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Forage Yield, Quality, Compatibility, and Persistence of Warm-Season Grass—Legume Mixtures

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ABSTRACT

Development of compatible, persistent, warm-season grass–legume mixtures could increase forage yield and quality during summer months. We established a trial to determine forage yield, quality, species compatibility, and persistence of binary mixtures of warm-season grasses with selected legumes, five of which are native to the central USA. Grass entries were switchgrass (*Panicum virgatum* L.), sideoats grama (*Bouteloua curtipendula* Michx.), and indiangrass [*Sorghastrum nutans* (L.) Nash]. Legume entries were purple prairieclover [*Dalea purpurea* Vent.; syn. *Petalostemon purpureum* (Vent.) Rydb.], roundhead lespedeza (*Lespedeza capitata* Michx.), leadplant (*Amorpha canescens* Pursh), Illinois bundleflower [*Desmanthus illinoensis* (Michx.) MacMill., B. Robins. & Fern.], catclaw sensitive brier [*Schrankia nuttallii* (DC.) Standl.], and cicer milkvetch (*Astragalus cicer* L.), a cool-season species. Unfertilized grass plots without legumes also were included. The experiment was on a Haynie very fine sandy loam soil (coarse-silty, mixed, calcareous, mesic Typic Udifluvents). All mixtures containing purple prairieclover, roundhead lespedeza, Illinois bundleflower, or catclaw sensitive brier yielded more forage than did grasses grown alone or with leadplant, except for pure switchgrass in 1986. All legumes increased the crude protein concentration of forage compared to that of grass-alone plots, except for leadplant with switchgrass in 1986. Inclusion of catclaw sensitive brier and cicer milkvetch with grasses consistently improved in vitro digestible dry matter concentration (IVDDM), while inclusion of roundhead lespedeza, leadplant, and Illinois bundleflower generally resulted in decreased IVDDM concentration of forage. Purple prairieclover generally did not influence IVDMD of mixtures. Persistence of all legumes was good. Cicer milkvetch was not compatible with these grasses because it developed a thick, dense canopy prior to initiation of growth by these grasses.

THE ADVANTAGES OF COOL-SEASON LEGUMES in cool-season pasture and hayland plantings have been well documented (Burns and Standaert, 1985; Wagner, 1954). Including adapted legumes with grasses in a mixture has consistently increased forage yield and quality compared to unfertilized grasses. Rumbaugh et al. (1982) reported that interplanting alfalfa (*Medicago sativa* L.) or cicer milkvetch into a stand of crested wheatgrass [*Agropyron desertorum* (Fisch.) Schult.] significantly increased forage yield, as well as protein concentration and yield of the grass. Broadcast-seeding of biennial sweetclover [*Melilotus officinalis* (L.) Desr.] into native range increased yield and protein concentration of western wheatgrass [*Pascopyron smithii* (Rydb.) A. Löve] (Nichols and Johnson, 1969).

Cool-season legumes may not be satisfactory companion species in warm-season grass pastures. Differences in seedling vigor, optimum time of establishment, growth habit, relative maturity, harvest schedules, and poor persistence contribute to incompatibilities between many perennial warm-season grasses and introduced cool-season legumes (Marten, 1985). Additionally, many adapted, introduced legumes, particularly *Medicago* and *Trifolium* spp., can incite bloat in livestock.

Many legume species commonly occur as components of native tall-grass prairie, but at a low frequency. Although not well documented, these native legumes likely nodulate (de Faria et al., 1989) and symbiotically fix atmospheric N_2. Walsh et al. (1983) previously reported the good N_2–fixing capabilities of diverse cicer milkvetch populations. Purple prairieclover, roundhead lespedeza, Illinois bundleflower, and catclaw sensitive brier are native legumes that evolved in tall-grass prairies. These legumes may be compatible in growth habit and, therefore, may be successful in mixtures with native warm-season grasses for pasture and hay plantings. Townsend et al. (1975) tested 15 legume species and concluded that cicer milkvetch merited additional evaluation for rangeland plantings, whereas Illinois bundleflower died after the first year. Conversely, Dovel et al. (1990) reported successful establishment of Illinois bundleflower with kleingrass (*Panicum coloratum* L.). Development of compatible, persistent warm-season grass–legume mixtures could significantly increase forage yield or quality during summer periods when cool-season grasses are less productive.

