ABSTRACT

Illinois bundleflower (*Desmanthus illinoensis* (Michaux) MacMillan ex Robinson & Fern.) appears to have the greatest potential as a forage species among 15 species of native legumes (Fabaceae) evaluated for forage yield, quality, and seed production. It ranked among the top five for all agronomic characteristics measured. Hoary tick clover (*Desmodium canescens* [L.] DC.), panicled tick clover (*Desmodium paniculatum* [L.] DC.), and roundhead lespedeza (*Lespedeza capitata* Michaux), ranked among the top five for grams per plant of forage and seed. All of the native legumes contained greater concentrations of crude protein and lower concentrations of neutral detergent fiber than typically found in the native warm-season grasses commonly sown for pasture, suggesting that these native legumes should improve forage quality in mixed pastures. Only white prairie clover (*Dalea candida* Michaux ex Willd.), purple prairie clover (*Dalea purpurea* Vent.), and Illinois bundleflower had lower concentrations of acid detergent fiber than that typically found in native warm-season grasses.

KEY WORDS

Fabaceae, Dalea, *Desmanthus*, *Desmodium*, *Lespedeza*, crude protein, neutral detergent fiber, acid detergent fiber

NOMENCLATURE

Yatskievych and Turner (1990)

From left, white prairie clover (*Dalea candida*), purple prairie clover (*Dalea purpurea*), and hoary tick clover (*Desmodium canescens*).
Photos by Jessie M Harris

Evaluation of

Native Legume Species

for Forage Yield, Quality, and Seed Production

Robert L McGraw, Floyd W Shockley, John F Thompson, and Craig A Roberts

The main pasture system for beef production in the north-central US is based on introduced cool-season grasses (Poaceae) such as tall fescue (*Festuca arundinacea* Schreb.), orchardgrass (*Dactylis glomerata* L.), and smooth bromegrass (*Bromus inermis* Leyss.) (Balasko and Nelson 2003). A problem with these cool-season grasses is they become dormant and are unproductive during hot summer months. Some livestock producers use pastures of native warm-season grasses, which are more productive at higher temperatures, for summer grazing. Moving livestock from cool-season grass pastures to native warm-season grass pastures during summer can improve animal production (Roberts and Gerrish 1999). Native warm-season grass pastures may also provide better wildlife habitat than introduced cool-season pastures, especially nesting and roosting cover for birds (Pierce and Clubine 1999). The most common native warm-season grasses used for pasture in the north-central US are indiangrass (*Sorghastrum nutans* [L.] Nash), switchgrass (*Panicum virgatum* L.), and big bluestem (*Andropogon gerardii* Vitman.) (Balasko and Nelson 2003).

Adding legumes (Fabaceae) to native warm-season grass pastures should improve forage quality, increase plant diversity, and provide wildlife benefits. Legumes can fix atmospheric nitrogen, in association with *Rhizobium* bacteria, and provide nitrogen to other plants in the ecosystem (Becker and Crockett 1976). Legumes generally contain more protein and less fiber than grasses at similar stages of growth and can be an excellent food source for both wildlife and domestic livestock (Cherney and Allen 1995).

All legumes typically used by livestock producers for pasture and hay in the north-central US are introduced species (McGraw and Nelson 2003). We wanted to determine if native legumes with potential as forage crops exist to complement native warm-season grass pastures. Little research has been published on the production and forage quality attributes of native legumes. Posler and others (1993) compared the forage yield and forage quality of 5 native legumes, purple prairie clover (*Dalea purpurea* Vent.), roundhead lespedeza (*Lespedeza capitata* Michaux), leadplant (*Amorpha canescens* Pursh), Illinois bundleflower (*Desmanthus illinoensis* [Michaux] MacMillan ex Robinson & Fern.), and catclaw sensitive brier (*Schrankia nuttallii* [DC. ex Britton and Rose] Standley), grown in binary combinations with indiangrass, switchgrass, and sideoats grama (*Bouteloua curtipendula* [Michaux] Torrey) to that of these grasses grown alone. They found that the addition of native legumes tended to increase yield and protein content as compared with grasses grown alone, except for the switchgrass–leadplant mixture; however, native legumes did not consistently improve digestibility. More information on the attributes of native legume species is needed to determine which have potential for improving warm-season grass pastures. The objective of this study was to evaluate 15 native legume species collected from several regions across the state of Missouri for forage yield, forage quality, and seed production.

