IMPACT OF DEFOLIATION ON HERBAGE AND SEED PRODUCTION OF *Strophostyles helvula* AND *S. leiosperma*

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ABSTRACT

Trailing wild bean (*Strophostyles helvula* (L.) Ell. [Fabaceae]) yielded up to 1793 g herbage/plant/y (3.9 lb) and out-produced smooth-seeded wild bean (*Strophostyles leiosperma* (Torr. & Gray) Piper) by a factor of 1.8 to 3.4, depending on location and growing conditions. In contrast to trailing wild bean that appeared to be photoperiod sensitive and produced most of its seeds in autumn (63 g/plant/y [2.2 oz]) at the best site, smooth-seeded wild bean responded to light defoliation by increasing seed yields during the growing season (from 12 to 86 g/plant/y [0.4 to 3.0 oz]). Herbage fiber concentration decreased and crude protein increased when defoliation occurred throughout the growing season. Results suggest these *Strophostyles* species are suitable candidates for rangeland reseeding, wildlife feed, and prairie restoration in the southern Great Plains region.

KEY WORDS

nutritive value, wild bean, forage, crude protein, fiber, lignin, CP, ADF, ADL

NOMENCLATURE

USDA NRCS (2004)

Strophostyles helvula is an annual legume found from Canada to the Gulf Coast of Texas.

Photo by James P Muir

Smooth-seeded wild bean (*Strophostyles leiosperma* (Torr. & Gray) Piper) and its close relative, trailing wild bean (*Strophostyles helvula* (L.) Ell. [Fabaceae]), are annual warm-season legumes native to Texas that often colonize open, disturbed areas (Diggs and others 1999). Both are common in the Cross Timbers region of north-central Texas and spread aggressively when sod-forming grasses are not dominant (Gee and others 1994). Trailing wild bean is an important rangeland plant throughout the US (Prichard and Forseth 1988) and Canada (Yanful and Maun 1996) whereas smooth-seeded wild bean, perhaps because it has smaller leaves, has been studied less despite reports of its presence as far north as Illinois (Anderson and van Valkenburg 1977). Preliminary observations on native germplasm in north Texas indicated that herbage and seed production of both species show promise for wildlife plantings, prairie restoration, native range reseeding, and cultivated pastures.

Legumes are generally high in nutrient quality, especially high levels of digestible crude protein derived from plant–Rhizobia symbiosis (White and Wight 1984; Clark and Ulyatt 1985). Smooth-seeded and trailing wild beans have been documented as important wildlife vegetation in the Cross Timbers region of Texas and Oklahoma (Gee and others 1994) but neither has been evaluated for range reseeding or cultivated pasture. Because no exotic annual, warm-season legumes with widespread adaptation have been successfully introduced in semiarid regions of the southern US, wild beans could become important both as herbage for domestic and wild herbivores as well as seeds for native birds.

Very little is known, however, about agronomic characteristics of these legumes. Lynd and Odell (1983) evaluated the productivity and dinitrogen fixation of trailing wild bean in Oklahoma. No other information is available on herbage quality and seed yields for either of these wild bean species. The objectives of this study were to determine crude protein, acid detergent fiber, and acid detergent lignin concentrations of the herbage, and to evaluate herbage and seed production of trailing and smooth-seeded wild bean in 3 distinct environments in Texas, under a range of defoliation regimes.

