Correlation of steer average daily gain with diet quality and forage phenology in an improved annual grassland

CHARLES A. RAGUSE, JAMES G. MORRIS, AND VIRGINIA N. LANDRY

Abstract

Management of legume-improved annual range forage is made difficult by the rapid declines in nutritive quality and animal gains as the plants mature. An improved ability to predict occurrence of the critical spring grazing period (CSGP) when these declines begin would help in making livestock management decisions. Objectives of this study were to construct a model to describe seasonal changes in steer average daily gain (ADG); to observe changes in nitrogen concentration ([N]) and in vitro organic matter digestibility (IVOMD) related to time of season and ADG; and to relate the phenological progress of maturation of rose clover (*Trifolium hirtum* L.) to ADG, [N], and IVOMD. Data from 5 years of a grazing experiment were used to construct the ADG model, which consisted of 3 season-related zones which were described by a series of linear and quadratic functions. Data for [N] and IVOMD from 2 spring seasons of sampling with esophageally fistulated steers, and from 1 season of hand-cut sampling of rose clover and other plant species from annual range were related to the CSGP. Nitrogen content of the forage was a more useful predictor of rapid ADG change during the CSGP than was IVOMD. The CSGP midpoint coincided with an approximately 0.5:0.5 mixture of 2 well-defined maturation stages of rose clover.

Key Words: esophageal fistula samples, organic matter digestibility, nitrogen content, phenological development, *Trifolium subterraneum, T. hirtum, Erodium* sp.

Authors are professors, Agronomy and Range Science and Animal Science Departments respectively, and undergraduate student intern, Animal Science Department (deceased), University of California, Davis 95616.
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Annual range forage is commonly grazed with stocker steers on California's annual rangelands (Oltjen et al. 1982, Wolters and Eberlein 1985). Annual legumes frequently have been introduced to improve yield and nutritional quality of the forage. Despite this, the characteristic changes in nutritional quality of the grass-legume-forb community with advance in maturity can lead to rapid and sharp declines in average daily gain (ADG) (Raguse et al. 1984, 1988). This is the spring "critical period" in grazing management as applied to improved annual grasslands.

Determination of an appropriate ending date for the grazing season has both biological and economic value (Vantassell et al. 1987). Indicator plant species and their developmental growth stages are potentially useful in this regard.

Objectives of this study were to construct a general, descriptive model from seasonal changes in steer ADG observed over 5 consecutive grazing seasons, to describe related changes in the nutritive value of the currently grazed forage at the time of seasonal decline in ADG, and to relate phenological changes in maturing rose clover to this critical period of the grazing season.

Materials and Methods

The study was conducted at the University of California's Sierra Foothill Range Field Station, Browns Valley, Yuba Co., Calif., a location representative of the lower-foothill oak woodland zone of the northern Sierra Nevada mountains. The field site was approximately 330 m elevation at 39° 14″N, 121° 18″W. Herbaceous vegetation, which is almost completely annual, is a variable mixture of grasses, legumes and other forbs. The soils are fine to fine-loamy, mixed, thermic Mollic Haploxeralfs or Typic Rhodoxeralfs (Alfisols).

The research plots consisted of 16 13.2-ha pastures in an area which previously had been control burned to remove woody vegetation (1966), re-seeded with the annual legumes subterranean clover (*Trifolium subterraneum* L.) and rose clover (1971 to 1974), and used in various grazing management studies since 1968. Botanical composition measurements documented existence of a stable annual plant community (Raguse et al. 1988).

In 1982 a 3-yr range fertilization experiment was initiated, using the 16 pastures as 2 replicates of 7 fertilization treatments (each replicate of the control consisted of 2 pastures) in a randomized complete block design. Beginning mid- to late November, each field was uniformly stocked with steers (initial weight approximately 215 kg) at an average of 2.5 ha steer^{-1}. Two subsequent increases in stocking rates within each season were based on forage levels measured along permanent transects in each field. The stocking rate increases were made to reduce within-season differences in forage allowance and to maintain it at comparable levels across fertilizer treatments. No animals were removed before the end of the grazing season. Grazing was terminated when forage quality declined to a point where approximately zero gain could be estimated from previous weighings. Other details of experimental procedures were given in Raguse et al. (1984, 1988).