MATERIALS AND METHODS

Seeds from 4 entries (sources) of white prairie clover (*Dalea candida* Michaux ex Willd.), 5 entries of purple prairie clover, 6 entries of Illinois bundleflower, 1 entry of showy tick clover (*Desmodium canadense* [L.] DC.), 5 entries of hoary tick clover (*Desmodium canescens* [L.] DC.), 7 entries of Illinois tick clover (*Desmodium illinoense* A. Gray), 5 entries of Maryland tick clover (*Desmodium marilandicum* [L.] DC.), 2 entries of tick clover (*Desmodium obtusum* [Muhlenb. ex Willd.] DC.), 2 entries of panicled tick clover (*Desmodium paniculatum* [L.] DC.), 3 entries of sessile tick clover (*Desmodium sessilifolium* [Torrey] Torrey and A. Gray), 10 entries of roundhead lespedeza, 3 entries of hairy lespedeza (*Lespedeza hirta* [L.] Hornem.), 3 entries of trailing lespedeza (*Lespedeza procumbens* Michaux), 2 entries of tall lespedeza (*Lespedeza stuevei* Nutt.), and 9 entries of slender lespedeza (*Lespedeza virginica* [L.] Britton) were collected from 11 regions throughout Missouri (Table 1). Seeds were hand-collected from each location between July and September 1993 from several randomly chosen plants of the local population.

During winter 1993–1994, seeds of each entry were planted in 5-cm diameter by 25-cm deep pots (2-in x 10-in) filled with commercial potting mixture. After germination, plants were thinned to 1 per pot and grown in a greenhouse. In spring 1994, 30 seedlings of each entry (3 replicates of 10 plants each) were transplanted into a field nursery located at Bradford Research Center near Columbia, Missouri. Plants were arranged in a spaced-plant configuration with approximately 1 m (3.3 ft) between them. Plants were inoculated with a solution containing soil collected from natural populations of each species to provide native *Rhizobium* for nitrogen fixation. Weed competition consisted mainly of annual grasses, which were controlled by mowing between plants. The field was irrigated as needed. No data were taken during establishment in 1994.

In both 1995 and 1996, one half of the plants in each replicate of each species were harvested when open flowers appeared (early flowering stage) to determine yield and forage quality. The remaining plants were harvested when most pods were mature to determine forage and seed yield. For both harvests, individual plants were cut approximately 5 cm (2 in) above the soil surface, dried at 55 °C (130 °F) for 24 h in a forced-air oven, and weighed. At the second harvest individual plants were threshed using a rubboard. The seed yield was measured by weight of seeds per plant and number of seeds per plant (calculated as the product of weight of 100 seeds and total weight of seeds per plant).

Dried samples of each individual plant harvested at the early flowering stage were ground in an Udy cyclone sample mill (UDY Corp, Ft Collins, Colorado) to pass a 1-mm screen. Forage quality was evaluated by measuring neutral detergent fiber (NDF; higher values indicate poorer forage), acid detergent fiber (ADF; an index of digestibility), and crude protein (CP). To determine neutral detergent fiber, acid detergent fiber, and crude protein, ground samples were analyzed spectrally with a near infrared reflectance NIRSystems scanning monochromator, model 5000 (Foss-NIRSystems, Silver Spring, Maryland) using software developed by Infrasoft International (Port Matilda, Pennsylvania). Samples were scanned with near infrared radiation from 1110 to 2490 nm, and log 1/reflectance (log 1/R) was recorded at 2-nm intervals. Spectral prediction equations for NDF, ADF, and crude protein were developed by regressing chemical analysis data against first and second derivative transformations of log 1/R. The regression

TABLE 1

The natural divisions, sections, and counties in Missouri where seeds of native legumes were collected and evaluated for forage yield, quality, and seed production.

