Quality of Forage and Cattle Diets on the Wyoming High Plains

R.H. HART, O.M. ABDALLA, D.H. CLARK, M.B. MARSHALL, M.H. HAMID, J.A. HAGER, AND J.W. WAGGONER, JR.

Abstract

Diets of cattle grazing crested wheatgrass [*Agropyron desertorum* (Fisch.) Schult.] or native range pastures and major forage species in these diets were analysed for crude protein (CP), acid and neutral detergent fiber (ADF and NDF), lignin, and in vitro dry matter disappearance (IVDMD) 1975-1978. Objectives were to determine (1) rate of change in forage quality, (2) effect of weather on rate of change, and (3) degree of selection for diet quality by cattle. CP of 6 forage species declined .03-.23 percentage points/day, while IVDMD declined .06-.90 points/day. CP and IVDMD of western wheatgrass (*Agropyron smithii* Rydb.), blue grama [*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.], and scarlet globemallow [*Spahaeralcea coccinea* (Pursh.) Rydb.] were high in spring, while ADF, NDF, and lignin were low, but quality of grasses decreased much faster than that of the forb. Quality of needleandthread (*Stipa comata* Trin. & Rupr.) was lower than that of the other two grasses in spring, but CP declined more slowly then, while IVDMD declined at the same rates as that of blue grama and western wheatgrass. Quality of sedges (*Carex* spp.) was similar to that of western wheatgrass and blue grama in spring, but CP decreased faster while fiber components increased slower than those of grasses. CP of western wheatgrass and blue grama was increased by abundant spring rainfall, while that of blue grama increased after heavy summer rains. As the season progressed, cattle on range selected diets higher in crude protein and lower in cellulose than expected on the basis of botanical composition of the diet and composition of individual species. Quality of forage consumed increased markedly in mid-July when immature blue grama replaced needleandthread in the diet. Quality of crested wheatgrass declined faster than that of range grasses, although it was higher early in the spring. Diets of cattle on crested wheatgrass pasture in early spring were lower in quality than clipped crested wheatgrass, because of consumption of standing dead material, but diets were higher in quality than clipped grass in late spring.

Performance of grazing animals, including weight gain, reproductive success and other parameters, is determined by both intrinsic and extrinsic factors. Chief among extrinsic factors are forage intake and forage quality, and forage intake is partially dependent upon forage quality. Therefore, information on forage and diet quality is essential to any prediction or modeling of livestock production on pasture or range.

Forage quality may be expressed as digestible nutrient concentration (dry matter, specific nutrients, or energy) and/or concentration of components which limit digestibility (fiber, lignin, and silica). It is well known that quality decreases with advancing maturity of forage species; nutrient concentration and digestibility decrease and concentration of digestion-limiting components increases. What is needed are (1) reliable estimates of the rate at which these changes occur in forages and diets; (2) information as to the degree which diet selection by the grazing animal can compensate for the decline in forage quality; and (3) understanding of the extent to which variations in rainfall and temperature can change forage quality.

Forage and cattle diets from crested wheatgrass [*Agropyron desertorum* (Fisch.) Schult.] and native range pastures were sampled at the High Plains Grasslands Research Station, Cheyenne, Wyo., from 1975 through 1978. Samuel and Howard (1982) determined and published the botanical composition of cattle diets on range from samples which were collected 1975-1977. This paper will present information on chemical composition and in vitro digestibility of these same diet samples, and of forage samples collected at the same time from the same pastures. Such information should prove helpful in explaining seasonal patterns of livestock gains, in helping range managers to develop grazing systems to maximize use of forages when quality is high, and in modeling the plant-animal interactions in range and pasture ecosystems.

Materials and Methods

The pastures and sampling procedures have been described by Samuel and Howard (1982). Esophageal-fistulated cattle collected diet samples from a crested wheatgrass pasture stocked with cow-calf pairs and heifers at 0.51 AUM/ha in May and June, and two native mixed-grass range pastures stocked at 0.12 and 0.23 AUM/ha June through November. In 1975, samples were collected biweekly, with collections in the morning of the first day and late afternoon of the following day. Animals were fasted overnight or for several hours before collection, respectively. From 1976 through 1978, diet samples were collected in the morning and afternoon in alternate weeks, two days per week. Two to 4 animals were collected in each pasture at each collection date. Following collection, samples were lightly squeezed by hand and oven-dried at 60° C for 48 hours.

At the same time diet samples were collected, samples of major forage species in the diet were clipped and collected. Only current year's growth was clipped to 1-2 cm from the ground, but no attempt was made to collect only green forage or to collect the same plant parts being selected by the cattle. These samples also were oven-dried at 60° C for 48 hours.