MATERIALS AND METHODS

The experiment was conducted during 2001 at 3 sites in Texas. The Stephenville site is located at N 32° 15' and W 98° 12', and elevation 395 m (1295 ft) on a Windthorst (fine, mixed thermic Udic Paleustalfs) fine sandy loam (pH 5.7; 3 ppm P; 179 ppm K; 1095 ppm Ca; and 171 ppm Mg). The site was dominated by Bermudagrass (*Cynodon dactylon* (L.) Pers. [Poaceae]) that was mowed and sprayed with Clethodim ((E,E)(+/-)-2-[1[[(3chloro-2-propenyl) oxy]imino]propyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one) at 0.15 kg ai/ha (0.13 lb ai/ac) in May 2001. The Vernon site is located at N 34° 0' and W 99° 0', and elevation 366 m (1200 ft) on a Miles (mixed thermic Udic Paleustalfs) fine sandy loam (pH 6.6; 20 ppm P; and 300 ppm K). The San Angelo site is located at N 31° 32' and W 100° 31', elevation 600 m (1970 ft) on an Angelo (fine, mixed thermic Torrertic Calciustolls) clay loam (pH 7.8; 70 ppm P; and 876 ppm K). The area was previously cropped with wheat. Plots in San Angelo and Vernon were also sprayed with Clethodim at the same rates as Stephenville, and weeds that escaped herbicide control at all 3 locations were removed by hand.

Seeds of trailing and smooth-seeded wild beans were collected from more than 8 range sites in the Cross Timbers area of Texas (Erath, Comanche, and Palo Pinto counties) during summer 2000. In March 2001 and 2003, these seeds were scarified, inoculated with a general "cowpea" *Rhizobium* inoculant, and germinated in 100-ml (6-in^3) containers filled with topsoil collected at the Stephenville site. Once danger of frost was over in April of each year, seedlings were outplanted at each location in plots consisting of 3 rows of 3 plants on 0.5-m (1.6-ft) centers. Plots were irrigated at outplanting with 40 mm (1.6 in) water. Severe weather, shearing winds at Vernon and drought at San Angelo, resulted in complete loss of plants at these locations in 2003. Precipitation was below average during the growing season at all 3 locations both years and irrigation was applied during the 2001 growing season whenever monthly rainfall fell below 30-y averages. Plots were irrigated with 50 mm (2 in) in April and June at Stephenville to a total of 499 mm (20 in) water from March to October 2001. No irrigation was applied in 2003 when 586 mm (23.4 in) rainfall fell, 40% in a single, early-June event. The long-term average precipitation for the same period at this location is 594 mm (23.8 in). Plots at San Angelo were irrigated with 25 mm (1 in) on July 6, 31 mm (1.24 in) on July 29, and 22 mm (0.9 in) on August 20 to a total of 370 mm (14.8) water (rain and irrigation) for the period March through October 2001, compared with long-term average of 424 mm (17 in) rainfall for these months. At Vernon, plots were irrigated with 14 mm (0.6 in) each in July and August, giving 327 mm (13 in) of water (rainfall and irrigation) from March to October 2001 compared with a long-term average precipitation of 597 mm (24 in) for the same period at this location. Plants that died within 14 d of outplanting were replaced in April both years at all locations.

Three defoliation treatments were initiated whenever the majority of plots were covered by the viney growth of wild bean plants. Timing and number of defoliations varied considerably by location and species. Defoliation treatments were unclipped (control), clipped 10 cm (4 in) from the plant base, and clipped 20 cm (8 in) from the base. Defoliation was repeated whenever plants regrew to fill in the plots while unclipped plots were harvested only once close to October 15, just before the first frost. Only the single inner plant was used to estimate herbage yield. Herbage was dried in forced-air ovens at 55 °C (131 °F) until a stable weight was reached. Total aboveground dry mass production was estimated by summing herbage yields from that plot during the growing season.

In 2001, representative herbage subsamples from defoliated plants from each plot were ground through a 1-mm screen and analyzed at the Stephenville herbage laboratory for acid detergent fiber (ADF), acid detergent lignin (ADL), and nitrogen (N) concentrations. Acid detergent fiber and ADL concentrations in herbage dry matter (DM) were determined according to Van Soest and Robertson (1980). Crude protein (CP) was estimated by measuring total herbage N concentration using a modification of the aluminum block digestion procedure of Gallaher and others (1975) and multiplying by 6.25. Sample weight was 1.0 g (0.035 oz), digest used was 5 g (0.18 oz) of 33:1:1 K_2SO_4:$CuSO_4$:TiO_2, and digestion was conducted for 2 h at 400 °C (752 °F) using 17 ml (0.6 oz) of H_2SO_4. Nitrogen concentration in the digestate was determined by semiautomated colorimetry (Hambleton 1977) using a Technicon Autoanalyzer II (Technicon Industrial Systems, Tarrytown, New York).

