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SEASONAL TRENDS IN FORAGE QUALITY OF PLANTS IN SUBIRRIGATED MEADOWS OF THE NEBRASKA SANDHILLS[1]

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ABSTRACT

Hay from subirrigated meadows is the primary source of forage for wintering beef cattle in the Nebraska Sandhills. Hay quality is an important consideration if the nutritional needs of livestock are to be met. Since the overall quality of the hay is a product of the individual components, quantifying the quality parameters of each species can be helpful in making management decisions in relation to harvesting schedules and manipulation of species composition. In-vitro organic matter digestibility (IVOMD) and crude protein (CP) were analyzed for ten of the most important forage species to quantify seasonal trends in forage quality and provide relative comparisons among species. Samples were collected from three areas (replicates) on nine dates from June 11 through September 6 during the 1985 growing season. Orthogonal comparisons were made among species within the categories of cool-season grasses, warm-season grasses, and non-grass species to detect seasonal difference in IVOMD and CP. Polynomial regressions were plotted which most appropriately fit seasonal trends for each species. The most pronounced deviation from the normal pattern of declining IVOMD and CP values over the growing season were for Kentucky bluegrass, prairie cordgrass, and red clover within the groups of cool-season grasses, warm-season grasses, and non-grass, respectively. Differences in seasonal patterns of IVOMD and CP for the species in this study indicated that any changes in species composition brought about by management practice and manipulation would have a significant effect on overall nutritive value of the hay.

† † †

Subirrigated meadows in the Nebraska Sandhills are important sources of hay and late-season grazing. A variety of native and introduced forages are common on these meadows, including warm- and cool-season grasses, legumes, sedges, rushes, and various forbs. The nutritive quality of forage from a mixed sward is determined by the nutritive quality of the individual species and the proportion that they contribute to the total composition. Quality differences among species may be attributed to structural and chemical composition of the plant parts. Thus, the balance of species prevalent at different times during the growing season is a primary determinant of the quality of forage in a mixed sward.

Several investigators have contributed to a better understanding of how advance in season affects quality of forages in Nebraska (Baker et al., 1951; Burzlaff, 1971; Keim et al., 1932; Myran, 1986; Streeter et al., 1968). However, a detailed study was lacking concerning forage quality of individual species common to subirrigated meadows. The purpose of this study was to quantify seasonal trends in forage quality of the major components of subirrigated meadow vegetation. Specific objectives were to 1) evaluate crude protein content (CP) and in-vitro organic matter digestibility (IVOMD) of ten meadow forage species sampled from early June through early September, and 2) provide comparisons of quality components among species and species groups to aid in management decisions.

MATERIALS AND METHODS

Description of the study area

Samples were collected on a subirrigated site on the "home meadow" of the Gudmundsen Sandhills Laboratory near Whitman, in Grant County, Nebraska. Soils at the study site are classified as Gannett-Loup fine sandy loams (coarse-loamy, mixed, mesic Typic Haplaquolls) which were derived from eolian sand parent material (Elder, 1969). Selected soil properties at the study site are presented in Table I.

Soil water was not a limiting factor during the

Table I. Soil characteristics of the study site, Gudmundsen Sandhills Laboratory, Whitman, Nebraska.

Depth (mm)	pH	Organic matter (%)	P (Bray-1) (ppm)	K (ppm)	NO_3-N (ppm)	SO_4-S (ppm)
0–150	7.6	11.1	5	120	2.1	16
150–300	7.7	4.1	3	102	1.3	4
300–450	7.8	3.4	4	107	1.0	3

Table II. Comparison of species and species groups by regression analysis to determine differences over harvest dates in crude protein (CP) and in vitro organic matter digestibility (IVOMD).

