ESTABLISHMENT OF

Desmanthus Species

IN EXISTING GRASS STANDS

James P Muir and William D Pitman |

ABSTRACT

Seedling emergence of 'Sabine' Illinois bundleflower (*Desmanthus illinoensis* [Michx.] MacM. [Fabaceae]), velvet bundleflower (*D. velutinus* Scheele), and 2 accessions of rayado bundleflower (*D. virgatus* [L.] Willd.; synonym = *D. bicornutus* S. Watson) planted into tilled or defoliated strips in bermudagrass (*Cynodon dactylon* [L.] Pers.) was generally low but greater in switchgrass (*Panicum virgatum* L.). Differences in years and sites reflected precipitation differences. Although the rayado bundleflowers had greater initial establishment, Illinois bundleflower was more winter-hardy and had greater second-year yields in both grass species following establishment seasons with adequate precipitation. Potential for interseeding *Desmanthus* at latitudes approaching or exceeding 31 °N appears greater for Illinois bundleflower.

KEY WORDS

interseeding, Illinois bundleflower, rayado bundleflower, velvet bundleflower, bermudagrass, switchgrass, Fabaceae, Poaceae

NOMENCLATURE

Diggs and others (1999)

Figure 1. Illinois bundleflower, a perennial legume native to the central US, contributes protein-rich seeds and forage to wildlife and nitrogen to soil.

Figure 2. Very little is known about velvet bundleflower, but seeds produced in these pods are important for wildlife.

Photos by James P Muir

Figure 3. Bundleflowers establishing within a strip of bermudagrass killed by herbicides.

Perennial legumes were once common components of native vegetation of prairies and woodlands of the central US (Weaver 1954; Grelen and Duvall 1966; Lewis and others 1974) but were among the species to be greatly reduced in abundance and often eliminated by excessive grazing pressure (Weaver 1954). These legumes contributed protein-rich seeds and forage to soils and wildlife and were meaningful sources of fixed nitrogen to the ecosystems (Grelen and Duvall 1966). In the south-central region of the US, potential exists to introduce native legumes into grass monocultures.

The genus *Desmanthus* (Fabaceae) is a widely adapted and underutilized forage resource (Burt 1993). Illinois bundleflower (*Desmanthus illinoensis* [Michx.] MacM.) is widely distributed in the south-central US (Fernald 1970; Lasseigne 1973; Bates 1974), and the cultivar 'Sabine' (Anonymous 1984) was released to provide a perennial native legume for range and pasture plantings (Figure 1). Rayado bundleflower (*D. virgatus* [L.] Willd.; synonym = *D. bicornutus* S. Watson) is widely distributed in the American tropics and subtropics into the southern portions of the US (USDA SCS 1980; Burt 1993) and accessions have recently been selected for south and central Texas (Grichar and others 1998). Velvet bundleflower (*D. velutinus* Scheele) is a temperate plant found throughout northern Texas (Diggs and others 1999) and has been recognized as useful for domesticated browsers or deer and as a seed source used by quail and other birds (Haferkamp and others 1984). Potential for cultivation of velvet bundleflower has not yet been thoroughly evaluated (Figure 2). Velvet bundleflower is shorter growing than the other 2 bundleflowers and is found mainly in semi-arid, open grasslands.

Competition from established grass stands has been reported as a limitation to seedlings of both Illinois (Dovel and others 1990) and rayado bundleflower (Burrows and Porter 1993). Such competition and an extended period of extremely slow seedling growth were speculated to be primary causes of failure of sod-seeded plots of Illinois bundleflower at Rosepine, Louisiana, in 1994 (Pitman, unpublished data). Transplanted seedlings of Illinois and rayado bundleflower, which were several weeks old and greater than 15 cm (6 in) tall, established despite aggressive competition on a fertile, high-moisture, clay, mine-reclamation site in central Florida (Adjei and Pitman 1993). Dovel and others (1990) reported that grass suppression either from disking or chemical defoliation resulted in higher seedling densities for Illinois bundleflower in the establishment year than the undisturbed control when interseeded into an established stand of kleingrass (*Panicum coloratum* L. [Poaceae]). High levels of seed production and dense stands of seedlings have been reported under favorable conditions from stands of both Illinois (Dovel and others 1990) and rayado (Gardiner and Burt 1995) bundleflower. Dovel and others (1990) suggested that the rapid spread observed for Illinois bundleflower could allow planting in widely spaced strips with subsequent spread into unseeded areas with appropriate man-

TABLE 1

Rosepine, Louisiana, and Stephenville, Texas, experiment site characteristics.

