Spring 2012

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Great Plains Research 22 (Spring 2012):35–43

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ABSTRACT—Our objective was to evaluate adaptation and compatibility of cool-season annual legumes overseeded into perennial grasses in the southern Great Plains. Freeze damage, vigor, and standing crop of 14 annual legume species were evaluated during spring at three locations in Oklahoma and Texas from 2006 to 2008. Across locations and years, standing crop of hairy vetch (*Vicia villosa* Roth) and Austrian winter pea [*Pisum sativum* L. ssp. *arvense* (L.) Poir.] averaged 3,513 and 3,210 kg dry matter (DM) ha^{-1}, respectively. Standing crop of crimson clover (*Trifolium incarnatum* L.) and arrowleaf clover (*T. vesiculosum* Savi) averaged 1,138 and 1,071 kg DM ha^{-1}, respectively. Although subject to freeze damage, annual medics produced more spring forage than annual clovers on soil with pH > 8.0. Most of the annual legumes survived winter, demonstrating their adaptability to pastures in the southern Great Plains, but hairy vetch and Austrian winter pea consistently provided the most spring forage.

Key Words: annual clovers, annual medics, hairy vetch, overseeding, pasture management, Austrian winter pea

INTRODUCTION

Introduced forage legumes are an important component of pasture-based livestock production systems. When integrated into existing grass pastures, legumes improve seasonal distribution, quality of forage, and availability of nitrogen in soil (Heichel 1985). Temperate forage legumes, primarily of Mediterranean origin, are most productive at 20°C (Sheaffer and Evers 2007). Where precipitation is abundant and summer temperatures are moderate, perennials such as alfalfa (*M. sativa* L.), red clover (*T. pratense* L.), and white clover (*T. repens* L.) may be used successfully. In the southern Great Plains, where winters are mild but summers are hot and dry, perennial legumes do not persist, but cool-season annual legumes are well adapted (Sheaffer and Evers 2007) and in many cases have become naturalized (Diggs et al. 1999).

Overseeding of warm-season perennial grasses with cool-season annual legumes allows 4 to 6 weeks of earlier spring grazing (Evers 2005). Commonly seeded annual legumes include arrowleaf clover, crimson clover, and hairy vetch. Arrowleaf clover has high forage yield and excellent reseeding potential, but it matures later and has less regrowth after grazing than crimson clover

Manuscript received for review, May 2011; accepted for publication, October 2011.

(Evers and Newman 2008). Crimson clover has excellent seedling vigor and early spring growth but is limited by poor reseeding ability (Evers and Smith 2006; Evers and Newman 2008). Interest in annual medics as winter pasture legumes has increased due to their ability to reseed under grazing (Muir et al. 2001; Muir et al. 2005). Cold tolerance often limits northern and western expansion of annual medics (Muir et al. 2005; Ocumpaugh et al. 2007).

Although efforts to improve adaptability of forage legumes and identify optimal management practices continue, research remains incomplete. Knowledge of winter survival of annual legume accessions and ability to provide forage during spring when overseeded or drilled into existing perennial grasses remains limited (Bow et al. 2008). To improve information available to pasture managers about which legume species to plant, winter survival and spring availability of 14 autumn-seeded legume species were evaluated across three locations in Oklahoma and Texas from 2006 to 2008. Objectives of the research were to identify legume species that survived winter with high spring standing crop and compatibility with perennial grasses.

METHODS

Experiment Locations and Establishment Methods

Legume evaluations were established at Burneyville and Ardmore, OK, and Stephenville and Vashti, TX, from 2006 to 2008 (Table 1). At Burneyville, soil was a Norwood clay loam, and legumes were seeded in separate plantings within a 10-year-old stand of eastern gamagrass (*Tripsacum dactyloides* L.), originally established in 76.2 cm rows, in September 2006 and October 2007. Legumes were broadcast seeded and lightly raked by hand within individual 3.0 by 4.5 m plots in the 2006 planting and no-till drilled with a HEGE 500 drill with 17.8 cm row spacings in 4.5 by 6.0 m plots in the 2007 planting. Before seeding each fall, the field was mowed at a 30 cm height and baled. Soil tests of the first planting in 2006 revealed pH = 8.2 and availability of P and K at 71 and 1,390 mg kg^{-1}, respectively. Soil tests of the second planting in 2007 revealed pH = 8.0 and availability of P and K at 75 and 1,436 mg kg^{-1}, respectively. Diammonium phosphate (18-46-0) was applied to each planting at 112 kg ha^{-1} in November 2006 and October 2007.

