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Overseeding Unimproved Warm-Season Pasture with Cool- and Warm-Season Legumes to Enhance Forage Productivity

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*Overseeding forage legumes into existing warm-season pasture may help to reduce cool-season forage deficit on small and resource-limited small farms in the southern Great Plains of the United States. Unimproved warm-season grass pastures were overseeded with Korean lespedeza (*Lespedeza stipulacea *Maxim) or were not overseeded with summer legume. These same plots were subsequently overseeded with hairy vetch (*Vicia villosa *Roth), crownvetch (*Coronilla varia *L.), black medic (*Medicago lupulina *L.) or ladino white clover (*Trifolium repens *L.) or, not overseeded with cool-season legume. Including lespedeza in a forage mixture increased total forage yield by an average of 15%, or 1700 kg ha^{-1} over 4 years. Overseeding with cool-season legumes provided a net benefit in total annual forage yield of 0.75 kg for each 1.0 kg of legume produced. Yield increases resulting from overseeding with hairy vetch or black medic were largely limited to the harvest season following sowing, while overseeded crownvetch or white clover provided limited short- to medium-term yield benefit. Improvement of low-productivity pasture resulting from legume introduction is likely to be slow and will require sustained management input to ensure the presence of a productive legume plant stand.*

KEYWORDS *legumes, overseeding, pasture improvement, nitrogen yield, herbage yield*

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INTRODUCTION

In the southern Great Plains (SGP) of the United States, perennial warm-season grasses may provide forage for less than 6 months of the year, and problems of seasonal forage deficit are common. Standardized performance analysis shows that high feed cost, arising from prolonged feeding of purchased feeds is closely linked to low return from livestock enterprises (Ramsey et al., 2005). Cool-season small-grain cereals, forage grasses, or legumes may be used to mitigate the seasonal shortfall and reduce the need for purchased feed. However, cropping with cool-season forages may present problems, especially in small and resource-limited farming systems. On marginal land cultivation may be undesirable and in low-input systems limited availability of equipment or labor may preclude annual establishment of cool-season crops. In these circumstances perennial or self-regenerating annual crops are desirable, to reduce the costs of establishment and minimize the risks of soil erosion. Overseeding to incorporate cool-season forages into existing pasture can increase total annual production and improve seasonal distribution of output, without the level of risk of soil erosion and prolonged production loss associated with crop establishment by clean-tillage (Bartholomew, 2005). Inclusion of cool-season legumes in low-input systems may be of particular interest because of a potential for yield improvement in mixed cropping that may be equivalent to the yield obtained from grass alone with N application of between 100 to 250 kg ha^{-1} (Evers, 1985; Ocumpaugh, 1990; George et al., 1995). Early season production (Evers, 1985), feed quality (Kalmbacher et al., 1980; Redmon et al., 1998; Mullen et al., 2000) and animal performance (Ocumpaugh, 1990) may all be increased when legumes are grown in mixture with cool-season grasses. As the cost of manufactured N increases the introduction of legumes into existing pastures may provide a sustainable and reduced-cost method of maintaining forage productivity on small and resource-limited farms. Legume use is not, however, without problems since early-season growth of legume may prejudice production of warm-season companion grass (George et al., 1995), and lack of persistence of legumes is a widely recognized constraint to their use (Beuselinck et al., 1994; Laberge et al., 2005). Little attention has been given to the performance and persistence of legumes grown in a low-input and low-productivity environment where unimproved warm-season grasses are the primary source of forage. The objectives of the work reported here were to evaluate the contributions of less commonly used cool- and warm-season legume species to year-round forage production when overseeded into unimproved warm-season grass and to assess their persistence in pasture.

MATERIALS AND METHODS

An experiment was undertaken over 5 years, from 2001 to 2005, 6 km S of Langston, OK at 35° 53′ N, 97° 15′ W on pasture comprised of a mixture of predominantly warm-season grass species, including sideoats grama (*Bouteloua curtipendula* Michx), splitbeard bluestem (*Andropogon ternarius* Michx), little bluestem (*Schizachyrium scoparium* [Michx.] Nash), big bluestem (*Andropogon gerardii* Vitman), switchgrass (*Panicum virgatum* L.), old field threeawn (*Aristida oligantha* Michx), Florida paspalum (*Paspalum floridanum* Michx), Scribner's panicum (*Panicum oligosanthes* Schult.) and, Carolina joint-tail (*Coelorachis cylindrica* Michx.). The pasture had been managed for hay production for over 10 years prior to the experiment. Soil type was a Coyle series sandy loam (fine-loamy siliceous thermic Udic Arguistoll). Soil analysis at the beginning of the experiment showed a pH of 6.1, soil nitrate-nitrogen of 9 kg ha^{-1}, phosphorus index (Mehlich 3) of 10 and a potassium index of 226 in samples taken within 15 cm of the soil surface. The experiment was established on land that was degraded under cultivation and subsequently abandoned for cropping in the early part of the 20th century, and is typical of low-productivity marginal land used for pasture by limited-resource farmers in central and eastern Oklahoma.