Little information is currently available regarding relative forage contribution, forage quality, compatibility, or persistence of native prairie legumes or cicer milkvetch with native warm-season grasses. Therefore, we initiated this study to compare the forage yields and nutritive values of pure stands of unfertilized switchgrass, sideoats grama, and indiangrass versus binary mixtures of these grasses with purple prairieclover, roundhead lespedeza, leadplant, Illinois bundleflower, catclaw sensitive brier, and cicer milkvetch. We also evaluated the stand persistence of the legume and grass components.

MATERIALS AND METHODS

Field plots of binary grass-legume mixtures and grasses alone were seeded in 1982 at the USDA, SCS Plant Materials Center near Manhattan, KS. Grass entries were 'Blackwell' switchgrass, 'El Reno' sideoats grama, and 'Osage' indiangrass planted at 7.8, 15.3, and 12.5 kg ha^{-1} pure live seed (PLS), respectively. Legume entries were 'Kaneb' purple prairieclover, roundhead lespedeza TO4336, leadplant TO4231, Illinois bundleflower PI434011, catclaw sensitive brier TO4412, and 'Lutana' cicer milkvetch planted at 10.6, 14.6, 14.7, 17.5, 69.0, and 10.8 kg ha^{-1} PLS, respectively, without inoculation. Only catclaw sensitive brier seed were scarified. The experimental design was a split-plot with four replicates, with grass and legume entries as whole- and subplots, respectively. Grass and legume entries were seeded in alternating 0.15-m rows in 1.5

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Abbreviations: CP, crude protein; DM, dry matter; IVDDM, in vitro digestible dry matter; and PLS, pure live seed.

Table 1. Forage yields of grass–legume mixtures and grass alone in 1985 and 1986.

Grass	Legume						Grass alone	LSD (0.05)
	PPC†	RHL	LP	IBF	CSB	CMV		
	Mg ha^{-1}							
					1985			
Switchgrass	5.5	6.9	1.7	5.2	4.2	3.5	1.5	0.5
Sideoats grama	7.1	5.0	0.4	4.2	4.4	3.1	0.2	0.5
Indiangrass	6.3	5.6	1.0	4.6	4.8	3.1	0.6	0.5
LSD (0.05)	0.9	0.9	0.9	0.9	NS	NS	0.9	
CV, %								16.0
					1986			
Switchgrass	4.9	4.3	3.6	5.9	5.1	4.6	3.6	0.5
Sideoats grama	3.4	3.1	0.6	2.3	3.7	4.3	0.3	0.5
Indiangrass	4.5	3.2	1.7	2.2	4.3	4.4	1.1	0.5
LSD (0.05)	1.3	NS	1.3	1.3	1.3	NS	1.3	
CV, %								26.0

† PPC = purple prairieclover, RHL = roundhead lespedeza, LP = leadplant, IBF = Illinois bundleflower, CSB = catclaw sensitive brier, CMV = cicer milkvetch.

Table 3. Weighted mean in vitro digestible dry matter concentration of warm-season grass–legume mixtures from July harvests in 1985 and 1986.