At Ardmore, legumes were drilled with tall fescue [*Lolium arundinaceum* (Schreb.) S.J. Darbyshire cv. PDF584] into a clean-tilled seedbed at a <0.6 cm depth with a HEGE 500 drill in September 2007. Plots were 4.5 by 6.0 m, and the fescue was seeded at 16.8 kg pure live seed (PLS) ha^{-1}. Soil was a Heiden clay with a pH = 7.1 and availability of P and K at 7 and 319 mg kg^{-1}, respectively. Diammonium phosphate was applied at 112 kg ha^{-1} prior to planting.

At Stephenville, legumes were no-till drilled at <0.6 cm depth with a HEGE 1000 drill with 19.0 cm row spacings within a 15-year-old stand of switchgrass (*Panicum virgatum* L. cv. Alamo) in October 2006. Before seeding, the switchgrass stand was mowed to a 5 cm height, baled, and removed. Plots were 1.5 by 7.6 m. Soil was a Windthorst fine sandy loam with a pH of 7.0 and P and K availability of 18 and 563 mg kg^{-1}, respectively. Diammonium phosphate was applied at 112 kg ha^{-1} at planting.

At Vashti, legumes were drilled with tall fescue (cv. Flecha) into a clean-tilled seedbed at a <0.6 cm depth using a HEGE 500 drill in October 2006 and September 2007. Soil was an Anocon loam with a pH = 6.7 and in which availability of P and K was 175 and 1,025 mg kg^{-1}, respectively. Plots were 1.5 by 7.6 m in the 2006 planting and 1.5 by 6.0 m in the 2007 planting. Fescue was seeded at 16.8 kg PLS ha^{-1} in both plantings. Before planting, diammonium phosphate was incorporated at 112 kg ha^{-1}.

Evaluation of Legume Adaptation and Compatibility

Freeze damage and vigor of legumes were assessed at Burneyville and Vashti in February 2007 and at Ardmore and Vashti in February 2008. Freeze damage was a visual rating by two observers on the whole-plot level, whereby 0 = no visual injury and 100 = complete plant death. The percentage of necrotic tissue on the plants is reported. Vigor was also a visual ranking of winter growth in February on a scale from 0 to 9, whereby 0 = dead plants and 9 = healthy, vigorous plants with growth. Standing crop was measured in late April at peak standing crop of the legumes. With the exception of the evaluation at Burneyville, spring standing crop of the annual legume species and associated grasses was determined by visual estimation of the proportion of standing crop in each of these groups, followed by harvest of total standing crop from two 0.2 m^2 quadrats at a 2.5 cm height. At Burneyville, only the standing crop of the legume component was determined because of the ease of harvesting each legume entry between the eastern gamagrass rows. Forage samples collected during April were dried in a forced-air oven at 60°C for 48 hr before determination of dry matter of the grass and legume components.

TABLE 1
PURE LIVE SEEDING RATES OF WINTER ANNUAL LEGUMES EVALUATED IN SOUTH-CENTRAL OKLAHOMA AND NORTH-CENTRAL TEXAS, 2006–2008