Dried forage and diet samples were ground to pass through a 1-mm screen and were stored in plastic bags to await analysis. Crude protein was determined by the Kjeldahl method as described by AOAC (1960). The Goering and Van Soest (1970) procedure was used to determine neutral detergent fiber, acid detergent fiber, and lignin. In vitro dry matter dissappearance (IVDMD) was determined using the modified Tilley and Terry (1963) method. Species and diets analyzed and components analyzed for differed somewhat among years, as shown in Table 1.

Analysis of variance for unbalanced designs was used to evaluate differences between pastures and times of sampling; variance among fistulated animals within pastures was used as an error

Hart is research agronomist, USDA, ARS, Cheyenne, Wyo.; Abdalla and Hamid are former graduate assistants, Range Science Department, Colorado State University; Clark, Marshall, Hager and Waggoner are former graduate assistants and animal nutritionist, respectively, Animal Science Division, Univeristy of Wyoming.

This research was carried out at the High Plains Grasslands Research Station, 8408 Hildreth Road, Cheyenne, Wyo. 82009, under cooperative agreements of USDA, ARS, with Univeristy of Wyoming and Colorado State University.

Manuscript received June 15, 1981.

Table 1. Dates on which cattle diets and forage were sampled, characterization of means used to calculate regressions, and parameters measured.

Year	Sampler	Sampling dates: Crested wheatgrass	Sampling dates: Native range	Means calculated	Parameters measured[1]
1975	Marshall	30 May-14 June	30 May-5 September	Biweekly	CP, NDF, ADF, lignin & IVDMD of Agsm, Bogr, Carex & Agde.
	Hamid	30 May-14 June	30 May-5 September	Biweekly	CP, ADF, lignin & IVDMD of Agsm, Bogr, Carex, & NR diets.
1976	Abdalla	19 May-17 June	8 June-9 September	Biweekly	CP, NDF, ADF, lignin & IVDMD of Agsm, Bogr, Carex, Spco & NR diets; CP & IVDMD of Agde.
	Hager	19 May-10 June	19 May-17 September	Monthly	IVDMD of Agsm, Bogr, Carex, Spco & Agde.
1977	Abdalla	1-16 June	1 June-16 September	Biweekly	CP, ADF, lignin & IVDMD of Agsm, Bogr, Stco, Spco, Agde, NR diets & CW diets.
	Clark	1-16 June	1 June-16 September	Monthly	CP, NDF, ADF, lignin & IVDMD of Agde, NR diets & CW diets.
1978	Clark		7 June-14 September	Monthly	CP, NDF, ADF, lignin & IVDMD of Agsm, Bogr, Stco & Spco.

[1]CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; Agde = crested wheatgrass; Agsm = western wheatgrass; Bogr = blue grama; Carex = sedges; Stco = needleandthread; Spco = scarlet globemallow.

term. Seasonal trends in digestiblity and chemical composition were calculated by regression analysis, which divided the variance into that due to date, years and/or samplers, and residual.

Results and Discussion

Sampling Time and Pasture Differences in Diet Samples

No consistent differences were found between morning and afternoon diet samples or between samples from the 2 range pastures. In 1975 lignin and acid detergent fiber concentrations of cattle diets sampled in the morning from range were higher than those of diets sampled in the afternoon, but the reverse was true in 1977. In 1976 acid detergent fiber was significantly higher in afternoon than in morning samples from range. In 1977, lignin was higher in morning diet samples from the crested wheatgrass pasture than in afternoon samples. No differences were noted between morning and afternoon samples in 1978.

Samples from the heavily stocked range pasture had a higher concentration of acid detergent fiber in July of 1976 than did samples from the lightly stocked pasture. However, in 1977 acid detergent fiber was lower in samples from the heavily-stocked pasture early in the season, but did not differ between pastures later, while neutral detergent fiber was lower throughout the season in samples from the heavily stocked pasture. None of the components differed significantly between pastures in 1975 or 1978. We concluded that both stocking rates were low enough to allow a high degree of diet selection by the cattle during the grazing season, so that no differences between stocking rates were apparent.

Because differences between pastures and times of sampling were seldom significant and not consistent, the linear regressions of forage and diet composition on date were calculated from the biweekly or monthly means over pastures, times of sampling, and animals as reported in the authors' theses.