Seedpods were collected from only the inner plant from all plots just prior to shatter and batched by plot over season. These pods were then air-dried and the seeds removed to estimate seed yield and number.

Plots at all locations were arranged in a randomized complete block design with 4 replications. Location, species, and defoliation regime were used as independent variables in the model and analyzed for interactions and main effects where appropriate ($P < 0.05$ unless specified in the text). Years were not included in the model because of plot failure, and Stephenville data for 2003 were analyzed separately. A least significant difference (LSD) test was used to separate defoliation and location means where appropriate at the probability level of 0.05.

RESULTS AND DISCUSSION

Herbage Production

Defoliation regimes did not affect herbage yield. There were, however, yield differences between species at each site (Figure 1). The San Angelo site was the least productive, and despite similar precipitation both species produced more herbage at Vernon than at San Angelo. Trailing wild bean was more productive relative to smooth-seeded wild bean at Stephenville where soil water was greater. It yielded greater herbage than smooth-seeded wild bean by a factor of 3.4 at Stephenville but only 1.8 at Vernon. These results indicate that smooth-seeded wild bean may have reached its maximum yield potential at 2 locations whereas the trailing wild bean may produce even greater yields with increasing soil water. Rainfall distribution may also be a factor in continuous forage growth. Despite 15% greater total rainfall and irrigation in 2003, forage yields of both species were considerably lower in 2003 at Stephenville than in 2001. Over 40% of the season's

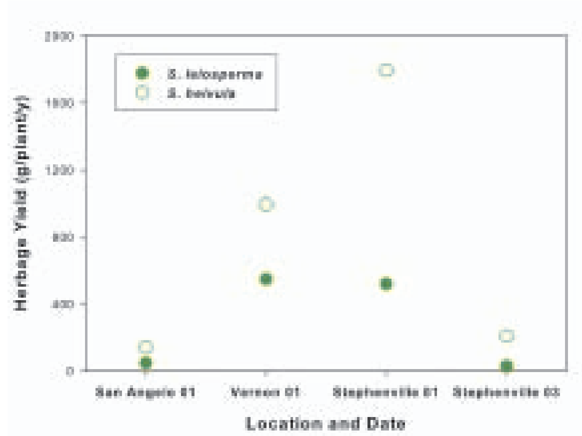

Figure 1. Herbage yield of *Strophostyles leiosperma* and *S. helvula* at 3 locations in Texas (2001 species by location interaction $P = 0.001$ and $LSD_{0.05} = 600$; 2003 Stephenville species $P = 0.001$) pooled over 3 defoliation regimes (1 g = 0.035 oz).

rainfall fell in early June and no irrigation was applied during mid-season 2001, resulting in more uneven moisture distribution that year.

Herbage yields of trailing wild bean and smooth-seeded wild bean were comparable with those reported for commercially available, annual, warm-season, herbaceous legumes in other subhumid and semiarid climates (Jones and Rees 1997). The 7 Mg/ha (6250 lb/ac) equivalent herbage yields measured for the trailing wild bean at Stephenville when irrigation mitigated rainfall distribution shortfalls, however, were greater than yields reported for other annual legumes grown under similar dryland conditions (Keating and Mott 1987; Muir 2002).

Seed Production

Trailing wild bean seed mass averaged 20 mg/plant/y, 2.5X the smooth-seeded wild bean seeds that averaged 8 mg. Seeds from plants that were not water stressed ranged up to 80 and 18 mg for trailing and smooth-seeded wild beans, respectively.