Common name	Scientific name and authority	Cultivars sown	Pure live seeding ($kg\ ha^{-1}$)
Arrowleaf clover	*Trifolium vesiculosum* Savi	Apache and Yuchi	8–10
Austrian winter pea	*Pisum sativum* L. ssp. *arvense* (L.) Poir.	Common[a]	22–39
Ball clover	*Trifolium nigrescens* Viv.	Common[a] and Overton	2–3
Burr medic	*Medicago polymorpha* L.	Ueckert and NF[b]	12–17
Button medic	*Medicago orbicularis* (L.) Bartal.	Estes and NF	4–10
Common vetch	*Vicia sativa* L.	Common[a]	33
Crimson clover	*Trifolium incarnatum* L.	Dixie and Overton	13–17
Hairy vetch	*Vicia villosa* Roth	AU and Common[a]	15
Little burr medic	*Medicago minima* (L.) L.	Devine and NF[b]	6–8
Rigid medic	*Medicago rigiduloides* E. Small	NF[b]	12–17
Rose clover	*Trifolium hirtum* All.	Overton R18	7–17
Subterranean clover	*Trifolium subterraneum* L.	Denmark	12–17
Tifton burr medic	*Medicago rigidula* (L.) All.	NF[b]	10–17
White sweetclover	*Melilotus alba* Medik.	Hubam and TX[c]	11–13

[a]Variety unknown.
[b]Experimental accession of the Samuel Roberts Noble Foundation.
[c]Experimental accession of the Texas A&M Experiment Station at Overton.

In all plantings and locations, legume entries were arranged in a randomized complete block design with four replications. An analysis of variance was conducted to determine main effects and interaction of legume species and environment (location-year) using mixed models procedure in SAS (Statistical Analysis Software, Cary, NC). Different cultivars and accessions of each legume species (Table 1) were pooled by environment in the analysis due to variation in seed availability among cultivars from year to year. Legume species and environment were considered fixed effects, and replications and their interactions were considered random effects in the analysis. Least significance differences among legume species were determined at $P \leq 0.05$.

RESULTS

Environment Effects

Legume species and environment interactions affected freeze damage, vigor, and standing crop of legumes and compatibility with perennial grasses throughout the study (Table 2). Interactions of legume species and environment were likely due in part to differences in precipitation, soil types, temperatures, and companion grasses among testing environments. Long-term precipitation (1971–2000) across the winter growing season (September to April) for Stephenville, Vashti, Burneyville, and Ardmore averaged 505, 538, 611, and 610 mm, respectively. For the 2006 to 2007 growing season, precipitation summed to 553, 617, and 430 mm at Stephenville, Vashti, and Burneyville, respectively. Thus, Burneyville had less precipitation than the long-term average and less than that of Stephenville and Vashti in the first year of these trials. During the 2007 to 2008 growing season, precipitation summed to 349, 378, and 384 mm at Vashti, Burneyville, and Ardmore, respectively. Thus, all locations had less precipitation from long-term location averages in the second year of these trials. Average annual temperatures were similar to long-term average annual temperatures (17°C) for each location, and the first fall freeze (November 30) and last spring freeze (March 5) dates were similar across locations.

TABLE 2
ANALYSIS OF VARIANCE OF FREEZE DAMAGE, VIGOR, AND SPRING STANDING CROP OF 14 ANNUAL LEGUME SPECIES OVERSEEDED WITH PERENNIAL GRASSES ACROSS SIX ENVIRONMENTS IN THE SOUTHERN GREAT PLAINS

			Standing crop	
Source of variation	**Freeze damage**	**Vigor**	**Legume**	**Grass**
	——— P value ———			
Environment	0.0303	<0.0001	<0.0001	<0.0001
Legume species	<0.0001	<0.0001	<0.0001	<0.0001
Environment • Legume species	<0.0001	<0.0001	<0.0001	0.0003

Freeze Damage and Early-Spring Vigor

Freeze damage varied among legume species (Table 3). Hairy vetch and rose clover did not suffer freeze damage (0%) at any of the testing environments. A few legume species on average had low levels (<8%) of freeze damage across environments. These included entries of arrowleaf clover, Austrian winter pea, ball clover, crimson clover, little burr medic, rigid medic, subterranean clover, and Tifton burr medic. Legume species that suffered freeze damage (>15%) on average across testing environments included button medic, burr medic, common vetch, and white sweetclover. Among testing environments, freeze damage was greatest at Vashti in 2008 and may have been compounded by the dry conditions at this location.

