ryegrass.
[c] CR = cereal rye.
[d] TT = triticale.
[e] SE = standard error of the mean from the statistical model.

Biomass Production, Grazing Periods and Goat Grazing Days

Herbage biomass was greater in year 1, followed by year 3 and finally year 2 (Table 3). Although the growing season

Table 3. The growing-season average and range of available biomass of annual ryegrass, cereal rye and triticale control-grazed with meat goats as winter forages, Raleigh, N.C., USA.

Item	RG[a]	Range	CR[b]	Range	TT[c]	Range
	kg DM/ha					
Year 1	3,606	1,904-4,815	3,436	2,240-3,919	3,639	2,352-5,151
Year 2	1,491	1,069-1,950	1,560	886-2216	1584	1,146-1,828
Year 3						
Period 1[d]	273	149-342	185	151-253	390	276-542
Period 2[e]	2,741	2,592-2,874	2,347	2,150-2,544	1,908	388-2,960

[a] RG = ryegrass.
[b] CR = cereal rye.
[c] TT = triticale.
[d] RG: 9 Dec to 18 Jan; CR: 9 Dec to 28 Dec; TT: 9 Dec to 28 Dec and 11 Jan to 20 Jan.
[e] 28 Feb until end of grazing (RG: 10 May; CR: 31 Mar; TT: 20 Mar).

was longer in year 2 (Table 4), the amount of biomass produced was half that of year 1 and nearly half that of year 3, due to environmental conditions unfavorable to forage growth. The higher-range values shown occurred toward the end of the grazing season, due to increased proportion of stem material. Similar increases in biomass were reported by Lema et al. (2004) when evaluating several cereal grain cultivars on small plots in Alabama. In addition, forage-availability values for period 1 (December to January) in year 3 were similar to those reported by Muir (2006b) for January. Hart et al. (1995) reported an average-forage availability of 3,478 kg DM/ha for a pasture consisting of a mixture of RG and wheat grazed by Angora does. Production values reported by Muir (2006b) for wheat pastures grazed by Boer X Spanish doe kids encompassed the biomass yields reported in the present study. Finally, many of the forage-DM production values reported by Lema et al. (2004) for two CR and several TT cultivars were lower than those reported in this study. In the present study, estimation of residual-forage biomass immediately after moving goats to a fresh strip of grass ranged from 413 kg/ha to 1270 kg/ha (data not shown), depending on the growth stage of the

Table 4.Grazing periods and number of grazing days per hectare in yearling meat goats managed on winter annual grasses using controlled, rotational grazing, Raleigh, N.C., USA.

Item	Grazing periods	Grazing season, No. days	Tester grazing days[a] No./ha	Put and take grazing days[a] No./ha	Total grazing days[a,b] No./ha
Year 1[c]					
RG[d]	28 Feb – 19 May	83	2,505	547	3,053
CR[e]	25 Feb – 14 Apr	48	1,474	0	1,474
TT[f]	28 Feb – 21 Apr	52	1,621	179	1,800
Year 2[g]					
RG	22 Jan – 4 May	102	1,432	1,200	2,632
CR	22 Jan – 8 Apr	76	1,200	532	1,732
TT	22 Jan – 23 Apr	91	1,437	758	2,195
Year 3[h]					
RG[i]	9 Dec – 18 Jan ; 28 Feb – 10 May	111	3,193	1,512	4,705
CR	9 Dec – 28 Dec; 28 Feb – 31 Mar	50	1,611	200	1,811
TT[j]	9 Dec – 28 Dec; 11 Jan – 20 Jan; 28 Feb – 20 Mar	48	1,263	139	1,402

[a] Grazing day = one animal grazing for one 24 hour period.
[b] Averaged across years 1 to 3: RG vs CR + TT, $P < 0.03$; CR vs TT, $P < 0.09$; SE = 436.
[c] 6 tester female goats/plot.
[d] RG = ryegrass.
[e] CR = cereal rye.
[f] TT = triticale.
[g] 3 tester female goat/plot until 3 Mar, then addition of 1 female and 2 castrated male tester goats/plot.
[h] All forages: 6 tester goats (4 females and 2 castrated males) 9 Dec to 28 Dec and 28 Feb until end of grazing.
[i] RG: 3 tester female goat/plot 28 Dec to 18 Jan.
[j] TT: 3 tester female goats/plot 11 Jan to 20 Jan.

forage and associated climatic conditions.