Grass	Legume						Grass alone	LSD (0.05)
	PPC†	RHL	LP	IBF	CSB	CMV		
	g kg^{-1}							
					1985			
Switchgrass	445	379	462	403	519	539	474	33
Sideoats grama	509	377	453	398	509	583	473	33
Indiangrass	485	394	484	393	521	565	500	33
LSD (0.05)	34	NS	NS	NS	NS	34	NS	
CV, %								5.0
					1986			
Switchgrass	453	395	423	418	466	558	443	26
Sideoats grama	487	391	434	410	481	588	458	26
Indiangrass	515	439	450	405	527	590	504	26
LSD (0.05)	29	29	NS	NS	29	29	29	
CV, %								3.9

† PPC = purple prairieclover, RHL = roundhead lespedeza, LP = leadplant, IBF = Illinois bundleflower, CSB = catclaw sensitive brier, CMV = cicer milkvetch.

by 6.1-m plots on 3 June 1982 with a Kincaid[1] 5-row cone planter (Kincaid Equipment Manufacturing Corp., Haven, KS). Leadplant was reseeded on 28 April 1983 because the original seeding did not establish. The experimental site was located on a very fine sandy loam soil with a pH 6.5, high available P and K, and low available NO_3–N.

Dry forage was removed from the experimental area by burning each spring in March prior to initiation of plant growth. Forage was harvested to a stubble height of about 10 cm twice in 1983 and once in 1984. Forage from two 0.1-m^2 rectangular quadrats was hand-clipped at about 2 cm above the soil surface from each plot on 1 and 9 July 1985 and 1986, respectively, and grasses were separated from legumes. Samples were dried in a forced-air oven at 60 °C, weighed to determine relative yield contributions, and ground in a rotary mill to pass a 1.0-mm sieve. The percent legume of the above ground dry matter (DM) yield was calculated as [legume DM/(legume DM + grass DM)] × 100. Forage was harvested to about 8 cm above the soil surface with a flail chopper on 2 and 11 July 1985 and 1986, respectively, except for cicer milkvetch, which was harvested on 12 June 1985 and 4 June and 11 July 1986. Subsamples were taken and dried as previously described to determine percentage dry matter.

Primary growth of legumes and grasses was sampled by hand-clipping 0.3 m of row length on 14 June 1985, 3 June 1986, and 12 June and 1 July 1987. Samples were prepared for laboratory analyses as described previously. The IVDDM concentration was determined using a modified Tilley and Terry technique (1963). Nitrogen was determined colorimetrically following a H_2SO_4/H_2O_2 digestion. Crude protein was calculated as N × 6.25.

Visual estimates of grass and legume stands were made on 25 April 1986 and 15 May 1987. Grass and legume entries were rated separately within all individual plots on a scale of 0 to 10 (0 = no surviving plants within the seeded rows and 10 = 100 % of the stand surviving within the seeded rows, respectively).

Data were analyzed by analysis of variance procedures for a split-plot design, with years as repeated measures (SAS, 1982). When years or interactions of main effects with years were significant, data were analyzed within years. Means were separated within years by the protected least significant difference at the 0.05 level of probability (Snedecor and Cochran, 1980).

[1] Mention of a trademark or proprietary product does not constitute a guarantee or warranty by Kansas State University or the USDA and does not imply its approval over other products that may also be suitable.

RESULTS AND DISCUSSION

Although the soil at this site is very low in organic matter and water-holding capacity, mean forage yields of these unfertilized plantings were 4.5 and 3.5 Mg ha^{-1} for 1985 and 1986, respectively (Table 1). Prairie her-

Table 2. Percent legume of grass–legume mixtures in 1985 and 1986.

Grass	Legume					LSD (0.05)	CV
	PPC†	RHL	LP	IBF	CSB		
	%						
				1985			
Mean	79	78	41	76	61	12	17.9
				1986			
Switchgrass	41	74	17	36	38	25	
Sideoats grama	55	77	64	56	46	25	
Indiangrass	40	56	45	77	48	25	
LSD (0.05)	NS	NS	25	25	NS		
							26.8

† PPC = purple prairieclover, RHL = roundhead lespedeza, LP = leadplant, IBF = Illinois bundleflower, CSB = catclaw sensitive brier.

Table 4. Weighted mean crude protein concentration of warm-season grass–legume mixtures from July harvests in 1985 and 1986.