	$P_r > F$					
	Linear		Quadratic		Cubic	
	IVOMD	CP	IVOMD	CP	IVOMD	CP
Cool-season grasses						
Kentucky bluegrass vs mean of redtop, timothy and slender wheatgrass	.0001	.0001	.0173	.8105	.3581	.4383
Slender wheatgrass vs mean of redtop and timothy	.0001	.6679	.0831	.6159	.5310	.3107
Redtop vs timothy	.4426	.8692	.1489	.6041	.2239	.0763
Warm-season grasses						
Prairie cordgrass vs mean of big bluestem and Indiangrass	.0001	.0001	.0137	.2344	.3346	.2318
Big bluestem vs Indiangrass	.0114	.1921	.1445	.8573	.4471	.9307
Warm-season vs cool-season grasses	.0001	.0001	.1686	.0208	.0190	.7367
Non-grasses						
Red clover vs mean of sedges and rushes	.0001	.0001	.7555	.2985	.3551	.9494
Sedges vs rushes	.0302	.2172	.8026	.7729	.2868	.9962
Grasses vs non-grasses	.0001	.0001	.0178	.0077	.2565	.2841

study because of natural subirrigation. Soils were water-saturated at the surface when growth was initiated in the spring and remained wet within the rooting depth of the vegetation throughout the growing season. Soil moisture on subirrigated sites is less variable from year to year than would be expected on upland, dryland sites, which tempers yearly fluctuations in growth.

Sampling procedure

Samples of ten species were collected from three plot areas (replicates) of about one hectare on nine dates throughout the 1985 growing season. Species collected were the dominant components of the vegetation and included big bluestem, *Andropogon gerardii* Vitman; Indiangrass, *Sorghastrum nutans* (L.) Nash; prairie cordgrass, *Spartina pectinata* Link; Kentucky bluegrass, *Poa pratensis* L.; redtop, *Agrostis stolonifera* L.; slender wheatgrass, *Agropyron trachycaulum* (Link) Malte; timothy, *Phleum pratense* L.; red clover, *Trifolium pratense* L.; rushes, *Juncus* spp.; and sedges, *Carex* spp. Nomenclature follows Great Plains Flora Association (1986). Each species of interest was sufficiently abundant within each plot to insure random sampling throughout the growing season. Collection dates were scheduled weekly during the first half of the growing season, and lengthened as the growing season progressed and changes in the phenology of the plants slowed. Collection dates were: June 11, 18, and 25; July 2, 9, 16, and 31; August 13; and September 6.

Individual plants of each species were randomly located and clipped along transects of each sampling area in order to represent the population of the entire plot area. Plants were clipped 50 mm above the soil which represented normal mowing height. Since a variety of growth stages and sizes were present on any given collection date for each species, a minimum of 20 plant units were composited to represent this variability in each sample. After each collection day, samples were inspected for species purity and dead material removed. Samples were oven-dried at 55°C and ground through a two mm screen in a Wiley mill, followed by grinding through a one-mm screen in a Udy cyclone mill. Duplicate samples were analyzed for in-vitro organic matter digestibility as described by Moore (1970). Rumen inoculum was collected from rumen-fistulated steers which were fed equal parts of meadow hay harvested in June, August, and September. Steers were supplemented with 0.45 kg of soybean meal one hour before fluid collections to insure adequate soluble nitrogen in the inoculum. Duplicate samples were analyzed for nitrogen by the Kjeldahl method (AOAC, 1975) and converted to crude protein ($N \times 6.25$).

Linear, quadratic, and cubic regressions over time were determined for CP and IVOMD of all species. From this set of regressions, the highest order, significant regressions for CP and IVOMD for each species were selected as the prediction equations. Differences in CP and IVOMD among species was determined by preplanned orthogonal contrasts (Roberts and Raison, 1983). Comparisons were designed to separate effects within three major plant groups: cool-season grasses, warm-season grasses, and non-grasses. The non-grass group included those species which technically did not belong to either grass group. Differences were considered significant at $P < .05$.

RESULTS AND DISCUSSION

Cool-season grasses

Cool-season grasses were the most abundant species present on the study site and thus have the greatest potential impact on overall hay quality. Redtop and timothy were introduced into subirrigated meadows by ranchers early in the Twentieth Century (Brouse, 1930). Kentucky bluegrass is an invading grass that has progressively increased since settlement. Slender wheatgrass is native to subirrigated meadow sites.