Hairy vetch, followed by Austrian winter pea, had the greatest early-spring vigor across testing environments (Table 3). Their early-spring vigor scores averaged 6.82 and 5.92, respectively. Legumes with low early-spring vigor scores, <2.15 on average, included entries of burr medic, common vetch, and white sweetclover. Most other legume species had slightly better to moderate early-spring vigor with average scores ranging from 2.70 to 3.53.

Legume Standing Crop

Spring standing crop depended on legume species and environment. Across environments, standing crop was greatest for hairy vetch and Austrian winter pea (Table 4). At Ardmore, spring standing crop averaged 3,763 and 2,982 kg DM ha^{-1} for hairy vetch and Austrian winter pea, respectively. Burr medic, little burr medic, Tifton burr medic, common vetch, white sweetclover, and subterranean clover performed poorly at Ardmore, as standing crop among these legumes ranged from 160 to 707 kg DM ha^{-1}. Arrowleaf clover, button medic, crimson clover, rigid medic, and rose clover had similar spring standing crop, ranging from 1,241 to 2,227 kg DM ha^{-1}.

At Burneyville, legume standing crop was measured in 2007 and 2008 (Table 4). Again, hairy vetch and Austrian winter pea performed well, as standing crop averaged 3,590 and 3,066 kg DM ha^{-1}, respectively, at this location in 2007. Many of the annual medics also had high spring standing crop at this environment. Standing crop ranged from 995 kg DM ha^{-1} for rigid medic to 3,755 kg DM ha^{-1} for button medic (Table 4). In 2008, Austrian winter pea and hairy vetch had the greatest standing crop, ranging from 3,387 to 4,181 kg DM ha^{-1}. Standing crop also was considerable for many of the annual medics, averaging from 1,976 kg DM ha^{-1} for little burr medic, 2,284 kg DM ha^{-1} for rigid medic, 2,439 kg DM ha^{-1} for Tifton burr medic and 2,580 kg DM ha^{-1} for button medic. Annual clovers generally performed poorly at this site in 2007 and 2008 (Table 4). Spring standing crop of crimson clover ranged from 473 to 961 kg DM ha^{-1} across years. Rose clover had the best standing crop of annual clovers, averaging 2,503 kg DM ha^{-1} in 2007 and 2,071 kg DM ha^{-1} in 2008.

Standing crop at Stephenville was highest for hairy vetch, Austrian winter pea, and rose clover, ranging from 2,818 to 3,292 kg DM ha^{-1} (Table 4). Arrowleaf clover, burr medic, and button medic had a moderate spring standing crop, ranging from 1,071 to 1,233 kg DM ha^{-1}. Across species and cultivars, forage mass of annual medics and

TABLE 3
VISUAL RATINGS OF FREEZE DAMAGE AND VIGOR OF LEGUMES
AT BURNEYVILLE AND ARDMORE, OKLAHOMA, AND VASHTI, TEXAS

	Freeze damage					Vigor rating				
	Burneyville	Ardmore	Vashti			Burneyville	Ardmore	Vashti		
Legume entry	2007	2008	2007	2008	Average	2007	2008	2007	2008	Average
	Percentage (%)					Scale 1–9				
Arrowleaf clover	0.00	0.63	0.00	0.00	0.16	1.00	3.44	4.38	2.58	2.85
Austrian winter pea	18.75	1.25	11.25	0.00	7.81	4.75	5.50	7.75	5.69	5.92
Ball clover	2.50	—	0.00	—	1.25	1.25	—	4.13	—	2.69
Button medic	0.00	2.69	1.56	55.65	14.98	3.88	2.70	3.19	1.03	2.70
Burr medic	15.00	9.42	18.75	85.17	32.09	2.75	2.71	2.75	0.38	2.15
Common vetch	—	58.75	—	15.00	36.88	—	1.00	—	3.06	2.03
Crimson clover	7.50	0.63	2.50	0.63	2.82	2.00	3.44	5.13	3.56	3.53
Hairy vetch	0.00	0.00	0.00	0.00	0.00	5.25	6.00	8.63	7.38	6.82
Little burr medic	2.50	0.63	0.00	21.88	6.25	4.00	2.46	3.00	1.66	2.78
Rigid medic	1.25	0.00	6.25	2.68	2.55	1.94	3.34	3.69	3.31	3.07
Rose clover	0.00	0.00	0.00	0.00	0.00	2.50	2.38	4.00	2.13	2.75
Subterranean clover	0.00	0.75	3.75	0.00	1.13	1.25	2.62	5.25	3.06	3.05
Tifton burr medic	4.50	0.50	1.50	2.63	2.28	3.75	2.13	3.50	2.33	2.93
White sweetclover	34.38	36.25	—	0.75	23.79	2.13	1.13	—	1.81	1.69
Average	6.17	8.58	3.80	14.18	8.39	2.80	2.98	4.62	2.92	3.31
LSD[a]	6.1	4.9	6.5	22.9	9.2	0.6	0.6	0.8	0.9	0.5