In spring of 2001 warm-season treatments consisting of overseeding with Korean lespedeza (*Lespedeza stipulacea* Maxim) or no warm-season overseeding were applied to areas of unimproved pasture that had been lightly tilled in the previous fall. Lespedeza was sown by hand-broadcasting pre-weighed amounts of seed, equivalent to a seed rate of 22 kg ha^{-1}. Plots were rolled following sowing to ensure seed-soil contact. In fall of 2001, five cool-season overseeding treatments, comprising four cool-season legume species and a no-overseeding treatment, were applied in factorial combination with the warm-season treatments. Cool-season legume species were; hairy vetch, (*Vicia villosa* Roth; local selection), crownvetch, (*Coronilla varia* L.; Penngift), black medic, (*Medicago lupulina* L.; George), or ladino white clover, (*Trifolium repens* L.; Regal), and these were sown in late September 2001, when warm-season pasture was nearly dormant. The choice of species for both warm- and cool-season planting was determined by their apparent potential for persistence, either by self-seeding (hairy vetch, black medic, and lespedeza) or by vegetative propagation (white clover and crownvetch). Prior to sowing cool-season legumes pasture was trimmed to a stubble height of 7 cm and clipped material was removed from the plot area. No herbicide was used to suppress warm-season pasture. A no-till seeder (Landpride, Salina, KS) was used to sow each species, at 9.3, 33.2, 11.4, and 5.1 kg ha^{-1} of pure live seed (PLS) for crownvetch, hairy vetch, black medic and white clover respectively. Seeds were drilled in rows at an inter-row spacing of 7.5 cm on plots 1.22 by 6.10 m. All legumes were inoculated with appropriate rhizobia immediately prior to sowing.

Warm-season legume overseeding treatments were repeated in April 2002, using the same plots as 2001. In mid-September of 2002 cool-season overseeding treatments were also repeated, and applied on the same plots as in 2001, using the methods described above with crownvetch, hairy vetch, black medic, and white clover sown at 10.2, 36.7, 16.8, and 5.2 kg ha^{-1} PLS, respectively. No further overseeding was made after 2002. Following recommendations from soil analysis, triple superphosphate (46% P_2O_5) was surface broadcast at 25 kg P ha^{-1} in early March of each harvest year.

Estimation of emergence and of established plant numbers was made by duplicate counts of live sown plants within a 15 cm square quadrat placed randomly within each plot. Emergence counts of cool-season legumes were made in November of 2001 and 2002 for the respective year's sowings. Established plant number at the beginning of each growing season was counted as described above in late March or early April of each harvest year 2002–05. Warm-season legume plant populations were estimated in May of 2001 and 2002 and in late March 2002–05.

DM yield estimates were made for each plot by clipping a strip 0.86 by 6.1 m from the center of the plot, using a sickle-bar mower adjusted to leave a 7 cm stubble. In 2001 a single harvest was made to estimate warm-season legume and grass yields in mid-September. In subsequent years the initial harvest in each year was made when mature seeds were evident on hairy vetch and black medic. Harvests of regrowth were made when crop height reached 20 cm.

At each harvest, a sample of approximately 200 g of fresh material was taken from each plot for hand-separation into the following components; sown cool-season legume, sown warm-season legume, grass and forb. Separated material was dried at 60 °C for 48 hours and weighed for estimation of component DM and sample DM content. After weighing the dried components of each sample were recombined and ground through a 1mm screen prior to analysis for nitrogen content by colorimetric analysis in a Technicon continuous flow autoanalyzer (Technicon Industrial Systems, Tarrytown, NY, USA) following extraction by standard micro-Kjeldahl procedures (AOAC, 1990).

Temperature records for the period of the experiment were obtained from a weather station at the experimental site, and rainfall estimates were derived as a mean of rainfall at Guthrie, OK (19 km west of the site) and Perkins, OK (16 km east of the site). Standardized rainfall and temperature data were combined to create an aridity index (Hollinger et al., 2001) that shows variation in heat and dryness, relative to long-term average conditions, throughout the experiment.