Rates of Seasonal Change in Forage and Diet Quality

Crude protein (CP), acid detergent fiber (ADF), and lignin concentrations and in vitro dry matter disappearance (IVDMD) of 5 forage species and of cattle diets from native range were determined for at least 2 and as many as 4 years of the study. Neutral detergent fiber (NDF) concentration of diets and all but one of the forage species was determined for 2 or 3 years (Table 1). In all species and diets, CP and IVDMD declined significantly with advance of season and maturity while all fiber components increased, although the increase was not always significant (Table 2). In all cases, the data fit a linear regression model better than or as well as a logarithmic, hyperbolic, or polynomial model.

Crude protein concentration of western wheatgrass (*Agropyron smithii* Rydb.), blue grama [*Bouteloua gracilis* (H.B.K.) Lag ex Steud.], and sedges (*Carex* spp.) declined more rapidly than that of needleandthread (*Stipa comata* Trin. & Rupr.), scarlet globemallow [*Spahaeralcea coccinea* (Pursh.) Rydb.], or cattle diets (Fig. 1). In May, crude protein of needleandthread was about 6 percentage points lower than that of the other 4 species, which were all about the same. Western wheatgrass and blue grama were similar in CP concentration throughout the season, but CP of sedges was about 2.5 percentage points lower than that of these grasses by the end of September. CP content of needleandthread and scarlet globemallow were about 3 and more than 6 percentage points higher, respectively, than CP of western wheatgrass and blue grama by the end of September. CP concentration of cattle diets was somewhat lower than that expected from the botanical composition of the diet (Samuel and Howard 1982) and CP concentration of the individual species early in the season, but was higher than expected by the end of the season. This reflects ingestion in the spring of significant amounts of standing dead material from the previous season, and selection for plant parts higher than average in CP concentration later in the year. An increase of about 1.6 percentage points in CP concentration of the diet was noted in mid-July. Samuel and Howard (1982) reported that at about this time needleandthread decreased sharply in cattle diets, to be replaced by blue grama which had a mean CP concentration over 2 percentage points higher. This change in protein concentration of the diet occurred over about 2 weeks and at slightly different times each year, so is represented by the dotted section of the time line of Figure 1, rather than by an abrupt change in the line.

Neutral detergent fiber concentration of western wheatgrass increased somewhat faster than that of blue grama, sedges, or

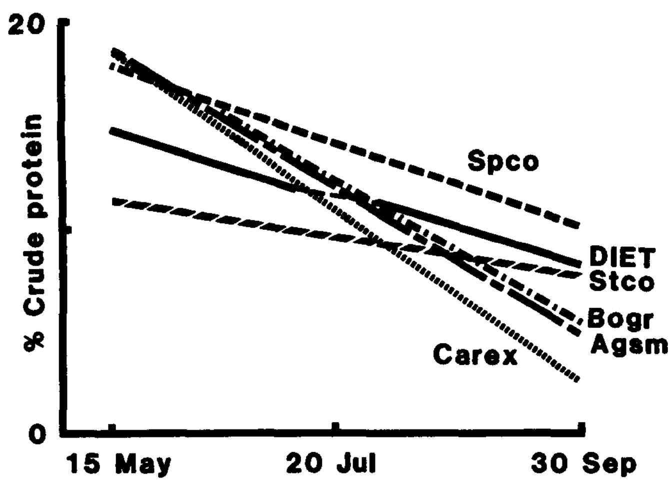

Fig. 1. *Crude protein concentration in major forage species and cattle diets on native range.*

Table 2. Seasonal changes in quality of range and pasture forage and cattle diets (CP = crude protein, NDF = neutral detergent fiber, ADF = acid detergent fiber, IVDMD = in vitro dry matter disappearance).