Grass	Legume						Grass alone	LSD (0.05)	CV
	PPC†	RHL	LP	IBF	CSB	CMV			
	g kg^{-1}								%
					1985				
Mean grass	83	81	73	92	116	145	43	10	13.4
					1986				
Switchgrass	53	71	42	61	75	146	31	16	
Sideoats grama	60	73	78	76	86	158	36	16	
Indiangrass	52	68	60	77	82	153	32	16	
LSD (0.05)	NS	NS	15	15	NS	NS	NS		
									14.5

† PPC = purple prairieclover, RHL = roundhead lespedeza, LP = leadplant, IBF = Illinois bundleflower, CSB = catclaw sensitive brier, CMV = cicer milkvetch.

Table 5. Crude protein concentration of three warm-season grasses within legume entries from seven harvest over 3 yr.

Harvest	Grass	Legume						Grass alone	LSD (0.05)	CV
		PPC†	RHL	LP	IBF	CSB	CMV			
		g kg^{-1}								%
						1985				
June	Grass means	66	69	53	77	72	92	57	10	17.9
July	Switchgrass	47	61	45	58	54	97	57	16	
July	Sideoats grama	74	58	42	71	64	109	46	16	
July	Indiangrass	45	57	40	73	46	81	32	16	
LSD	(0.05)	16	NS	NS	NS	16	16	16		18.6
						1986				
June	Grass means	54	52	48	69	63	—	48	9	20.4
July	Switchgrass	31	36	31	38	38	—	31	6	
July	Sideoats grama	36	43	35	47	44	—	36	6	
July	Indiangrass	31	33	29	53	38	—	30	6	
LSD	(0.05)	NS	7	NS	7	NS		NS		11.8
						1987				
June	Grass means	52	57	47	65	64	—	45	8	18.1
July	Grass means	43	49	41	55	45	—	42	5	14.2
September	Grass means	36	42	35	38	37	—	38	NS	17.0

† PPC = purple prairieclover, RHL = roundhead lespedeza, LP = leadplant, IBF = Illinois bundleflower, CSB = catclaw sensitive brier, CMV = cicer milkvetch

bage yields in the Kansas Flint Hills generally range between 2 and 4 Mg ha^{-1}, but have ranged from near 0 to more than 8 Mg ha^{-1} (Towne and Owensby, 1984). Abundant precipitation occurred in 1985 (93 cm) and 1986 (112 cm), compared to the 30-yr mean of 84 cm.

Forage yields of all binary mixtures, except for the switchgrass-leadplant mixtures, were substantially greater than those of corresponding grasses alone both years (Table 1). These results are in agreement with those of Dovel et al. (1990), who reported that Illinois bundleflower interseeded with kleingrass produced more forage than did kleingrass alone. Additionally, McGinnies and Townsend (1983) reported that mixtures involving crested wheatgrass or Russian wildrye [*Psathyrostachys juncea* (Fisch.) Nevski] with alfalfa or sicklepod milkvetch (*Astragalus falcatus* Lam.) produced significantly more dry matter than did grasses alone. Within legume entries, mixtures containing switchgrass generally produced higher yields than did mixtures containing switchgrass generally produced higher yields than did mixtures with the other grasses (Table 1). A notable exception was the yield of sideoats grama and purple prairieclover in 1985, which surpassed switchgrass and purple prairieclover. In both years, binary mixtures including purple prairieclover, roundhead lespedeza, Illinois bundleflower, or catclaw sensitive brier had significantly higher forage yields than did mixtures containing leadplant. Except for the indiangrass–leadplant mixture in 1986, yields of mixtures containing leadplant were not significantly different from those of grass-only plots.

The grass × legume interaction for percentage legume of the harvested dry matter was nonsignificant in 1985, yet it was significant in 1986 (Table 2). The harvested dry matter of plots containing cicer milkvetch was essentially 100% legume for both years; therefore, these data were not included in the statistical analysis. Townsend et al. (1990) reported that cicer milkvetch was very competitive with adapted cool-season grasses and comprised 80 to 90% of the forage by the third harvest year.