The experiment was established in a randomized complete block layout with five cool-season overseeding treatments in factorial combination with two warm-season overseeding treatments and each treatment combination was replicated four times. This structure was maintained throughout the experiment. An initial repeated measures analysis (Genstat, 2005) of 2002–05 data revealed significant year × overseeding interactions. Therefore, subsequent analysis of the effects of warm- or cool-season overseeding treatments on component and total herbage yields was made as a 5 × 2 factorial randomized complete block experiment with four replicates for individual years, or as aggregate yields over 4 years, following GenStat procedures for analysis of variance (ANOVA) (Genstat, 2005). The significance of differences in yield between treatments was assessed by Fisher's protected LSD (p = 0.05). Examination of relationships between cool-season legume and warm-season grass yields was made by linear regression using GenStat procedures (GenStat, 2005).

RESULTS

Rainfall amounts and distribution varied widely among years (Figure 1a). The aridity index data (Figure 1b) shows that 2003 was generally warmer and drier than the 30-year average, while the summer months (June, July, and August) of 2004 and 2005 were wetter and cooler than normal. In each of the years 2003–05 the principal growing period for cool-season forages, March to May, was warmer and drier than the long term average, with actual rainfall amounts between 27% and 67% below average. Forage production generally reflected these conditions with only one harvest taken in 2003, two in 2004, and three in 2002 and 2005.

Legume Establishment

Lespedeza populations in May of 2001 and 2002 showed a consistent establishment response to overseeding, with a mean of 650 pl m^{-2} in each case, but the responses to self-reseeding were much more variable, with seedling populations of 210, 820, and 110 pl m^{-2} in late March of 2003, 2004, and 2005, respectively.

Changes in cool-season legume plant stands throughout the life of the experiment are summarized in Figure 2. Acceptable fall-emerged stands of all cool-season legume species resulted from sowing in 2001. Resowing in 2002 provided significant reinforcement to plant stands in all species by late fall of 2002, even though emergence was generally less satisfactory than in the previous year for all species but crownvetch. By early 2005, without further sowing, surviving populations of all species fell within a range from 29 to 48 pl m^{-2}. The high plant populations observed in hairy vetch and

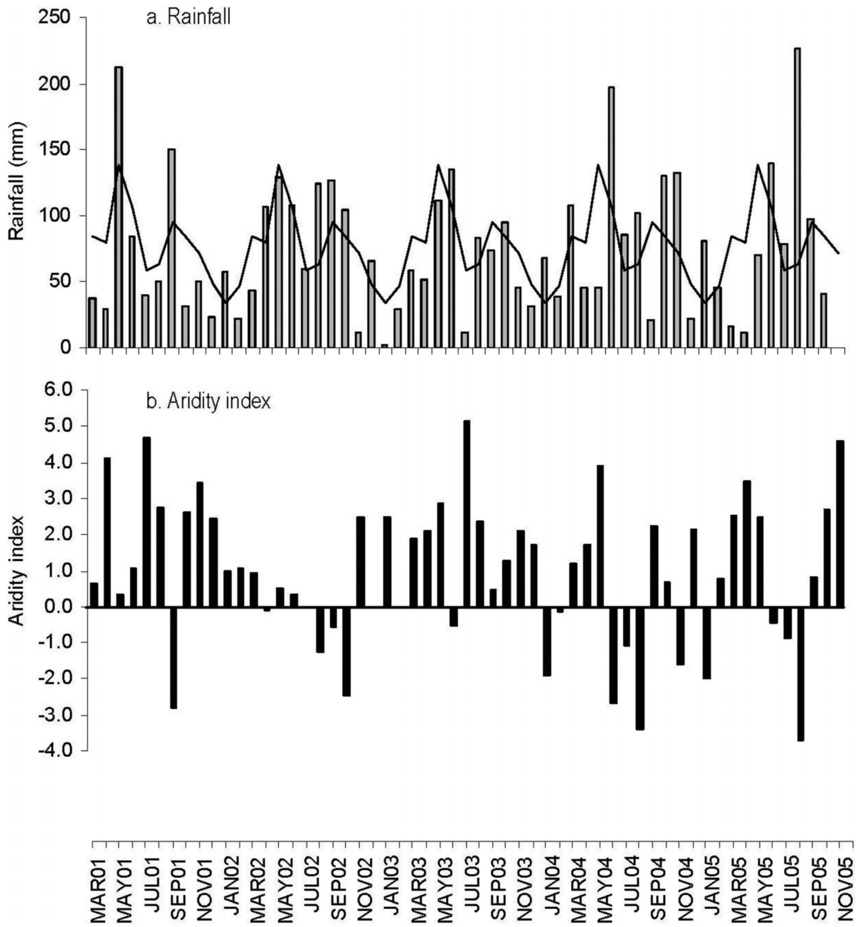

FIGURE 1 a) Monthly rainfall (▭) for the Langston OK field site 2001–05, and the 30-year average for each month (—). b) the aridity index for 2001–05. [Aridity index; positive values indicate warmer or drier conditions (more arid), negative values indicate cooler or wetter conditions (less arid)].

black medic in the seasons immediately following sowing were not maintained into 2004 and 2005.