Forage species or diet	Component	Years sampled	Least squares estimates of: Concentration 15 May (5 Jun for Bogr)	Change/day	Change ca. 20 Jul	r^2 Sample[1] dates	Samplers & years	n
Western wheatgrass (Agsm)	CP	4	18.5	-.098		.63**	.02	38
	NDF	3	58.4	.099		.62**	.12	15
	ADF	4	27.1	.13		.55**	.19*	32
	Lignin	4	3.9	.028		.40**	.41**	24
	IVDMD	4	77.2	-.26		.52**	.34**	45
Blue grama (Bogr)	CP	4	16.0	-.095		.41**	.06	29
	NDF	3	64.7	.027		.30*	.24	12
	ADF	4	33.0	.059		.36**	.13	26
	Lignin	4	5.4	.0036		.01	.47	19
	IVDMD	4	64.0	-.16		.24**	.52**	36
Sedge spp. (Carex)	CP	2	18.7	-.12		.75**	.03	19
	NDF	2	59.6	.0076		.04	.02	11
	ADF	2	34.2	.033		.22*	.40*	19
	Lignin	2	6.6	.0012		.01	.27	11
	IVDMD	2	68.3	-.14		.13*	.56**	25
Needleandthread (Stco)	CP	2	11.2	-.026		.42*	.07	13
	ADF	2	30.6	.10		.71**	.01	13
	Lignin	2	4.5	.026		.39**	.27*	13
	IVDMD	2	64.4	-.22		.59**	.21**	13
Scarlet globemallow (Spco)	CP	3	17.8	-.056		.59**	.15*	21
	NDF	2	38.1	0.39		.48	.00	6
	ADF	3	28.0	.050		.39*	.18	15
	Lignin	3	4.7	.016		.16**	.80**	13
	IVDMD	3	66.9	-.060		.10*	.43**	24
Diet on native range (NR diet)	CP	4	14.9	-.062	1.6	.61**	.02	26
	NDF	2	62.0	.15	-3.4	.63**	.00	14
	ADF	4	33.2	.098	-1.2	.48**	.44**	25
	Lignin	4	5.0	.029	-2.3	.17	.00	18
	IVDMD	4	74.1	-.25	2.5	.27**	.67**	22
Crested wheatgrass (Agde)	CP	3	20.2	-.23		.18**	.79**	10
	NDF	2	40.8	.35		.24	.72*	7
	ADF	2	20.6	.46		.64*	.34	7
	Lignin	2	0.8	.19		.54	.35	7
	IVDMD	3	84.7	-.90		.67**	.24	12
Diet on crested wheatgrass pasture (CW diet)	CP	1	16.0	-.14		.82*	.16	5
	ADF	1	28.6	.23		.68**	.32**	5
	Lignin	1	2.9	.090		.46	.45	5
	IVDMD	1	73.2	-.65		.74	.10	5

[1]*, ** Indicate regression is significant at the 5% and 1% level of probability, respectively.

scarlet globemallow (Fig. 2). However, NDF concentration of both grasses and the sedges was about 20 percentage points higher than that of scarlet globemallow all year long. Thus globemallow contains about 20 percentage points more of the easily digestible cell contents than do the grasses or sedges. Sedges had essentially the same NDF concentration all season.

Acid detergent fiber concentration of western wheatgrass increased faster than that of other species (Fig. 3), but ADF of all

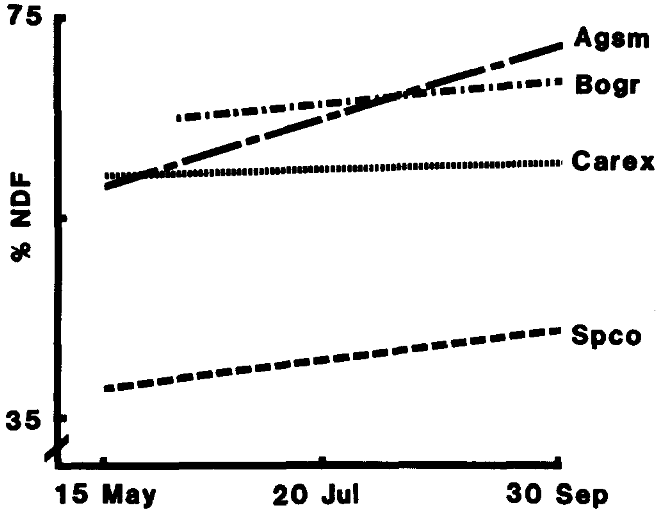

Fig. 2. *Neutral detergent fiber concentration in major forage species on native range.*

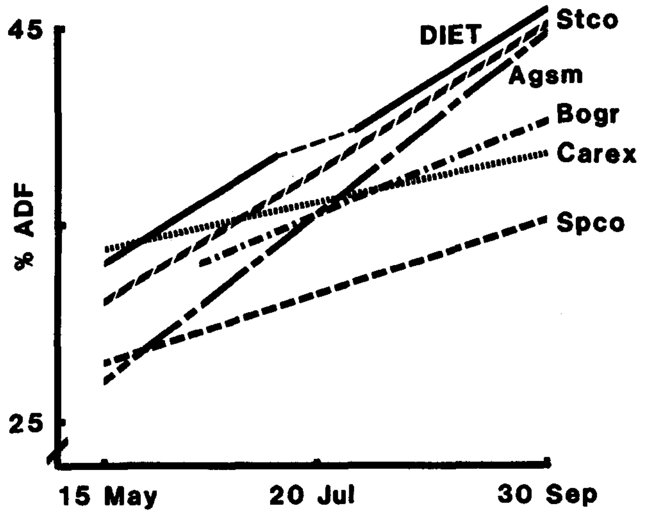

Fig. 3. *Acid detergent fiber content in major forage species and cattle diets on native range.*