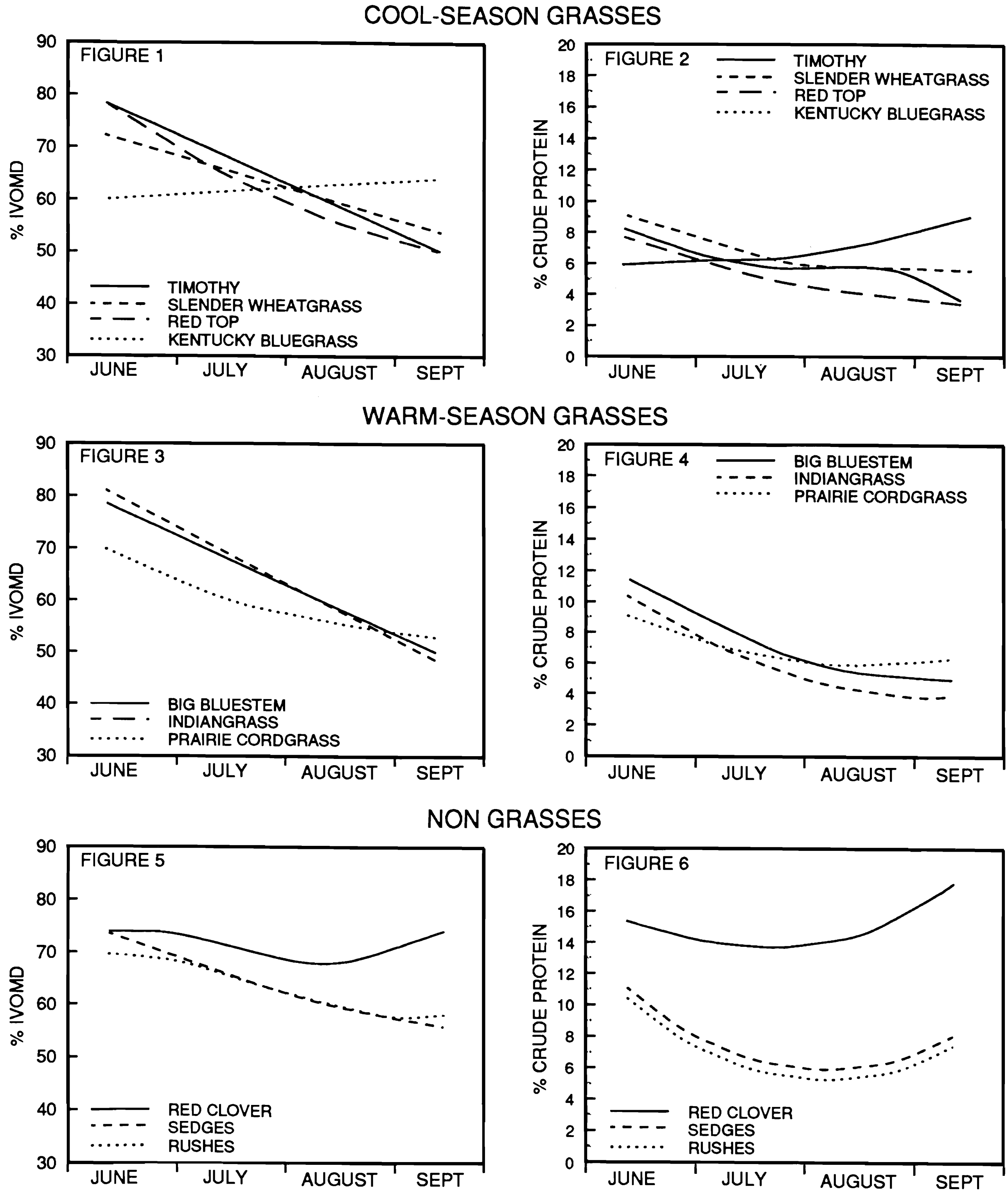
Redtop and timothy had similar seasonal trends for both IVOMD and CP (Table II, Fig. 1). Linear seasonal trends of IVOMD and CP were different for Kentucky bluegrass compared to the average of redtop, timothy, and slender wheatgrass. Regression analyses of seasonal IVOMD values indicated a linear best fit for Kentucky bluegrass, slender wheatgrass, and timothy with a quadratic best fit for redtop, whereas regressions of seasonal CP were quadratic for Kentucky bluegrass and slender wheatgrass and cubic for timothy and redtop (Table III and Fig. 1). Low r^2 values for both IVOMD and CP for Kentucky bluegrass and slender wheatgrass indicated a wide dispersion of mean values around the regression lines compared to the other species within the cool-season group (Table III). This was probably due to a greater sensitivity of these species to precipitation events and temperature. The most obvious differences among the cool-season grasses were the seasonal trends in both IVOMD and CP, which increased for Kentucky bluegrass but declined for the remaining cool-season grasses. These contrasts are best illustrated by Figures 1 and 2. The magnitude of the change for IVOMD from first to last harvest date was an increase of 5.7 percentage points for Kentucky bluegrass, compared to a decline of 19.9, 28.0, and 26.9 percentage points for slender wheatgrass, redtop, and timothy, respectively (Table IV). Likewise, over the same time span, CP increased by 2.4 percentage points for Kentucky bluegrass, but declined by 4.9, 4.9, and 5.7 percentage points for slender wheatgrass, redtop, and timothy, respectively.