Table 6. Crude protein concentration of three warm-season grasses across legume entries from seven harvests over 3 yr.

Grass	1985 June	1985 July	1986 June	1986 July	1987 June	1987 July	1987 Sept.
	g kg^{-1}						
Switchgrass	72	59	60	34	51	41	27
Sideoats grama	72	66	56	40	62	55	50
Indiangrass	64	53	51	36	52	40	36
LSD (0.05)	5	6	4	3	7	6	7
CV, %	17.9	18.6	20.4	11.8	18.1	14.2	17.0

In our trial, cicer milkvetch averaged nearly 90% of the aboveground dry matter in 1983, the year after seeding (data not presented).

Except for leadplant, the percentage of legume in the forage was lower in 1986 than 1985. Diseases reduced the percentage of some legumes in the mixtures. A severe rust epidemic, incited by *Uropyxis petalostemonis* (Farl.) DeT., resulted in substantial defoliation of purple prairieclover in 1986. Additionally, a rust epidemic, incited by *Uromyces lespedezae-procumbentis* (Schw.) Curt., defoliated roundhead lespedeza by late August 1986. An unidentified pathogen, tentatively identified as a *Cercospora* sp., was isolated from diseased, abscising leaves of Illinois bundleflower. However, there were no symptoms of disease on catclaw sensitive brier or cicer milkvetch.

Forage yields of grasses differed significantly among legume entries and between years (data not presented). Yields of sideoats grama and indiangrass were similar between years when comparisons were made within legume entries, whereas switchgrass yields were nearly always greater in 1986 (2.7 Mg ha^{-1}) than in 1985 (1.3 Mg ha^{-1}). In 1985, sideoats grama and indiangrass yielded less when grown alone than when grown with catclaw sensitive brier or purple priarieclover. In 1986, indiangrass grown with purple prairieclover and sideoats grama

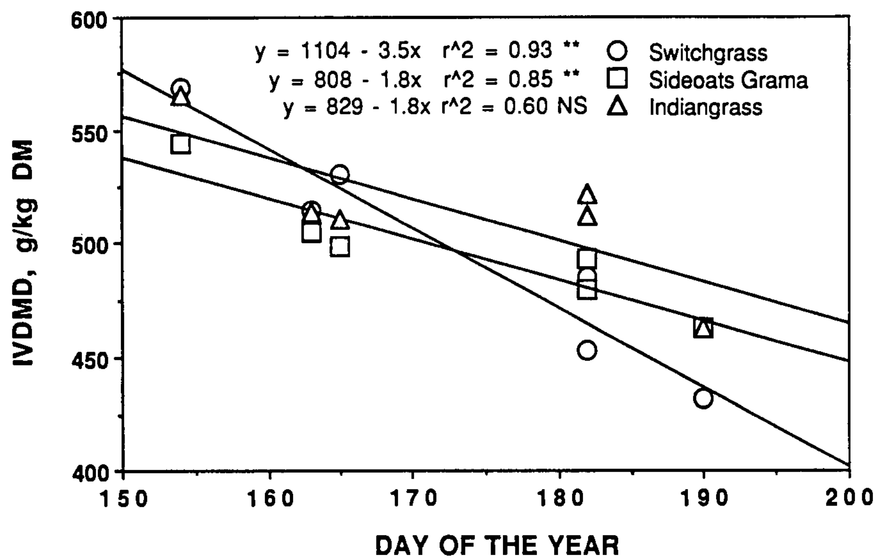

Fig. 1. In vitro digestible dry matter concentration of three warm-season grasses regressed by day of the year from six harvests over 3 yr.