Seed yields (Table 1) of trailing wild bean were greatest at Stephenville in 2001, while those of smooth-seeded wild bean were highest at San Angelo in 2001 (species by location interaction $P = 0.001$). The high seed yield of smooth-seeded wild bean at San Angelo, despite a precipitation deficit, indicates a possible capacity for early-season seed production prior to the onset of water stress. As an indeterminate annual, smooth-seeded wild bean appears to partition nutrients to seed production as early as possible and maintain vegetative (and reproductive) growth only when soil water is adequate and herbivory removes leaf area. Smooth-seeded wild bean, however, did not respond to low moisture conditions in late 2003 with a similar increase in seed set, so other factors may be involved.

Protecting plants from defoliation during the growing season (control) increased seed production of the trailing wild

TABLE 1

Seed yields of Strophostyles leiosperma *and* S. helvula *at 3 locations and 2 y in Texas as a function of defoliation intensity.*

	Stephenville		Vernon	San Angelo
	2001	2003	2001	2001
	g [z] seeds/plant/y			
S. leiosperma	15 a [y] B	3 B	12 a A	86 b A
S. helvula	63 a A	9 A	8 b A	12 b B
2001 species by location interaction *P* = 0.001				

	Control	Light defoliation	Heavy defoliation
S. leiosperma	21 b B	57 a A	34 ab A
S. helvula	53 a A	19 b B	10 b A
2001 species by defoliation interaction *P* = 0.06			

	Stephenville		Vernon	San Angelo
	2001	2003	2001	2001
Control	78 a A	14 A	11 b A	0 b C
20-cm height [z]	28 a B	2 B	10 a A	76 b A
10-cm height	21 b B	1 B	9 b A	47 a B
2001 defoliation by location interaction *P* = 0.06				

[z] Conversions: 1 g = 0.035 oz; 1 cm = 0.4 in

[y] Means followed by the same lower case letter (within rows for 2001) or upper case letter (within columns) are not different according to Duncan's Multiple Range Test (*P* = 0.05)

bean but appeared to decrease seed yield in smooth-seeded wild bean (2001 species by defoliation regime interaction *P* = 0.06; 2001 species by defoliation regime interaction *P* = 0.01, data not presented). Seed yield of smooth-seeded wild bean lightly harvested throughout the season was nearly 2.7X the seed production by control plants.

San Angelo had no seeds to harvest in control plots; plants had died by the time of harvest, apparently because of inadequate soil water (2001 defoliation regime by location interaction *P* = 0.06). In contrast, Stephenville's 2001 rainfall and irrigation, nearly double that of the other 2 locations, favored greater autumn seed yields. The more severe defoliation regime resulted in lower seed yields than the light defoliation only at San Angelo, where late-season droughty conditions precluded regrowth.

Smooth-seeded wild bean produced greater numbers of seeds than the trailing wild bean at Stephenville (both years) and San Angelo but did not exceed it at Vernon (species by location interaction *P* = 0.06; Table 2). At San Angelo, the season-long seed production of the smooth-seeded wild bean averaged across defoliation treatments was 29-fold greater than that of the trailing wild bean, suggesting an advantage in utilization of early summer soil moisture by smooth-seeded wild bean. Similar results were reported by Keating and Mott (1987) for phasey bean (*Macroptilium lathyroides* (L.) Urban [Fabaceae]), a commercially cultivated perennial herbaceous legume that, in Florida, exhibits the characteristics of an annual that can produce from 960 to 4920 seeds/m^2/season (89 to 457 seeds/ft^2), depending on soil water.

Responses of seed number to defoliation regimes differed between species (2001 species by defoliation interaction *P* = 0.09; 2002 data not presented). Smooth-seeded wild bean responded to light defoliation by increasing seed numbers when compared with plants severely defoliated or control plants. This response indicates that moderate grazing of smooth-seeded wild bean during the growing season would stimulate seed production for game birds and subsequent season stand regeneration from seeds. In contrast, to maximize seed production of trailing wild bean seeds, herbage removal should be minimized. Both wild bean species exhibited indeterminant flowering, but trailing wild bean delayed most of its reproductive activity to early autumn, while smooth-seeded wild bean flowered throughout the season.