Natural division [a]	Section	Counties	Species collected
Glaciated Plains	Western	Atchison, Holt	Illinois bundleflower; Illinois tick clover; roundhead lespedeza
Glaciated Plains	Grand River	Adair	Hoary and Illinois tick clover; roundhead and slender lespedeza
Glaciated Plains	Eastern	Adair, Boone, Lincoln, Pike	White and purple prairie clover; Illinois bundleflower; Maryland tick clover; tick clover; roundhead and slender lespedeza
Glaciated Plains	Lincoln Hills	Lincoln	Slender lespedeza
Ozark Border	Missouri River–North	Boone	Hoary, Illinois, Maryland, panicled and sessile tick clover; tick clover; roundhead lespedeza
Ozark Border	Missouri River–South	Cole, Miller, Osage	Purple prairie clover; Illinois bundleflower; hoary and Maryland tick clover; roundhead, hairy, trailing, tall, and slender lespedeza
Osage Plains		Benton, Henry, St Clair	White and purple prairie clover; Illinois bundleflower; Illinois and sessile tick clover; roundhead and slender lespedeza
Ozark	Springfield Plateau	Dade, St Clair	White and purple prairie clover; Illinois bundleflower; Illinois and sessile tick clover; roundhead and slender lespedeza
Ozark	Upper Ozark	Laclede, Texas	Purple prairie clover; Illinois bundleflower; hoary, Illinois, Maryland and panicled tick clover; roundhead, trailing, and slender lespedeza
Ozark	Lower Ozark	Oregon	Roundhead, hairy, trailing, and slender lespedeza
Ozark	White River	Barry	White prairie clover; hoary, Illinois and Maryland tick clover; roundhead, hairy, tall, and slender lespedeza

[a] Described in Nelson (1985).

TABLE 2

Calibration and validation statistics for quantification of neutral detergent fiber, acid detergent fiber, and crude protein of 15 native legumes by near infrared reflectance spectroscopy and modified partial least squares regression.

	n	R^2	Range	Mean	SEC [a]	SECV [b]	1 – VR [c]
				g/kg			
Neutral Detergent Fiber	70	0.95	415 to 702	542	11.9	18.2	0.89
Acid Detergent Fiber	68	0.96	255 to 518	419	15.3	18.7	0.94
Crude Protein	66	0.96	83 to 198	128	4.1	5.8	0.92

[a] SEC = standard error of calibration calculated in cross validation in modified partial least squares regression.

[b] SECV = standard error of cross validation in modified partial least squares regression.

[c] 1 - VR = 1 minus the variance ratio (VR) calculated in cross validation in modified partial least squares regression.

procedure was a modified partial least squares regression. Subsequent equations were validated with 4 validation groups, and outliers were eliminated in 2 outlier passes (Shenk and Westerhaus 1991). Optimum equations were chosen based on high coefficients of determination for calibration (R^2) and 1-variance ratios (1-VR), and low standard errors of calibration (SEC) and cross validation (SECV) according to criteria outlined by Windham and others (1989) (Table 2).

Chemical analysis procedures of ADF and NDF used for calibration were conducted using the procedure of Goering and Van Soest (1970). Samples for crude protein determination were sent to Custom Laboratories (Golden City, Missouri) for nitrogen extraction using the Kjeldahl method, and crude protein was later calculated as N • 6.25 (AOAC International 1995). Forage quality data are reported as grams of NDF, ADF, or crude protein per kg of plant dry weight (g/kg • 0.016 = oz/lb).

Data were analyzed using the Statistical Analysis System (SAS Institute 1985) to perform a one-way ANOVA (Proc GLM) in a randomized complete block design with 3 replicates. There were differences between years; however, this was mainly because the plants were older and thus larger in 1996 compared to 1995. Error variances between years for each species were examined for homogeneity and found to be similar; therefore, we combined data across years. Means were separated using Fisher's protected least significant difference tests (LSD) and reported as different at $P \leq 0.05$.

RESULTS AND DISCUSSION

Forage Yield

Forage yield at early flowering ranged from about 10 g/plant for white prairie clover to 64 g/plant for hoary tick clover (Table 3). Plants were harvested at the early flowering stage because recommendations for most introduced legumes, such as alfalfa (*Medicago sativa* L.), red clover (*Trifolium pratense* L.), white clover (*T. repens* L.), and birdsfoot trefoil (*Lotus corniculatus* L.), are to harvest between first flower and 50% flowering depending on the species (Miller 1984). At this stage of growth, most forage legumes reach the optimum compromise between forage quality, which declines with age, and forage yield, which usually increases to the early seed filling stage. The top 4 species (hoary tick clover, showy tick clover, roundhead lespedeza, and panicled tick clover) had similar forage yields and averaged 58 g/plant. Illinois bundleflower was intermediate for forage yield at 39 g/plant. The other 10 native legumes averaged 17 g/plant and were not significantly different from each other.