In year 1, grazing periods ranged from 28 February to 19 May for RG, 25 February to 14 April for CR and 28 February to 21 April for TT with six tester female goats grazed on each plot (Table 4). During year 2, three tester female goats were grazed from 22 January to 3 March on each plot, followed with six tester goats (four females and two castrated males) per plot until 4 May for RG, 8 April for CR, and 23 April for TT. In year 3, grazing started on 9 December with six tester goats (four females and two castrated males) per plot for each forage species. All goats were removed from the pastures on 28 December due to a lack of forage, with the exception of RG, where three tester female goats were left grazing per plot until 18 January. For TT, three tester female goats were grazed again on each plot starting 11 January. Five to seven cm of snow fell on the experimental site on 19 January, and all goats were removed from the plots on 20 January. In addition, 52 cm of snow fell on 24 January and covered the ground for the following 3 d. The combination of grazing TT for 9 d in January and heavy snowfall may have affected the subsequent regrowth of the plots that were last grazed, as evidenced by the range in TT biomass (Table 3) compared to RG and CR. Grazing of the three forage species resumed with six tester goats per plot on 28 February. Grazing ended on 10 May for RG, 31 March for CR, and 20 March for TT. The length of the grazing season in years 1, 2, and 3, respectively, were 83 d, 102 d and 111 d for RG, 48 d, 76 d and 50 d for CR, and 52 d, 91 d and 48 d for TT (Table 4). In addition, goats were grazed more days into spring on RG than CR (year 1 : + 35 d; year 2 : + 26 d; year 3 : + 40 d) or TT (year 1 : + 28 d; year 2 : + 11 d; year 3 : + 51 d), while differences between CR and TT were + 7 d and + 15 d for years 1 and 2, respectively, in favor of TT and -11d for year 3 in favor of CR. Differing from the strategy used in the present study, Muir et al. (2006a, b) used fixed, stocking rates to graze meat-goat kids on cultivated-winter pastures in east central Texas from January to April.

The total number of grazing days per ha (Table 4) averaged over the 3-year study was twice ($P < 0.03$) for RG (avg: 3,463) than for CR (avg: 1,672) or TT (avg: 1,799), with the latter two being similar ($P < 0.09$). The longer grazing season, as well as the greater number of goats grazed on RG paddocks as put-and-take animals to control forage growth, accounted for this difference.

Table 5. Average daily gain (ADG) and gain per hectare of meat goats managed on annual ryegrass, cereal rye and triticale under controlled, rotational grazing, Raleigh, N.C., USA.

					Treatment Contrasts *P-value*	
Item	**RG[a]**	**CR[b]**	**TT[c]**	**SE[d]**	**RG vs CR and TT**	**CR vs TT**
Average daily gain, g/d						
Year 1						
Female[e]	168.3	160.6	173.0	9.4	0.90	0.40
Year 2						
Female[f]	90.5	83.2	84.0	5.0	0.32	0.92
Short-term testers[g, §]						
Female	91.8	135.7	91.7	9.8	0.11	0.03
Castrated male	143.4	138.3	150.9	13.2	0.94	0.52
Year 3 – Period 1[h]						
Female	48.9	49.1	33.6	12.4	0.65	0.43
Castrated male	29.7	54.4	70.3	14.4	0.14	0.48
Year 3 – Period 2[j, ¶]						
Female	117.0	172.6	147.0	24.3	0.22	0.50
Castrated male	185.9	258.4	227.5	33.9	0.24	0.56
Gain/hectare, kg[k]						
Year 1	514	237	311	23	0.001	0.08
Year 2	237	144	184	10	0.004	0.05
Year 3	528	268	149	42	0.004	0.12

[a] RG = ryegrass.
[b] CR = cereal rye.
[c] TT = triticale.
[d] SE = standard error of the mean from the statistical model.
[e] 6 tester female goats/plot for duration of grazing season.
[f] 3 tester female goats/plot for duration of grazing season.
[g] 3 tester goats/plot (1 female, 2 castrated males) from 4 Mar until end of grazing.
[§] Sex effect: $P < 0.007$; Forage x sex interaction: $P < 0.04$; $SE = 13.0$.
[h] All forages: 6 tester goats/plot (4 females and 2 castrated males) 9 Dec to 28 Dec; RG: 3 tester female goats/plot 28 Dec to 18 Jan; TT: 3 tester female goats/plot 11 Jan – 20 Jan.
[j] All forages: 6 tester goats/plot (4 females and 2 castrated males) 28 Feb until end of grazing.
[¶] Sex effect: $P < 0.0004$; SE = 28.8.
[k] Gain/ha: ADG x No. grazing days/ha.