species increased significantly. ADF concentration of sedges increased more slowly than that of other species, while ADF of scarlet globemallow was lower than that of grasses and sedges for most of the season. These patterns parallel the patterns of NDF concentration. However, ADF increased more rapidly than NDF in all species, indicating an increase in cellulose and a decrease in hemicelluloses, pentosans, and other more digestible "fiber" fractions as plants matured. ADF of cattle diets was somewhat higher than expected all season long, and decreased about 1.2 percentage points in mid-July, again reflecting the change in diet from needleandthread to blue grama. ADF of diets, unlike that of individual species, did not increase as fast as NDF (Table 2). This may indicate cattle were selecting plant parts lower in cellulose.

Lignin concentration of blue grama and sedges changed little during the grazing season, while that of the other species increased (Fig. 4). Lignin concentration of scarlet globemallow increased more slowly than that of western wheatgrass or needleandthread. Lignin concentration of the diet was slightly higher than expected in spring, but about at expected levels for the rest of the season. A decrease of 2.3 percentage points occurred in mid-July, a decrease so marked that lignin concentrations of the diet at the end of July was nearly the same as that in mid-May.

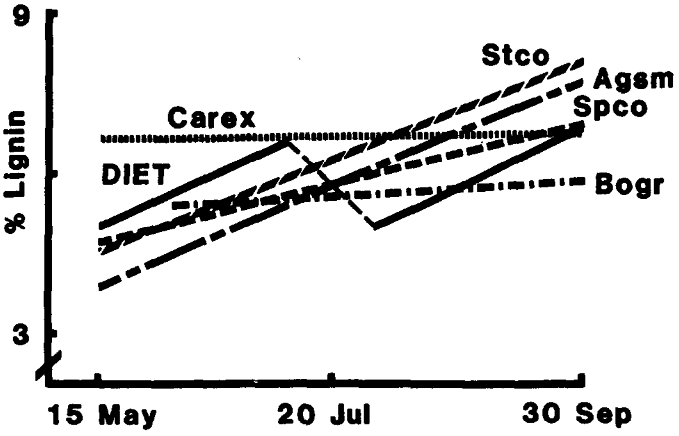

Fig. 4. *Lignin concentration in major forage species and cattle diets on native range.*

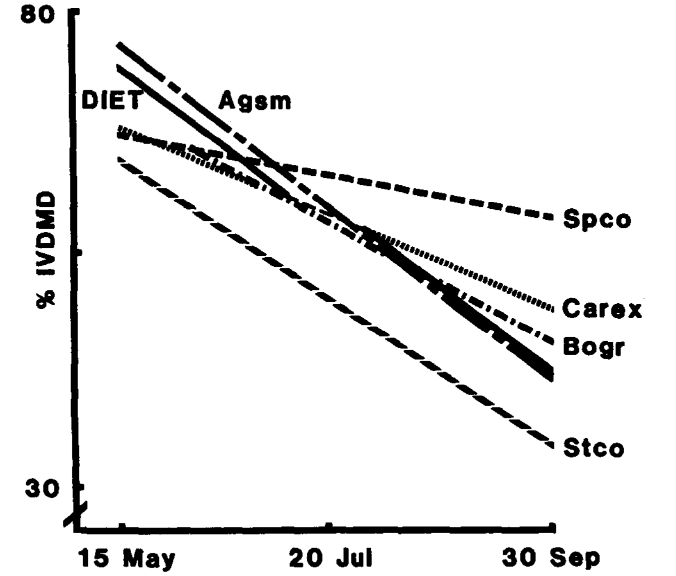

Fig. 5. *In vitro dry matter disappearance from major forage species and cattle diets on native range.*

In vitro dry matter disappearance from all species and cattle diets decreased significantly as the season progressed (Fig. 5). IVDMD of western wheatgrass and needleandthread decreased more rapidly than that of sedges or blue grama, while IVDMD of scarlet globemallow decreased more slowly than that of any other species. IVDMD of western wheatgrass was about 10 percentage points higher than that of the other species in mid-May, but by the end of September was about 4, 7, and 16 percentage points lower than that of blue grama, sedges, and scarlet globemallow, respectively. The greater decline in quality of western wheatgrass reflects the earlier maturity of this cool-season grass, with no regrowth following summer rains. IVDMD of needleandthread was lower than that of other species all season, and was 7 percentage points lower even than that of western wheatgrass by the end of September. IVDMD of diet was about as expected all through the season, and showed an increase of about 2.5 percentage points in mid-July.