Part of the work reported here was done during the 1983–84 grazing season. Forage samples were collected using esophageally-fistulated steers or were hand-cut where the steers were grazing. Samples were taken from 12 April to 1 June 1984 from 2 replicate pastures of the control and the following 3 fertilization treatments:

90 kg ha^{-1} N;
0 kg ha^{-1} N, 67 kg ha^{-1} P, 74 kg ha^{-1} S;
90 kg ha^{-1} N, 34 kg ha^{-1} P, 37 kg ha^{-1} S

Fistula-collected samples were taken as follows. The 2 steers were released into a sample field the day before sampling. About 1 hour after dawn on the following morning, they were harnessed for sampling using solid bottom collection harnesses. Ordinarily, 16 samples were collected per field, or 8 samples per steer. Sampling time averaged from 40 minutes to 1 hour. The samples were placed in plastic bags, labeled, and stored in a freezer until processed. After sample collection the steers were immediately moved to the next field where they remained overnight to become accustomed to the field and the steers in it.

Hand-cut samples of rose clover, subclover (*Trifolium subterraneum* L.), filaree (*Erodium botrys* L. and *E. cicutarium* L.), and a mixture of the principal forage grasses (primarily *Bromus, Festuca, Avena,* and *Hordeum* species) were taken from 16 April to 12 May 1984. Samples of the 4 species or species groups were chosen to represent forage that was being grazed. Three samples of each category were taken near the location of fistula sampling in each replicate pasture. The samples were dried to constant weight in a forced air oven at 57° C, ground through a 1-mm screen, and stored until analyzed.

Because fistula-collected samples were taken only from 1 pasture a day and hand-cut sampling was coordinated on the same day, 1 replicate of the 4 fertilizer treatments was sampled in sequence, usually in 4 consecutive days. This was followed by sampling of the second replicate, whereupon the full sampling schedule was