Average Daily Gain and Gain per Hectare

Forage species had no effect on ADG (Table 5) with the exception of CR vs. TT (135.7 g/d vs. 91.7 g/d; $P < 0.03$) in year 2 for the short-term female testers. Castrated males gained more weight than does in year 2 (139 g/d vs. 94 g/d; $P < 0.007$) and during period two of year 3 (224 g/d vs. 146 g/d; $P < 0.0004$). A similar growth rate pattern between castrated males and females was reported by Allan and Holst (1989) in grazed, Australian-bush kids. Differences

in ADG between sexes were similar across forages in year 3, whereas a forage-species-by-sex interaction was observed in year 2 ($P < 0.04$) as CR values were similar in both females and castrates. The low ADG observed for period one in year 3 was expected, due to the short grazing duration and the cold conditions that resulted in slow forage growth. Similarly, the harsh winter conditions encountered during year 2 of the study were reflected in lower ADG.

Gains per hectare (GHA) were greater (Table 5) for RG ($P < 0.001$ to $P < 0.004$) than for CR and TT each year of the study because CR and TT produced less biomass, resulting in fewer grazing-days-per-unit area (Tables 2 and 3). In addition, GHA in year 2 were greater for TT than CR ($P < 0.05$). Finally, GHA were 47 percent, 31 percent and 61 percent greater for RG than for the average of CR and TT in years 1, 2, and 3, respectively.

Hart et al. (1993) reported that growing Alpine, Angora and Nubian kids grazed on high-quality, wheat forage gained 50 g/d, whereas Kiesling et al. (1994) reported ADG ranging from 65 g/d to 141 g/d in growing Angora goats grazing CR. The performance-per-animal and per-unit area reported in the study herein were substantially higher than the values reported by Lema et al. (2007) and Muir (2006a, b). These differences arose from the objectives and approaches adopted. The former authors used continuous grazing at a set stocking rate of 12.5 goats/ha, and the latter authors used continuous grazing at stocking rates ranging from 5 goats/ha to 20 goats/ha, as well as several N-fertilization rates. We used a controlled-grazing approach with frequent moves and variable stocking using put-and-take animals in an attempt to control forage growth and optimize forage quality and animal performance. Physical location, climate, environmental conditions, soil fertility, animal age and genetics are among many factors that also will affect plant and animal response.

Ruminal pH, ruminal ammonia, plasma urea nitrogen, volatile fatty acids, full and empty live weight and hot and chilled carcass yield of castrated male goats (year 3).

Ruminal pH and RUA of castrated male goats (Table 6) were similar among forage species and averaged 6.67 and 25.7 mg/dL, respectively. These pH values were in the range appropriate for optimal activity of cellulolytic microflora (Church, 1979). Similar pH values (6.64) were reported by Molina Alcaide et al. (2000) with non-pregnant Granadina goats fed alfalfa (*Medicago sativa* L.) hay and with adult Damascus goats (Hadjipanayiotou and Antoniou, 1983) fed either barley or sudex (*Sorghum*, spp) hays of much lower quality (9.8 percent CP and 9.4 percent CP, respectively), or alfalfa hay of similar quality (23.3 percent CP). Conversely, lower pH values (6.4 and 6.2) and RUA concentrations (11.6 mg/dL and 5.6 mg/dL) were reported by Hart and Sahlu (1993) in yearling, Angora does grazing

Table 6. Ruminal pH, ruminal ammonia, plasma urea nitrogen, ruminal volatile fatty acids, full and empty live weight and hot and chilled carcass yield of castrated meat goats control-grazed on ryegrass, cereal rye and triticale as winter annual forages – determined at end of the study in year 3, Raleigh, N.C., USA.