Note: Dash (—) indicates not seeded.
[a]Least significant difference (LSD) for comparison of legume species within environments.

TABLE 4
SPRING STANDING CROP OF LEGUMES AT ARDMORE AND BURNEYVILLE, OKLAHOMA, AND STEPHENVILLE AND VASHTI, TEXAS

	Ardmore	Burneyville		Stephenville	Vashti		
Legume species	2008	2007	2008	2007	2007	2008	Average
	Yield (kg DM ha^{-1})						
Arrowleaf clover	1,347	2,063	471	1,233	999	313	1,071
Austrian winter pea	2,982	3,066	4,181	3,292	3,022	2,720	3,210
Ball clover	—	963	—	76	1004	—	681
Button medic	1,367	3,755	2,580	1,169	875	216	1,660
Burr medic	684	2,429	498	1,071	1,556	38	1,046
Common vetch	160	—	1,357	—	—	369	629
Crimson clover	2,227	473	961	278	1,718	1,175	1,138
Hairy vetch	3,763	3,590	3,387	2,997	3,812	3,529	3,513
Little burr medic	698	3,658	1,976	433	1,054	126	1,324
Rigid medic	1,275	995	2,284	43	1,008	1,033	1,105
Rose clover	1,241	2,503	2,071	2,818	1,071	202	1,650
Subterranean clover	707	14	336	0	1280	600	490
Tifton burr medic	472	2,856	2,439	82	898	132	1,146
White sweetclover	186	1,576	659	—	—	120	635
Average	1,316	2,149	1,784	1,124	1,525	813	1,455
LSD[a]	733	1,092	968	694	711	617	450

Note: Dash (—) indicates not seeded.
[a]Least significant difference (LSD) for comparisons among legume species within environments.

annual clovers averaged 660 and 748 kg DM ha^{-1}, respectively. At Vashti, standing crop was best for hairy vetch and Austrian winter pea, ranging from 3,022 to 3,812 kg DM ha^{-1} in 2007 (Table 4). Spring standing crop of annual medics and annual clovers averaged 1,078 and 1,214 kg DM ha^{-1}, respectively. In 2008, standing crop averaged 2,720 kg DM ha^{-1} for Austrian winter pea and 3,529 kg DM ha^{-1} for hairy vetch, respectively. Standing crop of annual medics and annual clovers averaged 309 and 831 kg DM ha^{-1}, respectively.

Compatibility of Legumes with Forage Grasses

Although hairy vetch and Austrian winter pea had the greatest spring standing crop of legume species, they demonstrated potential to reduce standing crop of companion grasses, switchgrass and tall fescue (Table 5). At Stephenville in 2007, spring standing crop of the existing switchgrass stand averaged 1,052 kg DM ha^{-1} when mixed with Austrian winter pea or hairy vetch compared to an average of 2,512 kg DM ha^{-1} across the other legume species. At Ardmore in 2008, standing crop of seedling tall fescue was reduced from an average of 1,767 kg DM ha^{-1} across other legume species to 1,035 kg DM ha^{-1} when combined with Austrian winter pea and hairy vetch (Table 5). Hairy vetch severely limited standing crop of seedling tall fescue at Vashti in 2007 and 2008. From 2007 to 2008, seedling tall fescue standing crop ranged from 158 to 301 kg DM ha^{-1} when seeded with hairy vetch compared to an average of 1,062 to 1,238 kg DM ha^{-1} across the other legume species. Seeding arrowleaf clover, crimson clover, rigid medic, and button medic with