Crude protein concentration of crested wheatgrass and diets on crested wheatgrass pasture decreased as the season advanced, while fiber components increased (Fig. 6). Quality of crested wheatgrass declined much more rapidly than quality of the range forage species (Table 2), because of the more rapid maturing of crested wheatgrass. Because 1977 was the only year in which enough diet samples were analyzed to provide a reliable estimate of diet quality, all comparisons between diet and crested wheatgrass quality were made from 1977 data. However, with the exception of CP concentration which was somewhat lower in 1977, composition of crested wheatgrass in 1977 did not differ markedly from the 2- or 3-year averages. Crude protein concentration of cattle diets was higher than that of crested wheatgrass from mid-May until the end of June, and the difference increased as the season advanced. ADF and lignin of the diet were originally higher than that of crested wheatgrass, probably because of ingestion by the cattle of standing dead material, but diet and forage fiber concentrations were about the same by early June and diets were lower in ADF and lignin by the end of June. IVDMD was lower in diets than in forage in May and early June, but was slightly higher in the diet by the end of June. All this indicates some selection by the cattle for higher quality forage than the average of forage available by the end of the season.

Variation among Years and Samplers

Variation among years was confounded with variation among samplers. Abdalla and Clark sampled for 2 years each, but sampled in only 1 common year, and Clark reported results monthly while Abdalla reported biweekly. Marshall, Hamid, and Hager sampled 1 year each, and only Marshall and Hamid sampled in the same Samplers and years could be thought of as a very incomplete factorial design, so incomplete that no satisfactory analysis to separate year and sampler effects was possible. Combined sampler and year effects were sometimes very large, accounting for as much as 80% of the total variation in lignin concentration of scarlet

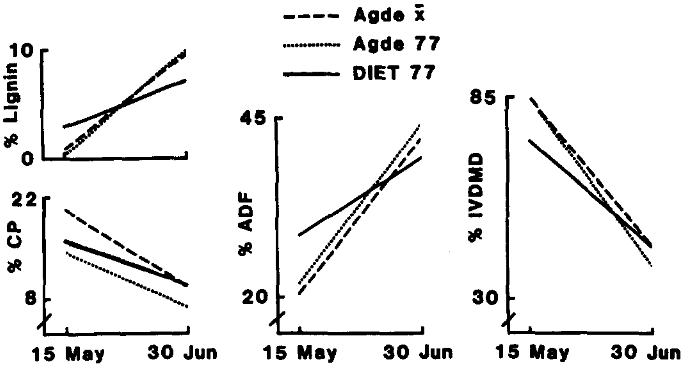

Fig. 6. *Crude protein, acid detergent fiber, and lignin concentration of, and in vitro dry matter disappearance from crested wheatgrass and cattle diets on crested wheatgrass pasture.*

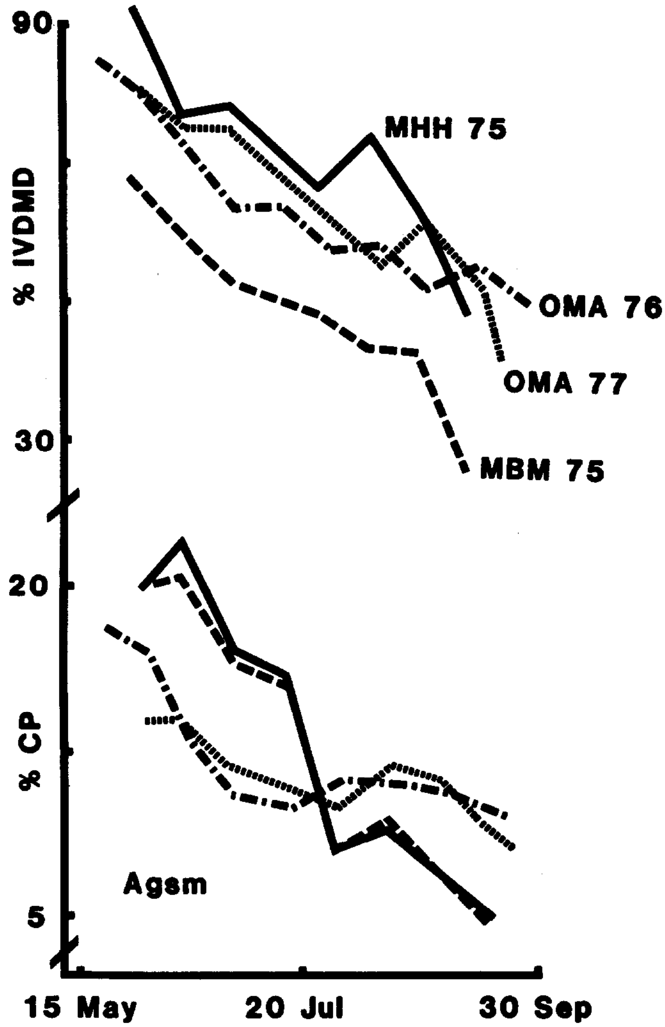

Fig. 7. *Variation within seasons, between samplers in the same season, and between seasons by the same sampler, in crude protein concentration of and in vitro dry matter disappearance from western wheatgrass.*