					Treatment Contrasts *P-value*	
Item	RG[a]	CR[b]	TT[c]	SE[d]	RG vs CR and TT	CR vs TT
Ruminal pH	6.76	6.62	6.65	0.06	0.15	0.73
Ruminal ammonia, mg/dL	25.4	24.7	26.9	1.9	0.88	0.45
Plasma urea nitrogen, mg/dL	16.4	21.9	24.1	1.5	0.024	0.37
Volatile fatty acids						
Acetate (mM/100 mM)	62.0	60.7	57.7	0.59	0.017	0.023
Propionate (mM/100 mM)	22.0	25.2	27.0	0.63	0.006	0.114
Acetate:Propionate	2.83	2.43	2.22	0.11	0.017	0.23
Isobutyrate (mM/100 mM)	1.68	1.47	1.57	0.14	0.41	0.65
Butyrate (mM/100 mM)	11.01	9.56	10.24	0.41	0.09	0.30
Isovalerate (mM/100 mM)	2.12	2.01	2.41	0.13	0.47	0.13
Valerate (mM/100 mM)	1.20	1.01	1.09	0.05	0.06	0.30
Full live weight, kg	36.1	36.5	36.6	1.82	0.85	0.97
Empty live weight, kg[e]	35.1	35.3	34.8	1.76	0.97	0.87
Hot carcass yield, %	51.3	51.2	51.6	0.74	0.92	0.75
Chilled carcass yield, %	50.1	49.9	50.4	0.73	0.93	0.63

[a] RG = ryegrass.
[b] CR = cereal rye.
[c] TT = triticale.
[d] SE = standard error of the mean from the statistical model.
[e] Determined following overnight shrunk in a dry lot without feed or water

either alfalfa or sainfoin (*Onobrychis vicifolia* Scop.), respectively. Hart et al. (1993) recorded lower pH and RUA concentrations in 6-month-old to 8-month-old Alpine, Angora and Nubian kids grazing a high-quality wheat (avg: 6.35 and 9.83 mg/dL, respectively) or a low-quality bermudagrass pasture and fed 0.20 kg/d of a 24-percent CP supplement (avg: 6.25 and 7.17 mg/dL, respectively). In addition, lower RUA concentrations (6.5 mg/dL) were obtained in Angora does fed chopped bermudagrass (*Cynodon dactylon* [L.] Pers.) hay and limit-grazed for 2 hours daily on a wheat/annual-ryegrass pasture (Hart and Sahlu, 1995). Finally, lower pH and or RUA values as reported herein were recorded in crossbred, castrated goats fed orchardgrass hay (*Dactylis glomerata* L.) and soybean (*Glycine max* L.) meal (Moore et al., 2002b), orchardgrass hay and varying amounts of grain (Luginbuhl et al., 1999), or orchardgrass hay and increasing amounts of soybean hulls (Moore et al., 2002a). Lower ruminal pH values due to addition of concentrate feed to forage diets are well documented in goats, sheep and steers (Rumsey et al., 1970; Hadjipanayiotou and Antoniou, 1983).

The RUA values from the present study were higher than most values reported in the literature for goats fed all forage or mixed diets with the exception of the study by Molina Alcaide et al. (2000) in non-pregnant Granadina goats fed alfalfa hay (34.6 mg/dL). Values closest to those reported herein were obtained with castrated, mixed-breed goats from Southern Ethiopia (21.0 mg/dL) fed vetch (*Vicia dasycarpa* Ten.) hay (Woodard and Reed, 1997) and with castrated, crossbred-Boer goats (25.21 mg/dL) fed orchardgrass hay *ad libitum* and corn (*Zea mays* L.) gluten feed at 1 percent BW (Moore et al., 2002b). Johnson et al. (1973) indicated that because wheat-forage protein is highly soluble, it is likely to be readily degraded. According to Contreras-Govea and Albrecht (2006), oat cultivars that are sown in late summer and harvested 77 d later contained high concentrations of both CP and water-soluble carbohydrates. The high values obtained in the present study could be due to the high-CP concentrations of RG, CR and TT (Table 2). In addition, the supply of water-soluble carbohydrate and N in terms of timing and amount may have been less than adequate to provide a ruminal environment favorable to the optimization of microbial growth (Hoover and Stokes, 1991). According to Mehrez et al. (1977), however, 23.5 mg RUA/dL are necessary to maximize the rate of barley DM fermentation, whereas Ørskov (1982) suggested that lower values (20 mg/dL) are adequate for highly fibrous diets.