The tendency for slender wheatgrass to have lower IVOMD value on the first collection date than either timothy or redtop and be higher on the last collection date is best illustrated by Figure 1 and comparing values in Table IV. This is in contrast to CP for slender wheatgrass, which maintained higher levels throughout the growing season than either timothy or redtop (Fig. 2 and Table V).

Warm-season grasses

Big bluestem, Indiangrass, and prairie cordgrass are the principal native, warm-season grasses common to subirrigated sites throughout the Nebraska Sandhills. Historically, the warm-season grasses were considered more abundant than they are today (Tolstead, 1942). On the study site, these grasses were minor components of the vegetation, but observations suggest that implementation of management practices which enhance their competitiveness with associated species could increase their abundance. Brejda et al. (1989), at the same study location, found that treating plots with atrazine reduced cool-season grasses and increased the warm-season grasses, primarily big bluestem and Indiangrass. McConnell and Waller (1986) documented a similar response on a subirrigated meadow in eastern Nebraska.

Orthogonal comparisons of warm-season vs cool-season grasses indicated that seasonal trends were different for these species groups (Table II). This indicated that collectively IVOMD and CP were influenced by the cool-season vs warm-season vegetation composition of the meadow and that any management practice that changed composition could be expressed in the cumula-



Figures 1-6. Seasonal trends of in-vitro organic-matter disappearance (IVOMD) and crude protein (CP) of cool-season grasses, warm-season grasses, and non-grasses from a subirrigated meadow site near Whitman, Nebraska, in 1985.

Table III. Regression parameters for seasonal trends of in vitro organic matter digestibility (IVOMD) and crude protein (CP) in Sandhills meadow forage.

	Intercept	Linear	Quadratic*	Cubic**	r^2
Cool-season grasses					
Kentucky bluegrass					
IVOMD	60.61	0.04	—	—	0.33
CP	6.50	-0.04	0.75	—	0.74
Slender wheatgrass					
IVOMD	71.80	-0.20	—	—	0.68
CP	9.55	-0.10	0.62		0.50
Redtop					
IVOMD	76.91	-0.51	2.20	—	0.96
CP	8.82	-0.18	2.58	-1.35	0.99
Timothy					
IVOMD	76.80	-0.30	—	—	0.94
CP	9.81	-0.24	4.73	-3.06	0.91
Warm-season grasses					
Indiangrass					
IVOMD	81.43	-0.36	—	—	0.94
CP	11.55	-0.19	1.16	—	0.98
Big bluestem					
IVOMD	78.80	-0.32	—	—	0.92
CP	12.73	-0.19	1.13	—	0.96
Prairie cordgrass					
IVOMD	69.99	-0.36	1.93	—	0.94
CP	9.83	-0.13	0.96	—	0.95
Non-grasses					
Rushes					
IVOMD	70.49	-0.09	-5.44	5.46	0.90
CP	10.50	-0.14	1.16	—	0.93
Sedges					
IVOMD	75.04	-0.41	2.02	—	0.98
CP	11.13	-0.15	1.25	—	0.97
Red clover					
IVOMD	74.07	0.07	-7.26	7.16	0.65
CP	15.70	-0.11	1.52	—	0.73