Seed number was affected by defoliation regime differently at all locations (2001 harvest by location interaction *P* = 0.09; 2003 species *P* = 0.004). Protecting plants from defoliation until the autumn (control) increased seed numbers at

TABLE 2

Number of seeds produced by Strophostyles leiosperma *and* S. helvula *at 3 locations in Texas in response to defoliation intensity.*

	Stephenville		Vernon	San Angelo
	2001	2003	2001	2001
	seeds/plant/y			
S. leiosperma	583 b [z] A	198 A	69 c A	825 a A
S. helvula	339 a B	68 A	13 b A	28 b B
2001 species by location interaction $P = 0.06$				

	Control	Light defoliation	Heavy defoliation
S. leiosperma	332 b A	737 a A	408 b A
S. helvula	212 a B	111 b B	58 b B
2001 species by defoliation interaction $P = 0.09$			

	Stephenville		Vernon	San Angelo
	2001	2003	2001	2001
Control	602 a A	314 A	46 b A	0 b C
20-cm height[z]	593 a A	68 B	43 b A	635 a A
10-cm height	188 b B	16 B	34 c A	477 a B
2001 defoliation by location interaction $P = 0.06$				

[z] Means followed by the same lower case letter (2001 within rows) or upper case letter (within columns) are not different according to Duncan's Multiple Range Test ($P = 0.05$).

Stephenville both years, while light defoliation increased seed set relative to severe defoliation, only in 2001. At San Angelo, however, plants lightly defoliated had greater seed set than the severely defoliated plants which, in turn, had greater reproductive activity than the undefoliated plants. At the Vernon location, plant development in 2001 was so poor that there were no differences in seed number in relation to defoliation intensity.

Herbage Nutritive Value

Herbage ADF and ADL concentrations showed similar responses and were highly correlated (r = 0.92) and were affected by an interaction of species, defoliation regime, and location (Tables 3 and 4). Fiber concentrations were lower for severely defoliated trailing wild bean compared to lightly defoliated plants at San Angelo and Vernon. In contrast, fiber fractions of smooth-seeded wild bean, which had finer stems, were not affected by defoliation at any location. Herbage harvested in control plots (undefoliated during the growing season) had the greatest fiber concentrations for both species at Vernon and for trailing wild bean at Stephenville. These values were greater at Vernon where water stress resulted in leaf abscission in late summer. These whole-plant ADF and ADL values were greater than those measured from hand-plucked leaves of commercially available annuals such as phasey bean and partridge-pea (*Chamaecrista fasciculata* (Michx.) Greene [Fabaceae]) that had ADF concentrations of 27% and 24%, respectively, over 2 years at Stephenville (Muir 2002).

Herbage levels of CP varied with species, defoliation regime, and location (species by location by defoliation interaction $P = 0.001$; Table 5) and were inversely correlated to herbage ADF and ADL concentrations (r = –0.83 and r = –85, respectively). Except for smooth-seeded wild bean at Stephenville, CP concentrations were much higher in plants defoliated throughout the season compared with control plants measured only in autumn and higher in severely defoliated plants then lightly defoliated plants. Crude protein concentrations in herbage legumes usually range from 15% to 25% (Brink and Fairbrother 1988; Aiken and others 1991). At Vernon and Stephenville in the autumn, plants had green foliage, with low CP concentrations reaching 8% in smooth-seeded wild bean at Vernon. Thro and Shock (1987) measured similar CP concentrations in some commercially cultivated annual, warm-season herbage legumes in the south-central US. Annual legumes tend to lose leaf biomass and CP concentration late in the growing season (Muldoon 1985), so their greatest contribution will be to early-season grazing and late-season seed for birds.