Castrated male goats grazed on RG had lower PUN (16.4 mg/dL; $P < 0.024$) concentrations than goats grazed on CR or TT (avg: 23 mg/dL). Concentrations of 25.6 mg/dL (Hart et al. 1993) were observed in Alpine, Angora and Nubian goats grazed on high-quality, wheat pasture (19.8 percent CP), whereas Luginbuhl et al. (2009) reported PUN values of 26.2 mg/dL in does suckling kids and grazed on three, tall-fescue cultivars (avg CP: 20.6 percent), Conversely, Lema et al. (2007) reported lower PUN values (avg: 14.7 mg/dL) in crossbred does grazed on CR (18.7 percent CP) or TT (18.3 percent CP). Similarly, Serrato-Corona et al. (2011) obtained PUN values of 17.6 mg/dL in young Alpine goats fed oat hay (8 percent CP). In addition, feeding sericea lespedeza (*Lespedeza cuneata* [Dum.-Cours] G. Don) or alfalfa hay (11.2 percent CP and 18.7 percent CP, respectively) with a 16 percent CP corn/cottonseed-based supplement to bucklings, Turner et al. (2005) recorded PUN values of 10.7 mg/dL and 21.1 mg/dL, respectively. Finally, growing, purebred- and crossbred-Boer bucks fed 71-percent orchardgrass hay and 29-percent concentrate mixture had PUN concentrations of 13.6 mg/dL (Luginbuhl et al., 2000). These results contrast with findings by Wildeus et al. (2007) who reported PUN concentrations of 30 mg/dL or above when feeding orchardgrass and alfalfa-hay-based diets with limited-concentrate supplementation to Spanish, Boer and Boer-cross wethers. As for RUA, differences in dietary protein, protein degradability in the rumen and protein-to-energy ratios may account for the dissimilarity of PUN results between studies. Stevens et al. (1994) reported average PUN concentrations of 17.6 mg/dL in clinically healthy, adult goats from a random sample of 30 farms from a list of clients of the College of Veterinary Medicine at North Carolina State University and Smith and Sherman (1994) indicated that normal PUN values are in the range of 10 mg/dL to 28 mg/dL. In the present study, the lower PUN concentrations found in the castrated goats grazed on RG are surprising given that RUA concentrations were similar across forages. According to Ørskov (1992), PUN and RUA are correlated positively, PUN being a function of ammonia absorption from the rumen and lower tract, and of the efficiency of protein utilization. The same author further indicated that PUN closely reflects dietary N balance from the perspective of the nutritional requirements of the host animal and of the ruminal microorganisms. The higher PUN concentrations observed in goats grazed on CR and TT may indicate a larger degree in excess N consumption relative to energy (Hammond et al., 1994). Additionally, non-protein N compounds can account for as much as one third of the total N in pasture herbage (Maynard et al., 1979).

Ruminal-acetate ($P < 0.017$) and propionate ($P < 0.006$) concentrations (Table 6) were higher and lower, respectively, in goats grazed on RG compared to those grazed on CR and TT, resulting in a greater acetate:propionate ratio ($P < 0.017$). In addition, ruminal-acetate concentrations were higher ($P < 0.023$) in goats grazed on CR than in those grazed on TT. Concentrations of isobutyrate, butyrate, isovalerate and valerate were similar across forage species. The VFA values reported herein were within the range of values typical of ruminants fed all forage diets (Maynard et al., 1979). Similar VFA values were reported by Hart et al. (1993) in Alpine, Angora and Nubian goats grazing high-quality wheat pasture (19.8 percent CP) and by Molina Alcaide et al. (2000) in non-pregnant Granadina goats fed high-quality alfalfa hay (18.1 percent CP). Butyrate values from the present study, however, were twice the values reported by Hart et al. (1993).

Full and empty BW and hot-and-chilled-carcass yield did not differ among forages (Table 6), and all harvested goats graded choice (data not shown). Similar chilled-carcass yields were reported by Johnson et al. (2010) for goats on a grazing- and hay-feeding system sacrificed at BW comparable to those reported herein.

Conclusions

Results indicated that these winter annual grasses were of excellent quality and exceeded the nutritional requirements of growing replacement stock. Growing goats achieved satisfactory weight gains when fed only on these forages under controlled-rotational-grazing management; however, RG resulted in superior per-hectare-live-weight gains. It seems evident that these winter annual grasses could represent a flexible and valuable component of a perennial-pasture and browse-based feeding system.

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