Legume Yields

Cool-season legume yields showed major differences among species and years (Table 1). Hairy vetch and black medic produced their greatest yields in the years immediately following fall overseeding (2002 and 2003). Crownvetch and white clover, in contrast, performed poorly in 2002 and 2003, but increased production relative to hairy vetch and black medic in 2004 and 2005. The production increase was more pronounced with crownvetch than with white clover. There was no apparent ($p > 0.05$) interaction

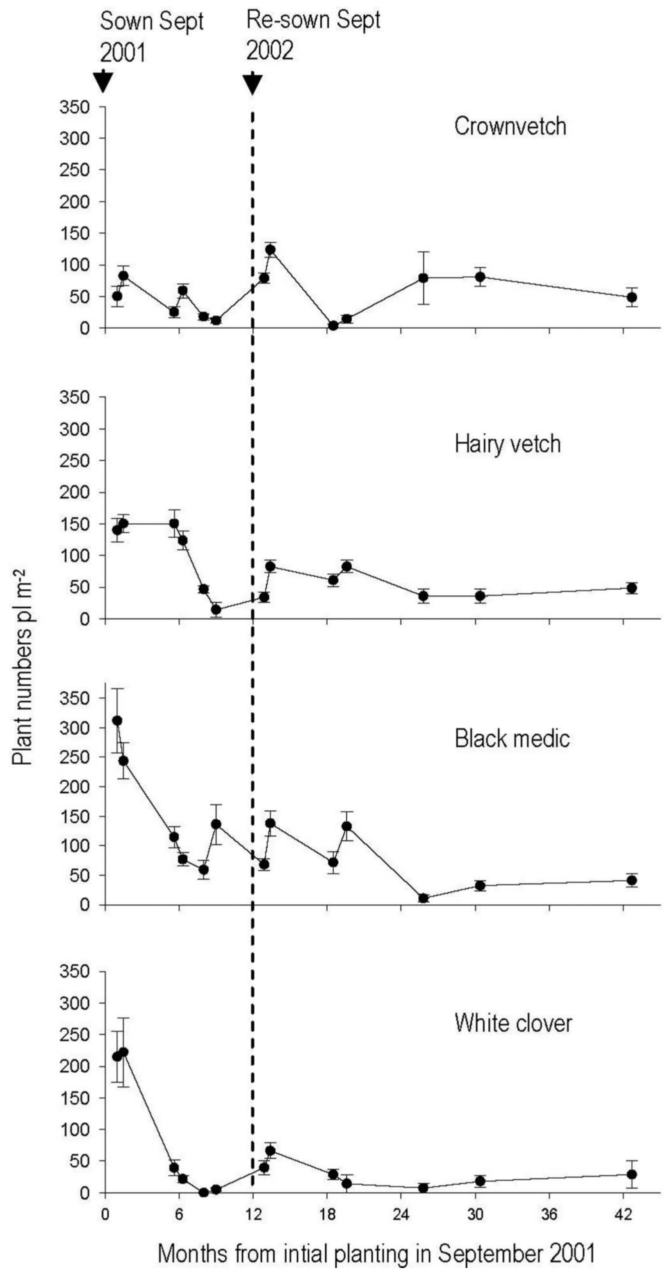

FIGURE 2 Progression of cool-season legume plant counts (pl m^{-2}) 2001–05, following no-till seeding in September 2001 and re-seeding in September 2002. Error bars indicate standard error of mean at each date.