*Quadratic coefficient = table value × 10^{-3}
**Cubic coefficient = table value × 10^{-5}

tive forage quality of the hay. Comparisons among the species of warm-season grasses (Table II) showed that big bluestem and Indiangrass differed in seasonal trends of IVOMD but not for CP, and that seasonal trends of IVOMD and CP for prairie cordgrass were different from the average values for big bluestem and Indiangrass (Table II and Figs. 3 and 4). On an individual species basis, the best-fit regressions of seasonal IVOMD trends were linear for Indiangrass and big bluestem and quadratic for prairie cordgrass. For CP, the quadratic relationship best described the seasonal trends for all three species (Table III and Figs. 3 and 4).

Although the seasonal trends in IVOMD for big bluestem and Indiangrass were different as indicated by orthogonal comparisons (Table II), the magnitude of these differences was small (Fig. 3) and differed by less than 2.6 percentage points for any collection date (Table IV). The primary contrast was between prairie cordgrass in relation to the average of big bluestem and Indiangrass (Table II and Fig. 3), which showed that seasonal IVOMD values for prairie cordgrass were consistently below the other two warm-season species until the last collection period. Over the first five collection dates, IVOMD was from 7.0 to 13.1 percentage points below the other two warm-season grasses, but exceeded them by 2.6 to 4.5 percentage points in September.

The best-fit regressions of seasonal trends of CP for Indiangrass, big bluestem, and prairie cordgrass were

Table IV. Mean percent in-vitro organic matter digestibility (IVOMD) and standard errors (SE) for ten meadow species collected over nine harvest dates, Gudmundsen Sandhills Laboratory, Whitman, Nebraska.

Species	Collection dates (month-day)								
	6-11	6-18	6-25	7-2	7-9	7-16	7-31	8-13	9-6
Cool-season grasses									
Kentucky bluegrass	58.3(1.1)	63.1(0.7)	63.4(0.2)	60.9(1.5)	61.0(0.9)	60.2(0.6)	63.9(1.0)	63.4(0.1)	64.0(0.8)
Slender wheatgrass	74.3(0.1)	68.2(0.6)	65.1(0.8)	70.9(1.3)	70.5(0.6)	61.2(0.1)	56.2(1.2)	63.5(1.6)	54.4(0.9)
Redtop	77.8(0.1)	69.3(0.4)	71.2(0.6)	68.5(0.3)	64.3(1.2)	60.5(0.5)	58.0(0.3)	52.2(0.2)	49.8(1.2)
Timothy	77.9(0.6)	74.8(1.6)	71.7(1.0)	71.3(0.7)	69.8(1.4)	60.8(1.1)	64.0(0.9)	59.4(3.0)	51.0(0.5)
Warm-season grasses									
Indiangrass	80.1(0.3)	74.1(0.4)	77.9(0.4)	76.8(1.1)	73.6(0.7)	69.5(0.6)	59.7(0.7)	58.6(0.5)	49.2(2.6)
Big bluestem	77.6(0.8)	74.1(1.8)	75.4(0.4)	74.4(0.7)	72.3(0.7)	66.7(0.8)	57.5(1.8)	60.9(0.0)	51.1(3.1)
Prairie cordgrass	68.8(1.2)	67.1(2.4)	66.3(0.4)	64.0(0.7)	60.5(1.3)	60.9(1.7)	54.0(0.9)	56.3(0.7)	53.7(1.2)
Non-grasses									
Rushes	71.5(3.0)	67.8(2.0)	66.0(0.9)	70.2(2.1)	64.9(0.9)	61.1(1.0)	58.9(0.2)	56.8(4.2)	57.5(1.9)
Sedges	74.2(1.2)	72.1(0.9)	68.8(1.8)	68.6(0.2)	65.8(0.8)	60.8(1.6)	59.2(2.0)	57.6(0.1)	54.6(0.6)
Red clover	74.3(0.4)	72.4(0.6)	76.5(1.0)	71.7(2.3)	73.7(1.0)	69.5(0.9)	66.6(1.9)	69.8(3.4)	72.9(1.5)