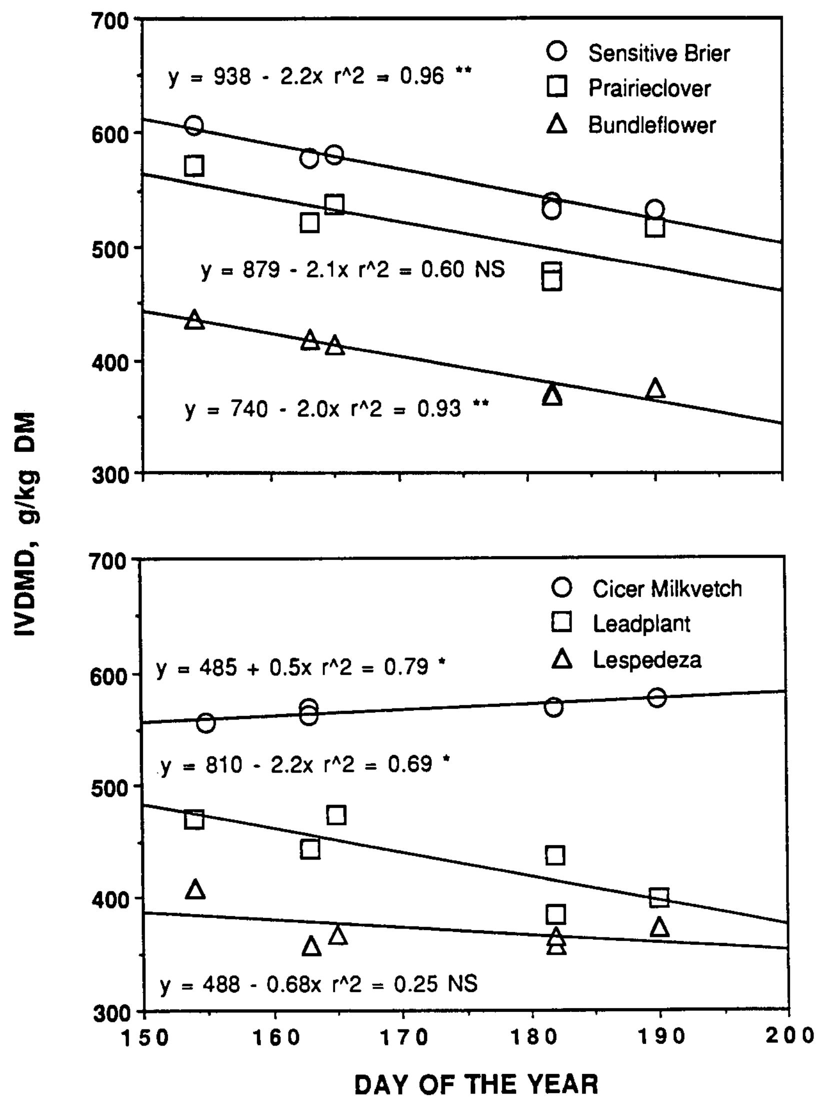

Fig. 2. In vitro digestible dry matter concentration of six legumes regressed by day of the year from six harvests over 3 yr.