TABLE 1 Effects of Cool-Season Overseeding Treatment on Annual Component and Total Herbage Yields (kg ha^{-1}) of Pasture 2002–05 (Means Over Warm-Season Legume Overseeding Treatments)

		Cool-season overseeding treatment					
		CV	HV	MD	WC	U	LSD
Year		kg ha^{-1}					P = 0.05
2002	CSL	30^{b}	1190^{a}	170^{b}	0	0	333
	WSL	580^{a}	110^{b}	310^{ab}	330^{ab}	530^{a}	273
	GRASS	2300^{b}	2260^{b}	2400^{b}	2460^{b}	2920^{a}	483
	TOTAL	2910^{b}	3560^{a}	2880^{b}	2790^{b}	3450^{a}	460
2003	CSL	110^{c}	4020^{a}	1240^{b}	20^{c}	0	464
	WSL	130^{a}	0	180^{a}	170^{a}	170^{a}	167
	GRASS	1080^{b}	170^{c}	1000^{b}	1120^{b}	1450^{a}	257
	TOTAL	1320^{c}	4190^{a}	2420^{b}	1310^{c}	1620^{c}	576
2004	CSL	270^{a}	310^{a}	40^{b}	60^{b}	0	177
	WSL	270^{ab}	10^{b}	140^{b}	360^{a}	240^{ab}	198
	GRASS	2780^{a}	3170^{a}	3210^{a}	2790^{a}	3010^{a}	658
	TOTAL	3320^{a}	3490^{a}	3390^{a}	3210^{a}	3250^{a}	677
2005	CSL	540^{a}	260^{ab}	90^{b}	130^{b}	0	318
	WSL	80^{ab}	10^{b}	30^{b}	150^{a}	90^{ab}	95
	GRASS	3250^{a}	3540^{a}	3390^{a}	3170^{a}	3350^{a}	601
	TOTAL	3870^{a}	3810^{a}	3510^{a}	3450^{a}	3440^{a}	586

Components of yield are; CSL = cool-season legume, WSL = warm-season legume, GRASS = grass from existing pasture. Treatments are pasture overseeded with; CV = crownvetch, HV = hairy vetch, MD = black medic, WC = white clover or, U = no cool-season overseeding. In each year means with no common superscript differ significantly ($p < 0.05$) within component, or total, herbage yields among overseeding treatments.

effect of warm-season overseeding treatment on yield of cool-season legume. Overseeded lespedeza produced an average 620 kg ha^{-1} of DM in 2001 and 750 kg ha^{-1} in 2002, following sowings in April of each year. Mean yields of lespedeza were reduced in succeeding years, at 260, 410, and 140 kg DM ha^{-1} in 2003, 2004, and 2005, respectively (Table 2). The mean warm-season legume yield was significantly reduced in hairy vetch plots compared with crownvetch and unsown cool-season treatments in 2002 and was negligible on hairy vetch treatments in 2003–05 (Table 1).

Grass Yields

Except for the hairy vetch treatment in 2003, warm-season grass was the predominant component of total forage yield throughout the experiment (Table 1). The mean annual DM yield of warm-season grass on plots that received neither cool- nor warm-season overseeding treatment was 2500 kg ha^{-1}. Warm-season grass production was reduced by 0.25 kg for each 1.0 kg increase in cool-season legume yield, and this response was consistent among years (Figure 3.). In 2001 grass yield was significantly reduced to a

TABLE 2 Effects of Warm-Season Overseeding Treatment on Annual Component and Total Herbage Yields (kg ha $^{-1}$) Of Pasture 2002–05 (Means Over Cool-Season Legume Overseeding Treatments)

Year		Warm-season overseeding treatment LES	U	LSD
		kg ha^{-1}		P = 0.05
2002	CSL	310^{a}	250^{a}	211
	WSL	750	0	
	GRASS	2470^{a}	2470^{a}	306
	TOTAL	3520^{a}	2720^{b}	291
2003	CSL	1050^{a}	1110^{a}	293
	WSL	260	0	
	GRASS	910^{a}	1020^{a}	162
	TOTAL	2220^{a}	2130^{a}	364
2004	CSL	140^{a}	140^{a}	112
	WSL	410	0	
	GRASS	3050^{a}	2930^{a}	416
	TOTAL	3600^{a}	3070^{b}	428
2005	CSL	180^{a}	230^{a}	318
	WSL	140	0	
	GRASS	3430^{a}	3250^{a}	380
	TOTAL	3750^{a}	3480^{a}	370

Components of yield are; CSL = cool-season legume, WSL = warm-season legume, GRASS = grass from existing pasture. Treatments are pasture overseeded with; LES = Korean lespedeza or U = no warm-season overseeding. In each year means with no common superscript differ significantly ($P < 0.05$) within component, or total, herbage yields among overseeding treatments.

mean of 1560 kg DM ha^{-1} by overseeding lespedeza, compared with a yield of 2050 kg DM ha^{-1} without overseeding lespedeza. In 2002–05, however, there was no significant effect of warm-season overseeding treatment on grass yield (Table 2).