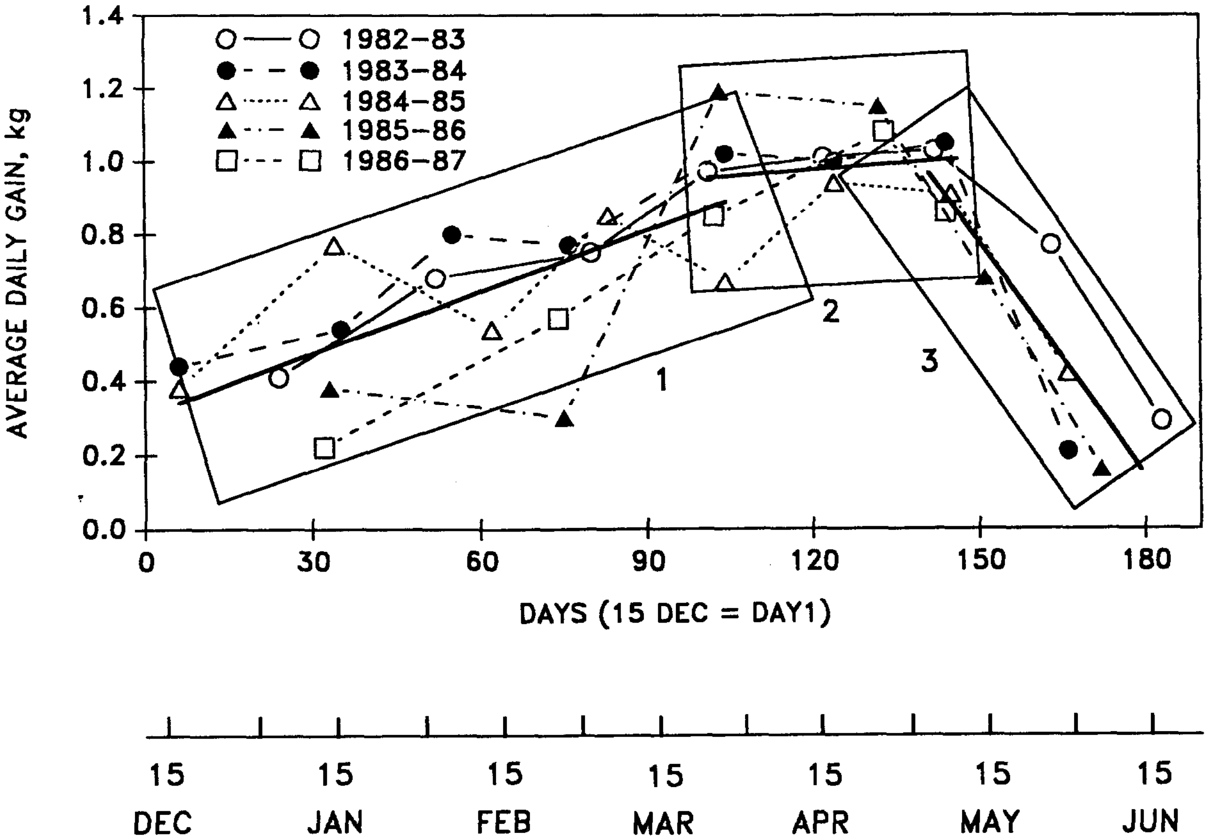

Fig. 1. *Average daily gains (ADG) over 5 consecutive grazing seasons, showing 3 within-season zones and the spring critical grazing period. Each point is the mean of 2 field replicates of 6 fertilizer treatments and a control (the latter used the mean of 2 fields as a replicate) (n = 16). See Table 1 for equations.*

Table 1. Relationship of average daily gains (ADG) of steers and of fistula-collected forage sample concentrations of nitrogen ([N]) and in vitro organic matter digestibility (IVOMD) to time of season on improved annual range pastures.

Parameter	Year(s)	Equation	r^2/R^2	Equation No.
		Fig. 1		
ADG, Zone 1 (1 Dec. to 1 Apr.)	$\bar{x}$, 1983–87	ADG = 0.307 + 0.0056X[1]	0.52*	1
ADG, Zone 2 15 Mar. to 10 May)	$\bar{x}$, 1983–87	ADG = 0.943 + 0.0013X	0.02	2
ADG, Zone (1 May to 15 June)	$\bar{x}$, 1983–87	ADG = 1.05 – 0.021X	0.79**	3
		Fig. 2		
ADG, 15 Mar. to 15 June	$\bar{x}$, 1983–87	$ADG = 0.803 + 0.15X - 0.00026X^2$	0.74**	4
		Fig. 3		
ADG, 15 Mar. to 15 June	$\bar{x}$, 1983–84	$ADG = 0.880 + 0.12X - 0.00021X^2$	0.78**	5
[N], 15 Mar. to 15 June	1983	[N] = 3.22 – 0.022X	0.80**	6
IVOMD, 15 Mar. to 15 June	1983	$IVOMD = 71.2 + 0.021X - 0.0026X^2$	0.93**	7
[N], 15 Mar. to 1 June	1984	[N] = 2.66 – 0.017X	0.89**	8
IVOMD, 15 Mar. to 1 June	1984	$IVOMD = 38.3 + 0.173X - 0.0026X^2$	0.58*	9

*,**Regressions significant at $P<0.05$ and 0.01, respectively.
[1]X = Days following calendar date indicated.

repeated. For purposes of data analysis and presentation, fertilizer treatment samples were combined and reported on the mid-point dates of each sampling interval: 12, 18, and 25 April and 4, 10, 16, and 30 May. Hand-cut sampling of subterranean clover and filaree was discontinued after 5 May because their availability had declined so that they were no longer an important part of the diet and it was not practical to collect samples of sufficient size for laboratory analysis.

The average botanical composition for the 8 pastures sampled (step-point cover, 16 March) was: rose clover, 14%, CV=41%; subterranean clover, 20%, CV=15%; filaree, 19%, CV=39%; and forage grasses, 35%, CV=13%. The remaining 12% of cover was composed of miscellaneous species of variable proportions and minor amounts.

As the plant samples were taken, the average phenological stage of development of rose clover was recorded using the following five-stage system.

0: Plants vegetative
1: Plants green, each having one or more visibly developing heads, heads green.
2: Plants green, with at least one-half of the heads in flower (flower color apparent).
3: Plants beginning to dry, flower color disappeared (petals dried) on at least one-half of the heads.
4: Plants completely dry, no green color remaining.