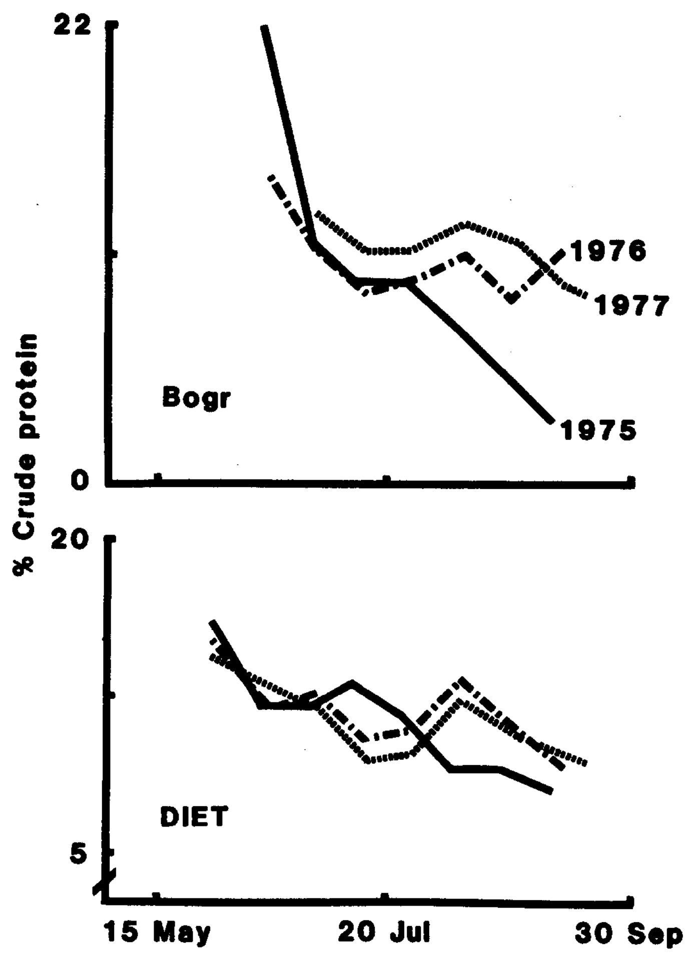

Fig. 8. *Variation within and among years in crude protein content of blue grama (Bogr) and cattle diets.*

globemallow, for example (Table 2). Samplers and years accounted for a significant fraction of the variation in IVDMD of range diets and all range species, and for a significant fraction of the variation in ADF and lignin in 4 and 3, respectively, of the 6 species and 2 diets studied. Significant sampler-year effects on CP were noted only in scarlet globemallow and crested wheatgrass.

Although sampler and year effects could not be separated statistically, some useful conclusions can be drawn from inspection of the data. Determinations of IVDMD of the same species collected in the same year but performed by different samplers varied widely. For example, when Marshall and Hamid determined IVDMD of western wheatgrass collected in 1975, differences between their results were greater than differences in IVDMD between 1976 and 1977 samples as determined by Abdalla (Fig. 7). However, crude protein determinations agreed very well between different samplers in the year. Therefore, we decided to examine crude protein concentrations of western wheatgrass, blue grama, and native range diets in 1975 through 1977 to see if any effects of precipitation and temperature were apparent. No data from 1978 were used because means were reported monthly, at intervals too long to detect short-term fluctuations in CP concentration. CP of both western wheatgrass (Fig. 7, mean of MHH 75 and MBM 75) and blue grama (Fig. 8) was higher in the spring of 1975 than in the spring of 1976 or 1977, reflecting greater spring rainfall in 1975 (Fig. 9). CP concentration of western wheatgrass was slightly higher in 1976 than in 1977 (Fig. 7), but more importantly sufficient growth for sampling and grazing was available 2 weeks earlier in 1976 than in 1977, when the first rain in excess of 10 mm did not occur until 7 June, as opposed to 27 May and 21 May in 1975 and 1976, respectively. However, CP concentration of both grasses declined much more rapidly in 1975 than in 1976 or 1977, because very little rain fell after 15 July in 1975. Vavra and Phillips (1980) reported sharp declines in CP and IVDMD of range forage in a drouth year in Oregon. CP concentration of blue grama increased noticeably in early August of 1976 and 1977, reflecting renewed growth after heavy rains on 30 July and 24 July respectively. Western wheatgrass, which had completed its growth cycle by that time, did not respond to these rains. No effects of temperature on forage quality were detected in this study.