Total Forage Yields

Total annual forage DM yield (comprising totals of sown cool- and warm-season legume and resident grass yields) was increased in 2002 by overseeding with hairy vetch, and in 2003 by overseeding with hairy vetch or black medic (Table 1), but there was no significant difference among cool-season overseeding treatments in 2004 or 2005. Overseeding with Korean lespedeza significantly increased total forage yield only in 2002 and 2004 (Table 2). Four-year aggregate total forage yield was increased by overseeding with hairy vetch, but overseeding with other cool-season legumes showed no significant difference from the non-overseeded treatments. The effect of lespedeza addition was similar among cool-season overseeding

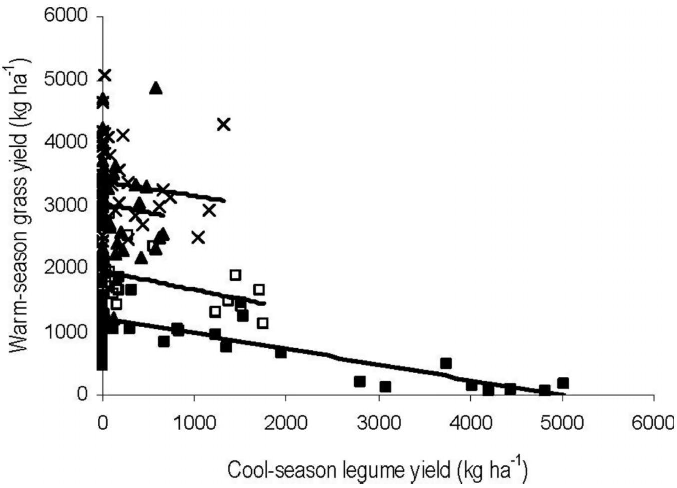

FIGURE 3 Effect of cool-season legume (CSL) yield on yield of unimproved warm-season pasture (WSG), 2002–05. □ 2002 WSG = 2450 – 0.25 CSL; ■ 2003 WSG = 1230 – 0.25 CSL; ▲ WSG = 3020 – 0.25 CSL; × WSG = 3390 – 0.25 CSL (R^2 = 0.73).

treatments, with no significant interaction (p > 0.05) between cool- and warm-season treatments, therefore yields in Table 3a are presented as means over warm-season overseeding treatment. On plots sown with lespedeza total forage yield over 4 years was increased by an average of 15% (1700 kg ha^{-1}) (Table 3b) compared with plots that did not receive warm-season legume, and 92% (1560 kg ha^{-1}) of this increase could be attributed to the yield of lespedeza harvested (Table 3b).

TABLE 3 Cool- and Warm-Season Legume Overseeding Treatment Effect on 4-Year Aggregate Total and Component Herbage Yields (kg ha^{-1}) 2002–05

	a) Cool-season overseeding treatment						b) Warm-season overseeding treatment		
	CV	HV	MD	WC	U	LSD P = 0.05	LES	U	LSD P = 0.05
			kg ha^{-1}				kg ha^{-1}		
CSL	950^{bc}	5780^{a}	1540^{b}	210^{c}	0	869	1670^{a}	1720^{a}	485
WSL	1060^{a}	130^{b}	660^{a}	1020^{a}	1020^{a}	428	1560	0	
GRASS	9400^{a}	9130^{a}	9990^{a}	9530^{a}	10730^{a}	1528	9850^{a}	9660^{a}	966
TOTAL	11410^{b}	15040^{a}	12190^{b}	10760^{b}	11750^{b}	1576	13080^{a}	11380^{b}	997

Yields are means over warm-season (a) and of cool-season (b) overseeding treatments. Components of yield are; CSL = cool-season legume, WSL = warm-season legume, GRASS = grass from existing pasture. For a) CV = crownvetch, HV = hairy vetch, MD = black medic, WC = white clover and U = no cool-season overseeding. For b) LES = Korean lespedeza, U = no warm-season overseeding. Means with no common superscript differ significantly (p < 0.05) within component, or total, herbage yields among overseeding treatments.