TABLE 5
EFFECTS OF LEGUMES ON SPRING STANDING CROP OF SWITCHGRASS AT STEPHENVILLE, TEXAS, AND TALL FESCUE AT ARDMORE, OKLAHOMA, AND VASHTI, TEXAS

	Stephenville	Ardmore	Vashti		
Legume species	**2007**	**2008**	**2007**	**2008**	**Average**
	Yield (kg DM ha^{-1})				
Arrowleaf clover	2,428	1,233	995	1,188	1,461
Austrian winter pea	990	861	1,208	604	916
Ball clover	2,225	—	1,005	—	1,562
Burr medic	1,751	1,300	1,440	1,036	1,382
Button medic	2,657	1,532	1,337	899	1,606
Common vetch	—	2,420	—	1,464	1,942
Crimson clover	2,455	996	1,230	756	1,359
Hairy vetch	1,114	1,208	158	301	695
Little burr medic	2,376	1,834	1,472	1,215	1,724
Rigid medic	2,779	1,524	1,191	813	1,577
Rose clover	2,214	2,602	877	1,651	1,835
Subterranean clover	3,264	1,401	1,434	498	1,639
Tifton burr medic	2,966	2,160	1,428	1,192	1,935
White sweetclover	—	2,434	—	1,432	1,933
Average	2,268	1,523	1,148	1,004	1,510
LSD[a]	982	732	510	616	495

Note: Dash (—) indicates not seeded.
[a]Least significant difference (LSD) for comparisons among legume species within environments.

tall fescue provided consistent standing crop of both grass and legume components at Ardmore and Vashti across years. Although only standing crop of the legume component was measured at Burneyville in 2007 and 2008, negative effects of legume species on standing crop of eastern gamagrass were not apparent as the legumes generally grew and senesced between rows of the existing stand of grass.

DISCUSSION

Annual Pasture Legumes for the Southern Plains

Hairy vetch and Austrian winter pea clearly demonstrated superior spring standing crop as autumn-seeded annual legumes across all the environments. Previous research has found hairy vetch to be adapted to a wide range of soil textures and pH (5.5 to 8.0). Bloat potential also is low, and it shows good cold tolerance. For successful overseeding of warm-season perennial grasses with winter annual legumes, it is important to reduce warm-season grass competition in autumn before seeding. Planting should occur four to six weeks before the average first killing frost at seeding rates of 22 to 34 kg ha^{-1}. Because of its large seed size, hairy vetch should be drilled 1.2 to 2.5 cm deep to result in good stands (Evers 2005). Caution is necessary when seeding legumes together with perennial grasses such as tall fescue on clean-tilled seedbeds, as competition from these legumes tended to overwhelm the grass seedlings, limiting their ability to establish. Compatibility of these legumes with established grasses such as switchgrass and eastern gamagrass, however, is questionable. Although they did not appear to reduce standing crop of eastern gamagrass, they reduced spring standing crop of switchgrass. This may be due to winter legumes reducing available soil moisture for the warm-season grass in spring. Grazing of swards with hairy vetch and Austrian winter pea by late April may reduce their dominance over and improve their compatibility with pasture grasses.

Crimson and arrowleaf clovers have been identified as the most dependable winter annual forage legumes in the southeastern United States (Sheaffer and Evers 2007). They performed moderately well across most environments in this zone of 760 to 890 mm annual rainfall, with the exception of Burneyville. A soil pH > 8.0 may have limited clover success on this site because iron-deficiency chlorosis occurs when pH exceeds 7.5 (Sheaffer and Evers 2007). Standing crop of arrowleaf clover also may have been limited at all locations by the mid-April harvests because arrowleaf clover is a later-maturing clover (Evers and Newman 2008). Planting early in the growing season or using later-maturing cultivars can maximize production of annual legumes and lengthen the grazing season (Butler et al. 2002). Crimson clover often is used successfully in pasture-based production systems because of its early maturity and excellent seedling vigor (Evers 1999). Blends of early- and late-maturing types may provide a longer season of high-quality grazing and enhance nitrogen contribution to the pasture (Muir et al. 2005).