When plants were allowed to reach the mature seed stage, Illinois bundleflower produced the greatest forage yield at 65 g/plant (Table 3). Roundhead lespedeza had the second greatest forage yield at 44.9 g/plant but did not differ from panicled tick clover, hoary tick clover, or tick clover at 41.8, 37.7, and 30.7 g/plant, respectively. The other 10 species had statistically similar forage yields ranging from 5.7 to 22.1 g/plant.

Seed Yield

If a native legume is to be marketed for use by livestock producers, adequate seed sources must be available. We determined seed production potential by measuring the weight of seeds per plant and the number of seeds per plant. The number of seeds produced can be important for natural reseeding in pastures. Illinois bundleflower and tick clover produced the greatest weight of seed at 7.7 and 6.0 g/plant, respectively (Table 3). Roundhead lespedeza produced 3.7 g/plant of seed and was statistically similar to tick clover. Panicled tick clover, showy tick clover, and hoary tick clover were similar and averaged 3.2 g/plant of seed. All other species produced less than 3.0 g/plant of seed. The top 3 species for weight of seed per plant, Illinois bundleflower, tick clover, and roundhead lespedeza, also produced the highest number of seeds per plant (Table 3). Purple prairie clover, however, which produced only 2.1 g of seed per plant, produced a similar number of seeds per plant as the top 3 species, because of its relatively small seed size. Purple prairie clover averaged 698 seeds/g compared to 426, 262, and 186 seeds/g for roundhead lespedeza, tick clover, and Illinois bundleflower, respectively.

Forage Quality

Forage quality is an important characteristic of plants used for livestock grazing. It is often evaluated by measuring concentrations of neutral detergent fiber, acid detergent fiber, and crude protein.

Neutral detergent fiber (NDF) is a measure of the amount of structural fiber or cell wall material in the plant and is often associated with animal intake (Collins and Fritz 2003). The NDF fraction is only partially digestible by the microorganisms in the rumen; thus, larger NDF values indicate poorer forage quality and lower animal intake. Concentrations of NDF in this study averaged 571 g/kg. The 2 native legumes with the lowest NDF values were purple prairie clover and Illinois bundleflower at 473 and 483 g/kg, respectively (Table 3). All other species had NDF concentrations greater than 500 g/kg with sessile tick clover having the most fiber at 645 g/kg. All 15 native legumes had lower concentrations of NDF than values found in the literature for the native warm-season grasses commonly grown for pasture. In a study conducted across several states, NDF concentrations averaged 730 g/kg for switchgrass, 738 g/kg for big bluestem, and 735 g/kg for indiangrass (Reid and others 1988). The NDF concentrations found in the native legumes, however, were relatively high compared to typical NDF concentrations found in common introduced forage legumes. Introduced legumes, when harvested in the early bloom stage of growth, typically have NDF concentrations ranging from 400 to 460 g/kg (Rohweder 1990a).

TABLE 3

Forage yield, quality, and seed production data averaged for 1995 and 1996 for 15 native legumes grown in central Missouri.

Species	Forage yield		Forage quality			Seed yield	
	Flowering	Mature	Neutral detergent fiber	Acid detergent fiber	Crude Protein		
	g/plant		g/kg			g/plant	seeds/plant
White prairie clover	10.2 c [a]	5.7 f	507 j	0.1 e	127 cd	0.1 e	77 d
Purple prairie clover	11.6 c	22.1 cdef	473 k	2.1 cde	152 a	2.1 cde	1441 a
Illinois bundleflower	38.8 b	65.0 a	483 k	7.7 a	142 b	7.7 a	1441 a
Showy tick clover	57.9 a	20.5 def	594 de	3.0 cd	127 cd	3.0 cd	645 b
Hoary tick clover	64.2 a	37.7 bcd	584 ef	3.3 c	131 c	3.3 c	691 b
Illinois tick clover	13.3 c	21.9 def	570 gh	2.4 cde	146 ab	2.4 cde	360 c
Maryland tick clover	23.7 c	19.0 def	585 ef	0.7 e	133 c	0.7 e	178 d
Tick clover	18.3 c	30.7 bcde	627 b	6.0 ab	123 d	6.0 ab	1578 a
Panicled tick clover	55.1 a	41.8 bc	580 fgh	3.4 c	130 cd	3.4 c	823 b
Sessile tick clover	19.6 c	13.6 ef	645 a	0.8 de	112 e	0.8 de	245 c
Roundhead lespedeza	55.9 a	44.9 b	582 efg	3.7 bc	112 e	3.7 bc	1574 a
Hairy lespedeza	17.2 c	9.8 f	610 c	0.8 de	112 e	0.8 de	255 c
Trailing lespedeza	22.0 c	17.7 ef	555 i	0.3 e	133 c	0.3 e	135 d
Tall lespedeza	19.9 c	13.6 ef	604 cd	2.0 cde	112 e	2.0 cde	960 b
Slender lespedeza	16.1 c	13.4 ef	568 h	1.5 cde	128 cd	1.5 cde	758 b