Hand-clipped plant samples and samples collected using esophageally fistulated steers were analyzed for nitrogen concentration [N] and organic matter (A.O.A.C. 1975). In vitro digestibility of organic matter (IVOMD) was measured by the two-stage procedure of Tilley and Terry (1963).

The 3-year study reported by Raguse et al. (1988) was extended by 2 additional grazing seasons (1985–86 and 1986–87) to further assess within-season forage-animal relationships. Experimental conditions were the same as in the first 3 years except that only animal weight, forage level (kg ha^{-1}), and botanical composition data were collected. Only the ADG data are reported in this paper.

Data were analyzed using analysis of variance. Linear and nonlinear regression procedures were used to determine significance ($P<0.05$) of trends in ADG, [N], and IVOMD over time.

Results and Discussion

Although [N] and IVOMD in the sampled forage in 1982–83 were influenced by fertilizer treatment (Raguse et al. 1988), this was much less so in 1983–84. By the fourth year (1985–86), differences in animal gain per unit area due to fertilizer treatments no longer were significant ($P>0.05$). In order to simplify presentation of results from the current study, all data for ADG, [N], and IVOMD will be combined over fertilizer treatments.

Figure 1 presents annual means (each data point is the mean of the 16 fields) for 5 grazing seasons for each weigh date for which ADG could be calculated. The data set can be divided into 3 zones, each reducible to a summary linear regression. In the first zone, ADG is characterized by generally rising values (Table 1, Equation 1). Lower ADG values than at the preceding weigh date seldom occurred and were followed by obvious compensatory gain. The second zone represents attainment of the maximum seasonal animal performance possible under the various constraints of the system (Equation 2). Its duration and peak ADG are the integrated result of animal, plant, soil, and weather-year conditions. The third zone begins abruptly and is related to maturation of the annual plant species, with the concomitant loss of nutritional quality (Equation 3). Frequently associated with the transition from zone 2 to zone 3 are important changes in plant species acceptability, which lead to differential, or patchy, grazing and large changes in grazing pressure as it is related to individual plant species.

The 3 linear regressions of Figure 1 converge near 1 May. We will define this date as the mid-point of a month-long "critical spring grazing period (CSGP)", a period of time during which management decisions relative to end-of-season must be made. As defined, the CSGP coincides with the end of zone 2, immediately prior to the period of rapidly declining ADG.

In Figure 2 we have isolated the 20 data points of zones 2 and 3 for the 5-year period. Each point represents a total of 16 pastures with a sample size of 15 to 25 animals per pasture. All 20 points of zones 2 and 3 from 1983–1987 fit a quadratic function (Table 1, Equation 4, n=20, r^2=0.74; and Fig. 2). This simple but plausible mathematical model for describing seasonal changes in ADG can be constructed given a representative sampling of variation within the grazing season and across years (Fig. 1). This analysis then provides the basis for a quantitative description of the transition between the CSGP and the subsequent precipitous decline in ADG (Fig. 2, Table 1).

The equation which describes the combined 1983 and 1984 ADG data from zones 2 and 3 (Table 1, Equation 5, n=9, r^2=0.78; and Fig. 3) is quite similar to the 5-year summary equation and the maxima