Rose clover performed moderately well at the high-soil-pH site at Burneyville in 2007 and 2008, Ardmore in 2008, and Stephenville in 2007, but poorly at Vashti in 2007 and 2008. Rose clover is adapted to slightly alkaline soils (Smith et al. 1992; Evers and Newman 2008), explaining why it performed better than other annual clovers on the high-soil-pH site at Burneyville. Standing crop of ball clover (*T. nigrescens* Viv.) and subterranean clovers were poor to marginal on all sites, and therefore are not recommended for planting in this 760 to 890 mm rainfall zone. Subterranean clover suffers from Fe deficiency on high pH soils and is susceptible to freeze damage during cold winters (Evers 1999).

Success of annual medics depended on the species. Little burr medic cv. Devine, as well as NF (Noble Foundation) and Estes button medics, suffered the least freeze damage and were generally the most productive. They had excellent spring standing crop on the high pH soils at Burneyville, where annual clovers suffered. Released in 2005, Devine little burr medic was developed by Texas AgriLife Research for central Texas between Dallas (32°N latitude) and San Antonio (29°N latitude). Desirable attributes included tolerance to freeze damage, better forage and hard seed production, and positive seed production under grazing (Ocumpaugh et al. 2007).

Burr medic suffered the most freeze damage, and its ability to provide consistent spring forage in north-central Texas and south-central Oklahoma appears limited. In 2008, all medics with the exception of rigid medic suffered heavy freeze damage and performed poorly at Vashti. Their persistence in the south-central US environments will depend on their ability to tolerate killing freezes and on hard seed production to develop soil seed reserves (Muir et al. 2001; Muir et al. 2005). Availability of sufficient soil moisture, high concentrations of soil P, and limited competition from grasses are necessary to ensure maximum growth. Naturalized populations of annual medics typically occur on disturbed sites without much competition from grasses (Diggs et al. 1999; Muir et al. 2001). Annual medics do not grow well with sod-forming grasses but may have a role with bunchgrasses in low summer-rainfall areas (Muir et al. 2001). Annual medics also have value if stands regenerate from year to year without additional inputs (Muir et al. 2005).

With the exception of hairy vetch and Austrian winter pea, legumes did not interfere with subsequent grass development, suggesting they may be successfully overseeded into existing pastures or seeded together with grasses in clean-tilled seedbeds. Key factors for success of legumes when overseeding or seeding with perennial grasses will include attention to proper soil pH, P, and K (Bow et al. 2008). A pH of 6.5 is considered optimum for nitrogen fixation, and legumes generally respond well to P fertilization (Snyder and Leep 2007). Seed yields and self-regeneration of annual clovers and medics also are important considerations when evaluating use of these legumes in forage systems (Muir et al. 2005). Research is needed to determine how grazing intensity affects the ability of winter annual legumes to produce sufficient seed to replenish soil seed banks and self-regenerate. Minimum volunteer reseeding stands of 100 legume seedlings m^{-2} have been noted as necessary for good stand persistence (Evers 2005). Successful reseeding of annual clovers also depends on production of an adequate seed crop with a high percentage of hard seed (Evers and Smith 2006). Hard seed is a dormancy mechanism where an impermeable seed coat prevents absorption of water and germination as opposed to soft seed, which absorbs water and germinates readily (Beuselinck et al. 1994). The rate at which hard seed in soil declines through time depends on legume species and climatic factors. Future research on legume persistence and reseeding under grazing will improve understanding of the value of different legumes in forage-based beef production systems regionally.

ACKNOWLEDGMENTS

The authors thank Jim Stein, John R. Bow, Julie Barrick, Tabby Campbell, and Shawn Norton for their contributions to this research and the Samuel Roberts Noble Foundation and Texas AgriLife Research and Extension Service for funding these efforts.

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