Forage Nitrogen Concentration and Yield

Main effects of overseeding treatment on N concentration of herbage harvested at the first cut in each year are summarized in Table 4. Nitrogen concentrations were greatest with the hairy vetch treatment in the first 2 years following cool season legume overseeding (2002 and 2003), but over the 2 final years of the experiment (2004 and 2005), only crownvetch plots showed N concentrations that were significantly ($p < 0.05$) greater than plots that were not oversown with cool-season legume. There was no significant effect ($p > 0.05$) of overseeding cool-season legumes on N concentration at second harvest in any of the three years in which more than a single harvest was made. Overseeding with lespedeza produced no significant difference in N concentration, compared with no warm-season overseeding, in any year. The total amount of N harvested in forage over four years 2002–05, is shown in Table 5 and was greatest in plots overseeded with hairy vetch and lespedeza (318 kg ha^{-1}) and least in plots that were not overseeded with legume (156 kg ha^{-1}). Overseeding with lespedeza increased harvested N yield by an average of 40 kg ha^{-1} over four years. The effect of cool-season overseeding on N yield was most apparent in the years (2002 and 2003) immediately following sowing of legumes and was reduced in the final two years of the experiment, so that there was no significant difference in N yield between legume-oversown and unimproved pasture plots by the final year of the experiment (Table 5.).

Forb Yield

Forb yield was not significantly ($p > 0.05$) changed by warm- or cool-season overseeding treatment in any year except 2003, when vigorous growth of hairy vetch caused extensive smothering of companion species and resulted in a minimal harvest of forb, a mean of 60 kg ha^{-1}, compared with a mean

TABLE 4 Effect of Cool-Season Legume Overseeding Treatment on Nitrogen Content (g kg^{-1}) of Herbage at Initial Harvest in Each Year (mid-May 2002 and mid-June 2003–05)

	Cool-season legume overseeding treatment					
	CV	HV	MD	WC	U	LSD
Year	Forage Nitrogen content g kg^{-1}					$p = 0.05$
2002	19.8^{b}	31.2^{a}	17.4^{c}	18.7^{bc}	18.1^{bc}	1.84
2003	15.4^{b}	21.2^{a}	16.2^{b}	13.8^{c}	11.1^{d}	1.21
2004	16.2^{a}	14.5^{b}	13.8^{bc}	12.5^{c}	13.6^{bc}	1.39
2005	16.5^{a}	12.8^{b}	14.5^{b}	14.3^{b}	13.6^{b}	1.71

CV = crownvetch, HV = hairy vetch, MD = black medic, WC = white clover, U = no cool-season overseeding. In each year means with no common superscript differ significantly ($p < 0.05$) among overseeding treatments.

TABLE 5 Effect of Overseeding of Unimproved Warm-Season Pasture with Warm- or Cool-Season Legumes on Amount of Nitrogen Harvested in Herbage Annually 2002–05, and Total Over the 4-Year Period

	Overseeding treatment										
	CV+ LES	CV	HV+ LES	HV	MD+ LES	MD	WC+ LES	WC	U+ LES	U	LSD
Year	kg ha^{-1}										p = 0.05
2002	72.9^{bc}	42.4^{d}	94.1^{a}	84.2^{ab}	63.3^{c}	45.1^{d}	50.5^{d}	52.0^{cd}	77.5^{b}	41.7^{d}	11.5
2003	34.5^{cd}	27.8^{cd}	94.8^{a}	86.5^{a}	58.0^{b}	41.3^{c}	29.8^{cd}	38.2^{c}	34.2^{cd}	21.7^{d}	15.6
2004	74.0^{a}	63.2^{ab}	66.1^{ab}	65.0^{ab}	62.8^{ab}	53.8^{c}	55.5^{c}	57.4^{bc}	72.0^{a}	44.7^{c}	14.1
2005	63.9^{a}	61.1^{a}	63.3^{a}	56.4^{a}	62.0^{a}	53.6^{a}	51.4^{a}	58.2^{a}	60.3^{a}	47.9^{a}	11.7*
Total	245.3^{b}	194.5^{cd}	318.3^{a}	292.1^{a}	246.1^{b}	193.8^{cd}	187.2^{cd}	205.8^{c}	244.0^{b}	156.0^{d}	38.5

CV = crownvetch, HV = hairy vetch, MD = black medic, WC = white clover, U = no cool-season overseeding and LES = Korean lespedeza. In each year means with no common superscript differ significantly (p < 0.05) among overseeding treatments.
*Differences among treatment means were not significant (P > 0.05) according to F test.

of 850 kg ha^{-1} on all other cool-season overseeding treatments. Mean forb yields were 570, 1000, and 890 kg ha^{-1} in 2002, 2004, and 2005, respectively.