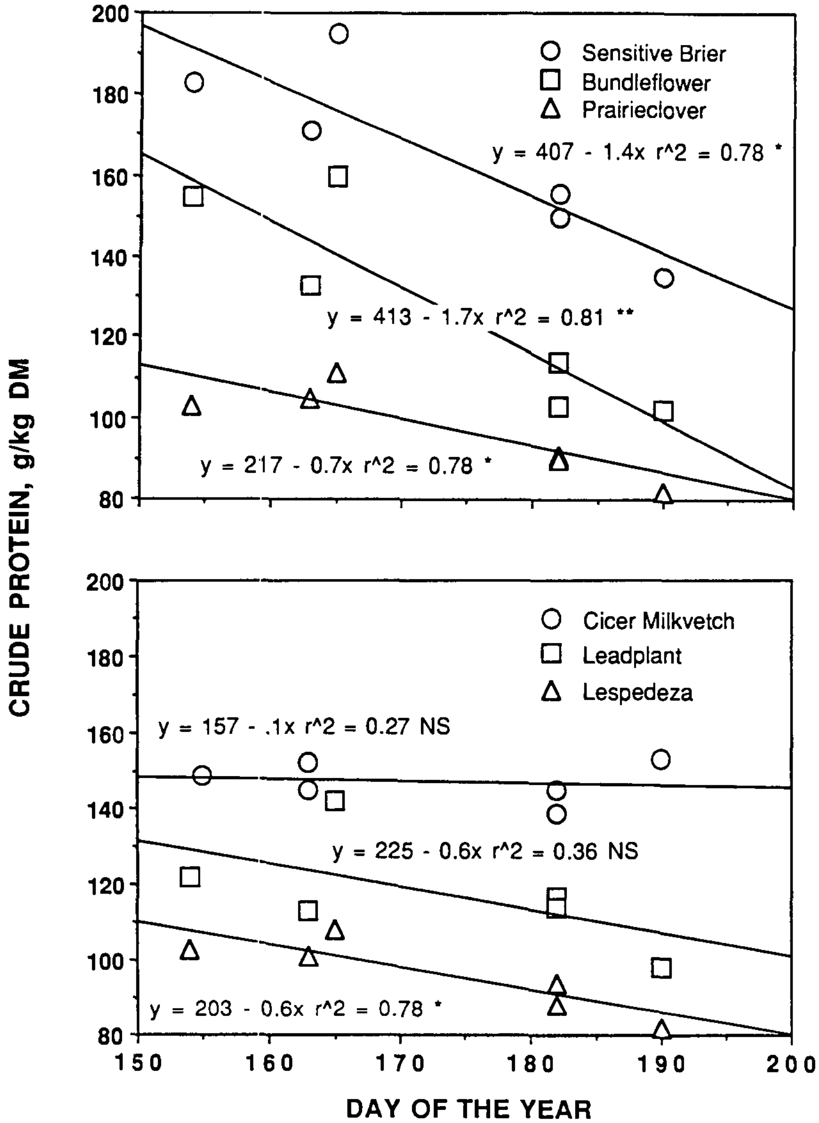

Fig. 3. Crude protein concentration of six legumes regressed by day of the year from six harvests over 3 yr.

grown with catclaw sensitive brier continued to yield more than when they were grown alone, indicating that the two legumes were supplying fixed-nitrogen to these grasses. Conversely, yields of these grasses in monoculture and in mixtures with leadplant were not significantly different.

Legume yields differed significantly among entries and between years (data not presented). Purple prairieclover and roundhead lespedeza yielded more forage (4.9 and 4.5 Mg ha^{-1}, respectively) than did other legumes in 1985 (mean = 2.2 Mg ha^{-1}), whereas cicer milkvetch, which was harvested twice, had the highest yield in 1986 (4.0 Mg ha^{-1}). Leadplant, the only entry that required reseeding, established slowly and consistently yielded the least dry matter, averaging only 0.5 Mg ha^{-1}.

The inclusion of legumes did not consistently improve forage IVDDM concentration over that of grasses alone (Table 3). Cicer milkvetch had the highest IVDDM concentration for the July harvests. High values for laboratory digestibility of cicer milkvetch have been documented previously (Townsend et al., 1978; Gabrielsen et al., 1985). In 1985, mixtures of catclaw sensitive brier with switchgrass or sideoats grama had higher IVDDM concentrations than did these grasses alone. Mixtures with leadplant trended lower in IVDDM concentration than did the corresponding grasses alone. In 1986, none of the grass–legume mixtures were significantly higher than the grasses alone for IVDDM concentration, probably because the percentage legume was lower than in the previous year. In vitro digestibilities of mixtures containing roundhead lespedeza or Illinois bundleflower were nearly always inferior to those of grasses alone. Other *Lespedeza* spp. accumulate high concentrations of tannins which limit digestibility (Barnes and Gustine, 1973), and perhaps roundhead lespedeza also accumulates high concentrations of tannins. In general, the influence of purple prairieclover was positive on forage digestibility when compared to values for grasses alone, while the influence of leadplant was negative.