CP concentration of diet (Fig. 8) fluctuated less than that of western wheatgrass and blue grama, the 2 major species in the diet, presumably because the cattle selected more dead material in the spring and the more proteinaceous plant parts and plant species later in the season. Although mean CP concentrations of forage and diet gave some evidence of selection (Fig. 1), the evidence from yearly patterns of CP concentration was much stronger. CP concentration of cattle diets increased as much as that of blue grama following the late July rains of 1976 and 1977, indicating the cattle were consuming large amounts of the new growth of blue grama and perhaps that of the other minor species in the diet as well.

Conclusions

Quality of western wheatgrass, blue grama, and scarlet globemallow was high in spring, but quality of these grasses decreased

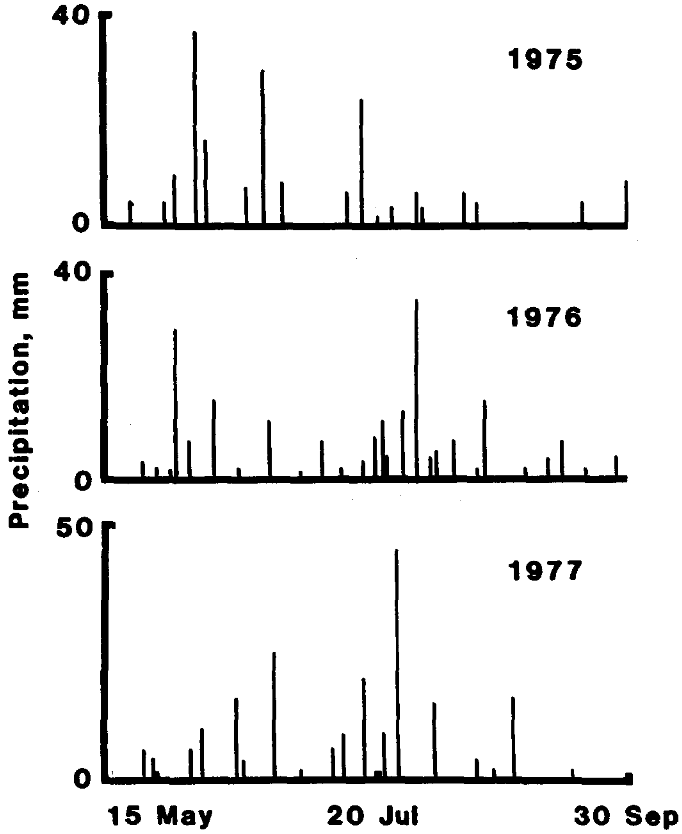

Fig. 9. *Seasonal precipitation pattern, 1975-77, at High Plains Grasslands Research Station, Cheyenne, Wyoming.*

much more rapidly than that of globemallow. This is a characteristic difference between grasses and forbs. Quality of needleandthread was somewhat lower than that of the other grasses and decreased about as rapidly. Crested wheatgrass began growth and reached maturity earlier than any other grass in the study, and was very high in quality in early spring, but decreased in quality much more rapidly than any other species. Crude protein of sedges was about the same as that of grasses in the spring, but decreased more rapidly, while the various fiber components were as high as or higher than those of grasses initially, but increased less with advancing season. There was some indication that as the season progressed cattle selected plant parts higher than average in crude protein and lower than average in cellulose concentration. However, this selection did not prevent diet quality from declining as the season progressed. Quality of blue grama, western wheatgrass, and cattle diets on range, as indicated by crude protein content, increased after heavy rains.

Literature Cited

AOAC. 1960. Official methods of analysis (9th ed.) Assoc. Official Agr. Chem. Washington, D.C.

Goering, H.K., and P.J. Van Soest. 1970. Forage fiber analysis. USDA, ARS, Agr. Handbook 379.

Samuel, J.J., and G.S. Howard. 1982. Botanical composition of summer cattle diets on the Wyoming High Plains. J. Range Manage. 35:305-308.

Tilley, J.M., and R.A. Terry. 1963. A two-stage technique for the in vitro digestion of forage crops. J. Brit. Grassl. Soc. 18:104-111.

Vavra, M., and R.L. Phillips. 1980. Drought effects on cattle performance, diet quality and intake. Proc. West. Sec. Amer. Soc. Anim. Sci. 31:157-160.