DISCUSSION

The work reported here demonstrated that an adequate plant stand of cool-season legume, defined as ≥ 20 pl m^{-2}, based on Cuomo et al., (2003), can be established by no-till seeding into nearly-dormant unimproved warm-season pasture. The results showed, however, that establishment of an apparently satisfactory plant stand did not necessarily result in significant production of legume. Warm- and cool-season legume yields were lower than reported in other work (Davis et al., 1994; Rao and Phillips, 1999; Rumbaugh and Johnson, 1986; Muir et al., 2005). Some yield limitation may be attributed to the low productivity of the experimental site that is typical of unimproved mixed grass pasture in the SGP (Berg, 1995; Gillen and Berg, 1998), but the use of a no-till management regime in the work reported here is also likely to have reduced legume production. In contrast with other research, for example, that of Cuomo et al., (2003) and Laberge et al., (2005), no chemical suppression of the existing crop was made prior to sowing legumes, even though this has been identified as an important determinant of success for overseeded forages (Bartholomew, 2005). Warm-season grass suppression was not undertaken here because the warm-season pasture was close to the end of its growing season when cool-season legumes were sown and it was assumed that existing pasture would not compete with establishing legumes. In addition, there was concern that suppression of warm-season grass in fall would have negative consequences for its productivity in the following growing season, and our objective was to augment the existing forage resource, rather than to replace it with legumes.

Management of a sequence of cool- and warm-season crops for regeneration by self-seeding is subject to constraints that are likely to seriously limit the sustainability of this type of pasture system. Delay in harvest of cool-season legume in order to encourage seed deposition is likely to increase competition for emerging warm-season legume and regrowing warm-season grass (Posler et al., 1993; George et al., 1995). However, even though warm-season grass output may be reduced by oversowing with cool-season legume the results show that there should be a net benefit of approximately 0.75 kg in combined legume-grass herbage for each 1.0 kg of cool-season legume produced.

Self-regeneration of hairy vetch and black medic was limited, even when harvest was timed to encourage seed production and deposition. The poor self-seeding performance of hairy vetch reflects results reported by Volesky et al. (1996), but black medic has reported capacity for regeneration by self-seeding (Rumbaugh and Johnson, 1986) and is noted for the persistence of its seedbank (Pavone and Reader, 1982). However, recent work has also reported poor reseeding and low forage production by George black medic in the SGP (Muir et al., 2005) and these authors showed that a local ecotype of black medic could be significantly more productive of both seed and forage than George. Self-seeding of lespedeza was also variable and further demonstrates the uncertainty of dependence on regeneration of a companion legume by self-seeding. Yields of hairy vetch, black medic, and lespedeza were generally greater in years immediately following overseeding than in years following self-seeding. Additional study of the benefits of annual seeding of both cool- and warm-season legumes, compared with self-seeding, in limited resource environments should be made.

Yield data indicate an increase in contribution of crownvetch and white clover over the life of experiment, consistent with their capacity for vegetative propagation (Beuselinck et al., 1994), but their net impact on forage yield over four years was small. It is debatable whether such a slow rate of improvement could be recommended for practical application, although slow colonization is not unique to the species or conditions studied here; Cuomo et al. (2003), for example, reported that Kura clover took 4 years from planting to reach its greatest stand density. If vegetative spread provides a more persistent stand of legume, as indicated by Beuselinck et al., (1994) and Woods and Caddel (1994), then slow colonization may be acceptable in low-input systems, especially if it is associated with low cost and limited disturbance to existing pasture.

The increase in harvested N yields resulting from overseeding warm- and cool-season legumes indicates that there is potential to increase the fertility of a low-input system if herbage N can be recycled through grazing animals or by return of manure. However, the amounts of N produced on low-productivity pasture are likely to be less than those commonly associated with grass–legume systems (Evers, 1985; Ocumpaugh, 1990) and are unlikely to be sustained if legume stands are not regularly reinforced or renewed. The possibility of increased pasture fertility is an important justification for inclusion of legumes in mixed pasture, but the results reported here show that the potential for direct contribution of legume DM to overall pasture yield can be considerable and should not be overlooked.

CONCLUSION

Legumes can be established in unimproved warm-season pasture by overseeding, without suppression of existing vegetation. Hairy vetch, black medic and Korean lespedeza established quickly, but the effect of overseeding on herbage yield was short-lived and largely limited to the harvest season following sowing. Establishment of overseeded crownvetch or white clover was slow and produced limited short- to medium-term benefit in herbage yield. Under low-productivity conditions legumes can contribute to an increase in N harvest from pasture and thus have potential for increase in fertility, if the incremental N is recycled. However, the amounts of N produced were variable among species and generally lower than commonly reported. Improvement of low-productivity pasture by introduction of legumes is likely to be slow and will require species that are persistent, or that can regenerate effectively, or sustained management input to ensure the presence of a productive legume plant stand. Overseeding of legumes may not be as sustainable or as low-input a strategy for improvement of pasture on small farms as is commonly perceived, even though the initial costs of their introduction to a pasture system are low.

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