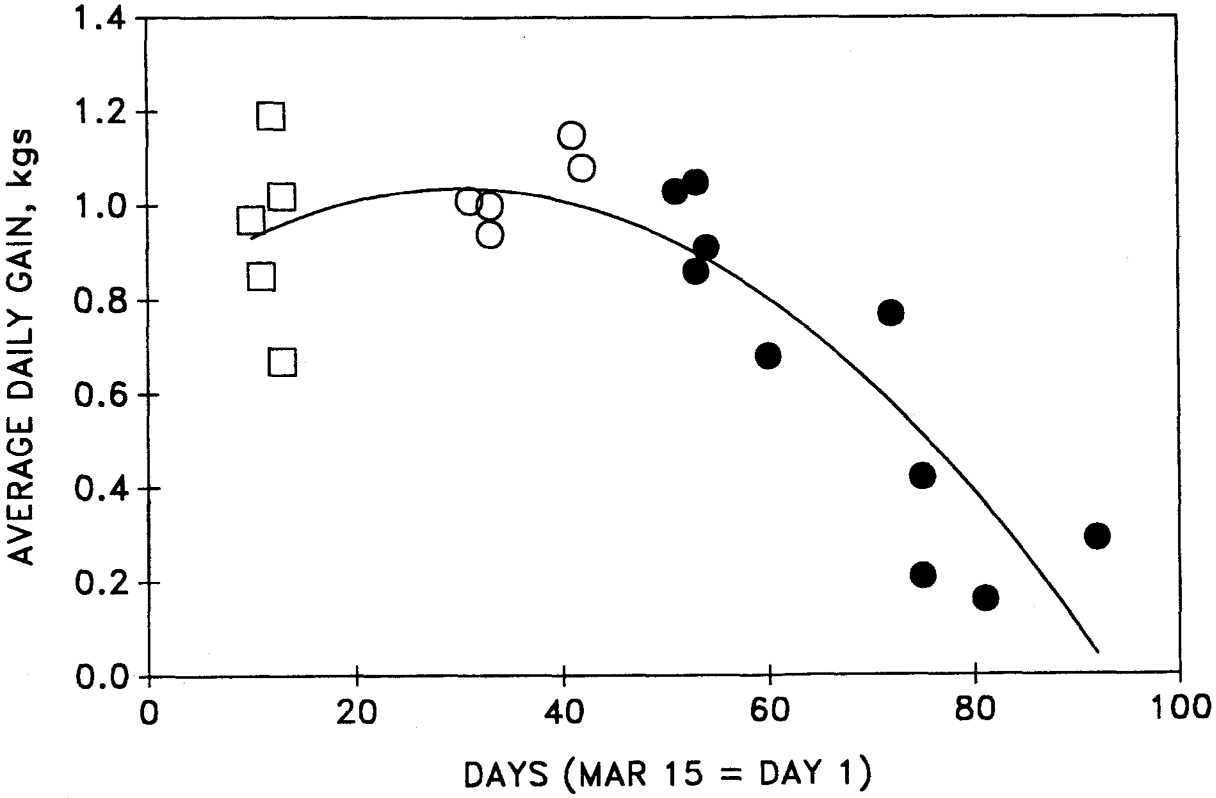

Fig. 2. *Transition of ADG from zone 2 (open symbols) to zone 3 (closed symbols), 1983–87. See Table 1, equation No. 4.*