[a] Means are compared among species (within columns). Those followed by the same letter are not significantly different at the 0.05 level.

Acid detergent fiber (ADF) is mainly cellulose and lignin because the acid soluble fibers such as hemicellulose are removed (Collins and Fritz 2003). The ADF concentration is believed to be associated with forage digestibility and is used to calculate total digestible nutrient values. Concentrations of ADF in this study averaged 416 g/kg. The native legume with the lowest ADF concentration was white prairie clover at 275 g/kg (Table 3). Purple prairie clover and Illinois bundleflower ranked second statistically for low ADF at 293 and 298 g/kg, respectively. These 3 native legumes had low levels of ADF compared to values reported for common introduced forage legumes and for native warm-season grasses commonly sown for pasture. Introduced legumes, harvested in the early bloom stage of growth, typically have ADF concentrations ranging from 310 to 350 g/kg (Rohweder 1990a). Acid detergent fiber concentrations averaged 405 g/kg for switchgrass, 431 g/kg for big bluestem, and 429 g/kg for indiangrass in a multistate study (Reid and others 1988). White and purple prairie clover and Illinois bundleflower should improve forage digestibility when sown in pastures with these native grasses. The remaining 12 native legumes had ADF concentrations ranging from 389 to 472 g/kg, which are greater than the ADF concentrations reported for common introduced legumes.

Higher crude protein concentrations are considered an indicator of higher forage quality. Crude protein concentrations averaged across both years for the 15 native legumes ranged from 112 to 152 g/kg (Table 3). Purple prairie clover had the greatest crude protein concentration but was not significantly different from Illinois tick clover at 146 g/kg. Illinois bundleflower had the third greatest concentration of crude protein at 142 g/kg but was not statistically different from Illinois tick clover. All 15 native legumes had higher crude protein concentrations than those typically reported for the commonly used native warm-season grasses. Reported crude protein concentrations averaged 78 g/kg for switchgrass, 79 g/kg for big bluestem, and 66 g/kg for indiangrass (Reid and others 1988). Planting native legumes into pastures of these native grasses should increase the amount of protein available for grazing animals. The crude protein concentrations found in these native legumes were less than one would expect for the introduced forage legumes when harvested at similar stages of growth. Common introduced forage legumes typically average between 170 to 190 g/kg crude protein (Rohweder 1990b).

CONCLUSIONS

Compared with introduced legumes commonly used in the north-central US for pasture, the native legumes in this study had less crude protein and more cell wall fiber. It does not appear that native legumes would be a good substitute for the common introduced legumes when forage quality is the only consideration. Some producers, however, are interested in using only native species when establishing pastures for grazing and wildlife purposes. Native legumes should improve forage quality when mixed with commonly used native warm-season grasses. All native legumes contained greater concentrations of crude protein and lower concentrations of NDF than typically found in the native warm-season grasses commonly used for pasture. Three native legumes, white and purple prairie clover and Illinois bundleflower, had lower concentrations of ADF than typically expected for native warm-season grasses or common introduced forage legumes. These legumes should improve digestibility when mixed with native warm-season grasses. Although white and purple prairie clover tended to have good forage quality, they had relatively poor forage yields. Four native legumes, hoary tick clover, panicled tick clover, roundhead lespedeza, and Illinois bundleflower, ranked among the top five for forage yield, when harvested at both the early bloom and mature seed stages, and for g/plant of seed. When all of the agronomic characteristics measured in this study were considered, Illinois bundleflower appeared to have the greatest potential as a forage species. It ranked first for g/plant of seed and forage dry matter yield harvested at mature seed stage, second for lowest NDF, third for lowest ADF, third for greatest crude protein concentration, and fifth for forage yield harvested at early bloom stage.

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