Table V. Mean percent crude protein (CP) and standard error (SE) for ten meadow species harvested over nine dates, Gudmundsen Sandhills Laboratory, Whitman, Nebraska.

Species	Collection dates (month-day)								
	6-11	6-18	6-25	7-2	7-9	7-16	7-31	8-13	9-6
Cool-season grasses									
Kentucky bluegrass	6.3(0.2)	7.1(0.7)	6.1(0.2)	4.9(0.4)	6.1(0.6)	5.9(0.2)	7.0(0.2)	7.1(0.4)	8.7(0.4)
Slender wheatgrass	10.0(0.3)	8.4(0.4)	6.9(0.4)	8.2(0.9)	9.5(0.8)	5.0(0.2)	4.6(0.2)	7.3(0.4)	5.1(0.1)
Redtop	8.9(0.4)	7.3(0.1)	6.5(0.1)	6.1(0.2)	5.5(0.1)	5.3(0.1)	4.8(0.1)	4.3(0.1)	4.0(0.1)
Timothy	9.8(0.3)	8.0(0.4)	6.6(0.2)	6.5(0.4)	7.1(0.1)	5.3(0.2)	5.3(0.2)	5.8(1.1)	4.1(0.1)
Warm-season grasses									
Indiangrass	11.9(0.2)	9.8(0.1)	9.0(0.2)	7.6(0.2)	7.0(0.5)	6.3(0.1)	5.1(0.2)	4.8(0.1)	3.7(0.4)
Big bluestem	13.0(0.5)	10.9(0.3)	10.0(0.4)	9.0(0.1)	8.6(0.4)	6.8(0.1)	5.3(0.3)	6.3(0.8)	4.3(0.7)
Prairie cordgrass	9.8(0.3)	8.9(0.2)	8.0(0.2)	7.7(0.3)	6.8(0.1)	6.5(0.4)	5.6(0.3)	6.4(0.1)	6.0(0.2)
Non-grasses									
Rushes	10.9(0.1)	8.8(0.5)	8.7(0.5)	8.4(0.7)	7.4(0.1)	6.9(0.1)	6.6(0.3)	6.9(1.1)	7.4(1.1)
Sedges	11.1(1.3)	10.1(0.1)	8.9(0.3)	8.3(0.1)	7.5(0.3)	7.0(0.3)	7.2(0.4)	6.4(0.2)	7.2(0.5)
Red clover	16.3(0.3)	13.8(0.2)	14.8(0.1)	13.1(1.1)	15.1(0.3)	13.2(0.6)	13.9(0.6)	15.2(1.2)	17.7(0.8)

all quadratic (Table III), but big bluestem maintained a consistently higher value than Indiangrass (Fig. 4). Regressions shown in Fig. 4 indicate that prairie cordgrass had a lower CP value early in the growing season, but exceeded the CP of both big bluestem and Indiangrass by the last collection date. Crude protein for the first collection date was 9.8% for prairie cordgrass compared to 11.9 and 13.0% for Indiangrass and big bluestem, respectively. By the last collection date, prairie cordgrass CP was 6.0% compared to Indiangrass (3.7%) and big bluestem (4.3%). Similar seasonal trends in CP were shown for prairie hay from eastern Nebraska, which was harvested over the same seasonal time span as in this study. Crude protein of hay harvested in early July, early August, and mid-September was 7.2, 5.7, and 4.1%, respectively (Baker et al., 1947) compared to big bluestem which was 8.6, 6.3, and 4.3% from this study (Table V) at similar harvest dates. Big bluestem and other warm-season grasses were major components of the hay from the study of Baker et al. (1947).