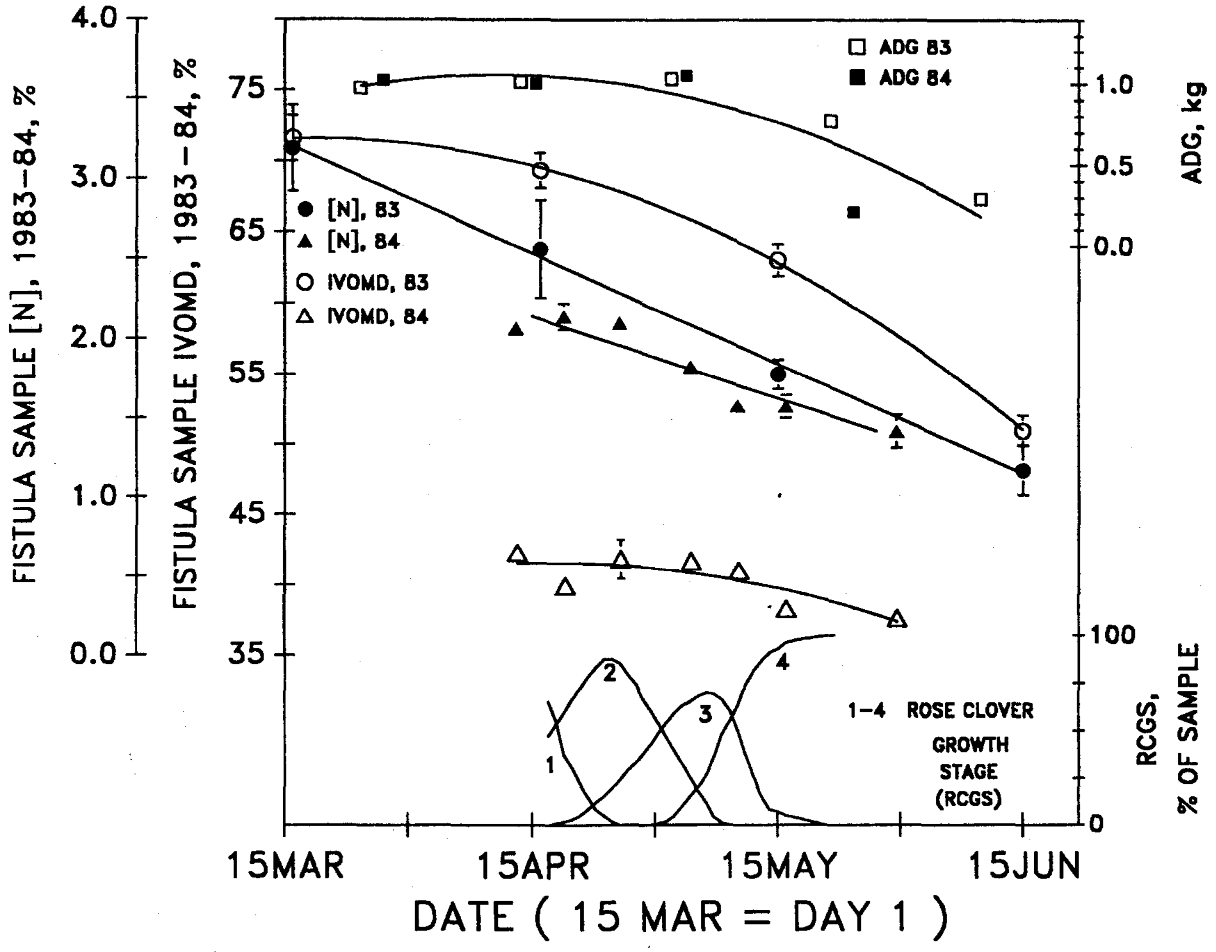

Fig. 3. *Average daily gains (ADG) in zones 2 and 3 and related [N] and IVOMD values from esophageally fistulated steers in 1983 and 1984, and phenological development of rose clover during 1984. See Table 1 for equations.*

of both curves fall on 13 April. The remainder of Figure 3 presents [N] and IVOMD from esophageally collected samples for both years, and the sequence of phenological stages for rose clover in 1984. Regression equations describing the time-related trends of [N] and IVOMD are given in Table 1. Although the time interval covered by analyses for [N] and IVOMD was shorter in 1984 than in 1983, the closer spacing of sample dates permitted a more precise description of the decline. They also were well located with respect to the (later) defined CSGP. Peak IVOMD values, calculated from the first derivatives of Equations 7 and 9, occurred on 19 March 1983 and 17 April 1984. Values for [N] were comparable for the 2 years (Eq. 6, 8). And, despite the disparity between absolute values for IVOMD for the 2 years, the pattern and rate of decline (1 May values were 94% and 104% of 15 March values for 1983 and 1984, respectively) was similar (Eq. 7, 9). Diet samples in 1983 and 1984 were collected by different samplers. Hart et al. (1983) have reported that years accounted for a significant fraction of the variation in IVDMD determined on esophageally fistulated cattle collected diet samples, while values for crude protein agreed well. The closeness of ADG values for April and May of 1983 and 1984 (Fig. 3) is evidence that dietary quality and availability were similar for the 2 years. However, neither [N] nor IVOMD demonstrated changes abrupt and consistent enough to serve alone as reliable predictors of the ADG decline. Moreover, sampling and sample processing costs together with laboratory turnaround time would normally discourage their use as real-time management decision aids.