The grass × legume interaction was nonsignificant for IVDDM concentration of grasses. When regressed by day of the year, IVDDM concentration of switchgrass declined faster than did IVDDM concentrations of sideoats grama and indiangrass (Fig. 1). The 3.5 g kg^{-1} decrease per day in concentration of IVDDM of switchgrass is similar to the 3.0 to 5.0 g kg^{-1} decrease per day and the 2.15% decline per week reported by Anderson et al. (1988) and Anderson and Matches (1983), respectively, for switchgrass.

The grass × legume interaction was nonsignificant for IVDDM concentration of legumes (Fig. 2). Catclaw sensitive brier, purple prairieclover, and cicer milkvetch had higher IVDDM concentrations than did the other entries. We are unable to explain the slope of the regression equation for cicer milkvetch. However, the overall IVDDM concentration is similar to that reported by Sheaffer and Marten (1991) for nonintensively-managed cicer milkvetch.

The inclusions of legumes significantly improved crude protein (CP) concentration of forages compared to that of grasses alone, except for the leadplant–switchgrass mixture in 1986 (Table 4). The inclusion of Illinois bundleflower or catclaw sensitive brier generally resulted in improved grass CP concentration (Table 5). Conversely, grasses grown with purple prairieclover or leadplant rarely had CP concentrations that differed from those of corresponding grasses grown alone. The exceptionally high concentrations of CP in grasses grown with cicer milkvetch was partly due to the severe reduction in growth of companion grasses. The CP concentration of sideoats grama was equal to or significantly higher than that for switchgrass and indiangrass at all harvests (Table 6).

The grass × legume interaction was nonsignificant for legume CP concentration. All legume entries had higher concentrations of CP than did grasses, except for grasses grown with cicer milkvetch in 1985 (Fig. 3; Table 5). Catclaw sensitive brier and cicer milkvetch had higher CP concentrations than did other entries. Crude protein concentrations for leadplant, purple prairieclover, and roundhead lespedeza declined at similar rates.

Stands were excellent for grasses grown alone or in binary mixtures with purple prairieclover, roundhead lespedeza, and leadplant. As previously noted, none of the grass entries survived into 1987 when seeded with cicer milkvetch, probably because it developed a thick, dense canopy prior to initiation of growth by these grasses. Stands of sideoats grama grown with Illinois bundleflower were significantly better than were stands of switchgrass or indiangrass when grown with bundleflower. Illinois bundleflower apparently was quite competitive with these latter two grasses. Stands of grasses grown with catclaw sensitive brier also were rated low. Catclaw sensitive brier has a prostrate growth habit similar to that of cicer milkvetch. However, unlike cicer milkvetch, it initiates spring growth at approximately the same time as the grasses.

Legumes generally persisted well in combinations with all grasses. In both years, roundhead lespedeza and catclaw sensitive brier had significantly better stands than did leadplant or cicer milkvetch. Legumes had better stands when grown with sideoats grama than with indiangrass in 1986. However, differences were nonsignificant for legume stands within grass entries in 1987. Although stands of cicer milkvetch were rated lower than those of some other legumes, it yielded and persisted well. The poor seedling vigor and difficulties encountered in initially obtaining adequate cicer milkvetch stands are well documented. However, improved seeding management (Kenno et al., 1987) and new cultivars (Townsend 1980, 1985) may alleviate stand establishment problems. This introduced, bloat-free legume appears to be well adapted for pastures in eastern Kansas, but not with these warm-season grasses.

In conclusion, binary mixtures of purple prairieclover, roundhead lespedeza, Illinois bundleflower, or catclaw sensitive brier with adapted warm-season grasses as forage crops appear promising.

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