TABLE 3

Herbage acid detergent fiber (ADF) of Strophostyles leiosperma *and* S. helvula *at 3 locations in Texas in response to defoliation intensity (species by location by defoliation interaction P* = 0.04*).*

Location	Species	Defoliation Intensity		
		HEAVY	LIGHT	CONTROL
		% ADF in herbage		
Stephenville	*S. leiosperma*	30.7 a [z] A	30.4 a A	31.4 a A
	S. helvula	28.7 b A	33.1 b A	37.2 a B
San Angelo	*S. leiosperma*	26.9 a A	27.2 a A	——
	S. helvula	22.0 b B	26.0 a A	——
Vernon	*S. leiosperma*	30.7 b A	32.4 ab A	36.1 a A
	S. helvula	30.0 c A	35.1 b A	43.5 a B

[z] Means followed by the same lower case letter (within rows) or upper case letter (columns within location) are not different according to Duncan's Multiple Range Test (*P* = 0.05).

TABLE 4

Herbage acid detergent lignin (ADL) of Strophostyles leiosperma *and* S. helvula *at 3 locations in Texas in response to defoliation intensity (species by location by defoliation interaction P* = 0.03*).*

Location	Species	Defoliation Intensity		
		HEAVY	LIGHT	CONTROL
		% ADL in herbage		
Stephenville	*S. leiosperma*	6.05 a [z] A	5.76 a B	6.75 a B
	S. helvula	5.64 b A	6.57 b A	8.06 a A
San Angelo	*S. leiosperma*	4.89 a A	4.78 a A	——
	S. helvula	4.16 a B	5.25 a A	——
Vernon	*S. leiosperma*	6.26 b A	6.92 ab A	7.29 a A
	S. helvula	6.70 b A	5.74 b B	9.03 a B

[z] Means followed by the same lower case letter (within rows) or upper case letter (within columns within location) are not different according to Duncan's Multiple Range Test (*P* = 0.05).

TABLE 5

Herbage crude protein (CP) of Strophostyles leiosperma *and* S. helvula *at 3 locations in Texas in response to defoliation intensity (species by location by defoliation interaction P* = 0.001*).*

Location	Species	Defoliation Intensity		
		HEAVY	LIGHT	CONTROL
		% CP in herbage		
Stephenville	*S. leiosperma*	16.8 a [z] A	16.5 a A	14.5 b A
	S. helvula	16.4 a A	14.2 b B	10.1 c B
San Angelo	*S. leiosperma*	20.2 b A	22.7 a A	——
	S. helvula	15.3 b B	16.7 a B	——
Vernon	*S. leiosperma*	14.1 b A	15.2 a A	8.0 c A
	S. helvula	11.4 b B	12.3 a B	9.2 c A

[z] Means followed by the same lower case letter (within rows) or upper case letter (within columns within location) are not different according to Duncan's Multiple Range Test (*P* = 0.05).

CONCLUSIONS

Of the 2 species, trailing wild bean produced greater herbage where soil water conditions permitted season-long growth. Trailing wild bean also appears to respond more readily to well-distributed soil water, indicating that the smooth-seeded wild bean may have reached its maximum yield potential at 2 locations in 2001 whereas the trailing wild bean may produce even greater yields with increasing soil water.

In contrast to the trailing wild bean, smooth-seeded wild bean appeared to respond to light defoliation by increasing seed yields and seed numbers. Moderate herbivory of smooth-seeded wild bean could stimulate seed production for game birds and stand regeneration whereas trailing wild bean seed production is maximized when defoliation is minimized. As an indeterminate, apparently photoperiod-insensitive annual, smooth-seeded wild bean plants initiate seed production as early as possible in the season and maintain vegetative (and reproductive) growth only when soil water is adequate and herbivory delays critical biomass accumulation. Trailing bean, by contrast, may be more photoperiod sensitive; both herbivory and water stress in late summer negatively affect seed set.

Defoliation tended to foster greater CP and lower fiber concentrations in wild bean herbage although values in herbage selected by herbivores that would usually reject stems may be quite different. Wild beans may be an important source of herbage for herbivores during the growing season, especially if herbivory is continuous. In contrast, the benefit of these annual legumes for seed-ingesting fauna may well extend into late autumn and winter, as soil seedbanks become important for foraging wildlife.

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