Non-grasses

Rushes and sedges are common native components of the vegetation on subirrigated meadows in the Nebraska Sandhills, increasing in abundance with increased soil wetness (Ehlers et al., 1952). Rushes and sedges were minor components on the study site; however, both have a wide distribution in the Sandhills, becoming major components of the vegetation on some sites. Red clover is an introduced legume that has been recognized for its contribution to both yield and forage quality (Ehlers et al., 1952). Calves wintered on hay from a subirrigated meadow which contained one-third clover gained 0.32 kg/day more than calves on hay without clover (Brouse, 1955).

A comparison of seasonal trends of IVOMD and CP between grass vs non-grass categories indicated that seasonal trends are different and best described as quadratic for both IVOMD and CP (Table II). Within the non-grass category, seasonal trends of IVOMD for sedges were different than rushes, but CP trends were not different. Comparing red clover vs the average of sedges and rushes indicated that linear seasonal trends differed for both IVOMD and CP (Table II).

Seasonal trends in IVOMD were best described as cubic for both rushes and red clover and quadratic for sedges (Table III). Differences in both IVOMD and CP between red clover and either rushes or sedges were pronounced, widening as the growing season progressed (Figs. 5 and 6). By September, IVOMD for red clover was 18.0 and 17.9 percentage points higher than rushes and sedges, respectively (Table IV). Values for CP were even more pronounced between red clover and either rushes or sedges. Although seasonal trends were similar (Fig. 6), the spread in values at any of the collection dates were large (Table V). Red clover CP at the first collection date was 16.3% compared to about 11% for rushes or sedges. By September, red clover was over ten percentage points higher than either sedges or rushes. The relative differences and seasonal trends of CP among red clover, sedges, and rushes plotted by Gomm (1979) for Colorado meadows from a report by Miller and Amemiya (1954) were very similar to those detailed in this study. With the exception of Kentucky bluegrass, the upward trend in both CP and IVOMD late in the growing season for the non-grass category was in contrast to both cool-season and warm-season grasses which showed an overall seasonal decline (Figs. 1 and 4).

MANAGEMENT IMPLICATIONS

Overall seasonal trends in forage quality of wet meadow sites other than the Nebraska Sandhills have been well documented for meadow hay harvested at progressively later dates during the growing season, including studies by McLean et al. (1963), Rumberg et al. (1964), Stewart and Clark (1944), Streeter et al. (1974), and Wilhite et al. (1955). In the present study, emphasis was placed on seasonal trends of forage quality of individual species that were major components of a subirrigated meadow near Whitman, Nebraska. Comparisons of seasonal trends in IVOMD and CP showed that there can be significant differences in forage quality among different species depending on when they are harvested. When management strategies are implemented with the intent to improve forage quality by manipulating species composition, these decisions should be based on the seasonal trends of important forage quality parameters associated with particular species. Numerous studies have shown that the species composition of subirrigated meadows can be altered by a variety of management practices: nitrogen fertilization stimulates cool-season grasses at the expense of warm-season species (Ehlers et al., 1952); phosphorus fertilization stimulates legumes (Brouse and Burzlaff, 1968); increased soil wetness favors sedges and rushes (Rumberg and Sawyer, 1965); time of cutting changes overall species composition (Baker et al., 1951); and meadow grazing in lieu of haying may impact meadow composition unless rotated with haying (Clanton and Burzlaff, 1966). These studies document that management practices can have a profound effect on the species composition of subirrigated meadows. This in turn would result in a change in the overall forage quality as substantiated by the results of this study. Any management practice which favors one forage group or species over others will increase the impact of the favored species on the nutritive value of the hay. Conversely, negative impacts can result if desirable species are reduced. When forage quality data are combined with yield data, decisions on vegetation management and manipulative practices can be made that will achieve specific production goals for quality as well as yield.

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