A potentially useful predictor of impending ADG decline is the phenological maturation of an appropriate indicator plant. In Figure 3, changes in the development of rose clover are related to the previously described changes in ADG, [N] and IVOMD. Rose clover exhibits several desirable characteristics for an indicator species. It is now almost ubiquitously distributed in annual range communities, has a determinate pattern of inflorescence development, demonstrates a nearly time-linear sequence of the chosen phenological stages ($Y = 1.245 + 0.0985X$ $r^2 = 0.95$, where Y = average stage of development and X = the number of days from 18 April under 1984 growth conditions), and has distinctly different maturation stages which are readily identifiable. For the environmental conditions represented by the study, the estimated peak ADG (near 1 May) occurred when the number of rose clover plants at stage 2 was declining while those at stage 3 were still increasing. Only minor variations in stage sequence were observed in relation to fertilizer treatments. Variations due to site differences were more apparent, but these could be used to advantage in differential management of rangeland units where important microclimatic-edaphic differences exist, e.g., as for north- and south-facing slopes.

Limited resources precluded more extensive analysis of hand-cut plant samples. However, all samples analyzed were collected within the CSGP. Samples collected near the time of disappearance of subterranean clover and filaree (midpoint = 4 May) showed [N] of grass and filaree to be similar (1.4 and 1.3%, respectively), as were rose and subterranean clovers (2.1 and 2.3%, respectively). Differences in [N] between the 2 groups were significant ($P<0.01$). The IVOMD values of rose and subterranean clover and filaree (49, 52, and 49%, respectively) were similar, but IVOMD of the grasses was only 41%. These average group differences also were significant ($P<0.05$).

The plant species composition of steer diets was not measured, but as availability of earlier-maturing and nutritious species (e.g., subterranean clover) declined, it is likely that change in species composition of the diet was a significant factor in initiating the ADG decline (Ridley et al. 1986). The principal remaining plants were the mixture of annual grasses and rose clover. The quality of these continued to decline. For example, over the 18-day period from 24 April to 12 May, IVOMD of hand-cut samples of grasses and rose clover declined at the following rates (Y = IVOMD, X = days from 24 April):

$$Y_{grasses} = 47.5 - 0.337X,\ r^2 = 0.99,\ P = 0.062$$

$$Y_{rose\ clover} = 53.6 - 0.267X,\ r^2 = 0.56,\ P = 0.26$$

the [N] of grasses also declined similarly, as

$$Y_{grasses} = 1.76 - 0.019X,\ r^2 = 0.82,\ P = 0.094$$

but [N] of rose clover did not change

$$Y_{rose\ clover} = 2.08 - 0.000024X,\ r^2 = 0.01,\ NS$$

Interpretation and Application

The rose clover phenology data from 1983–84 indicate that one should expect to find roughly equal amounts of stages 1 and 2 (with 1 decreasing and 2 increasing) and very little of stage 3 at the beginning of the CSGP. At the CSGP midpoint, roughly equal amounts of stages 2 and 3 will be present with stage 4 beginning to appear. Finding stage 3 rapidly disappearing and stage 4 predominating would indicate that the CSGP is ending and ADG is already declining.

If the equations for IVOMD and [N] are used to estimate their values at the 1 May CSGP midpoint, 1983 predicted values were approximately 67 and 2.2%, and 1984 values were approximately 41 and 1.9%, respectively.

It appeared that [N] was a more reliable indicator of steer diet quality decline than was IVOMD. A working hypothesis for use of [N] data to predict the CSGP midpoint would be to find [N] at 2% following a 30% decline over the previous 6-week period. Ridley et al. (1986) concluded that N content was particularly important as a determinant of nutritive value as plants approached maturity; they also reported significant differences in the N balance of sheep diets where either subterranean clover or rose clover were fed in spring or late spring. Our results suggest that, with good judgement, careful observation, and a few years experience, the combination of well-timed recording of seasonal weight gains, keeping track of key species (especially subterranean clover) availability, and following phenological development of an appropriate indicator species can aid a range manager in determining when to end the grazing season. Plant sample analysis for [N], if available and affordable, would provide additional information of value.

Finally, it is worth noting that the coherence and uniformity of the 5-year set of ADG was somewhat unexpected. There were important differences in weather-year characteristics, soil fertility, and species composition and availability during this time. Despite this, and under the grazing management employed (Raguse et al. 1988), the within-season pattern of ADG obviously provided a valuable reference based against which forage quality measures could be evaluated. It is also a measure which is feasible for many, if not most, ranch or grazing managers to employ.

In Memoriam

This paper is dedicated to the memory of Virginia ("Ginny") Landry, whose hard work and cheerful outlook contributed an important dimension to this study.

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