Site	Location	Elevation m (ft)	Soil	Soil nutrients [a]/kg P	K	Ca	Mg	Soil pH	30-y average rainfall mm (in)
				mg					
Stephenville Bermudagrass	32° 13' N, 98° 12' W	400 (1312)	Windthorst fine sandy loam	14 [b]	236	993	250	5.8	740 (29)
Stephenville Switchgrass	32° 13' N, 98° 12' W	400 (1312)	Windthorst fine sandy loam	7	256	1840	531	6.4	740 (29)
Rosepine Bermudagrass	30° 57' N, 93° 17' W	63 (207)	Bowie fine sandy loam	8	54	1824	65	5.2	1450 (57)

[a] Texas A&M extractant used to estimate plant-available nutrients.
[b] Conversion: 1mg/kg = 1 ppm.

agement. Observations of Burrows and Porter (1993) with rayado bundleflower suggest that strategic grazing to reduce competition prior to bundleflower seedling emergence, along with subsequent protection of establishing bundleflower seedlings from defoliation, could contribute to spread of this legume.

One objective of these trials was to measure establishment responses of Illinois, rayado, and velvet bundleflower seeded into grass-suppressed strips within monocultures of bermudagrass (*Cynodon dactylon* [L] Pers. [Poaceae]) in Texas and Louisiana and a switchgrass (*Panicum virgatum* L. [Poaceae]) monoculture in Texas. A second objective was to determine what method and degree of grass suppression was needed to successfully establish bundleflowers in these grass pastures.

MATERIALS AND METHODS

Establishment of Illinois bundleflower 'Sabine', velvet bundleflower accession PMT-2406 (USDA, NRCS Plant Materials Center, Knox City, Texas), and 2 lines of rayado bundleflower (PI 90906 and PI 90857) was assessed in bermudagrass stands at Stephenville, Texas, and Rosepine, Louisiana, and in 'Alamo' switchgrass at Stephenville in 1998 and 1999. Seedbed preparation treatments included strip tillage with a 45-cm-wide (18-in) strip rototilled to a 20-cm (8-in) depth, herbicide desiccation (glyphosate {N-(phosphonomethyl) glycine}; 4.7 l active ingredient per ha [2 qt/ac]) in strips 15, 30, and 45 cm (6, 12, and 18 in) wide (Figure 3), and an essentially undisturbed control. Each year in a new but adjacent site, the 4 entries were hand-planted into single-row plots 5 m (16.4 ft) in length with rows spaced 1.5 m (4.9 ft) apart. At each site each year, a randomized complete block design with factorial arrangement of treatments was used with 4 replications.

The Stephenville site (Table 1) is in the Cross Timbers land physiographic region of north-central Texas characterized by shallow, sandy, low-phosphorus soils with low water-holding capacity. The Rosepine site is in the Coastal Plain of west Louisiana, with inherently infertile, shallow, droughty soils.

At each site, the bermudagrass variety was the most widely planted for that region. At Stephenville, the variety was 'Coastal', and common bermudagrass was the variety at Rosepine. Preliminary germination tests of the legumes were used to adjust seeding rates to a live seed basis. Seeding rates of all 4 entries were calculated to provide 40 live seeds (not including non-viable and hard seeds) per 5-m (16.4-ft) row. Seeds were mechanically scarified and inoculated with *Desmanthus*-specific inoculant (Urbana Laboratories, 225 Florence Road, St Joseph, Missouri 64504) immediately before planting. Seeds were placed by hand in 1-cm-deep (0.4 in) troughs and covered with soil in late May or early June at Stephenville, where seedbeds were irrigated with 76 mm (3 in) of water prior to planting in April 1998 to enhance grass regrowth and herbicide effectiveness. Spring seeding of scarified seeds was undertaken since greater loss to germination, spoilage, and predation would be likely in autumn plantings. Due to extremely dry soils and lack of effective precipitation from early April through June 1998, planting was delayed until the first week of July in 1998 at Rosepine. The 1999 planting at Rosepine was made in early June.

Responses assessed include whole plot plant counts in June, August, and October and average plant height measurements in October of the establishment year in bermudagrass at each location. *Desmanthus* dry matter standing crop was determined for the 1998 plantings at Stephenville in August 1999 by harvesting all plant material in the entire plots at soil height and drying in a forced-air oven at 55 °C (131 °F) to a constant weight. At Rosepine, only plant counts were taken in June of the second growing season. In the switchgrass experiment,

TABLE 2

Monthly rainfall during the experiment at Rosepine and Stephenville.

Location/year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	mm [a]											
Stephenville												
1998	66	64	108	84 [b]	116	59	41	63	72	91	41	49
1999	30	1	37	51	9	51	35	1	48	53	2	64
2000	28	17	47	63	58	176	2	0	7	108	149	38
Rosepine												
1998	271	112	112	92	0	28	70	130	307	96	147	215
1999	172	21	143	154	170	162	189	4	65	98	28	110
2000	22	16	108	176	211	90	58	59	87	32	330	67

[a] Conversion: 1 mm = 0.04 in.
[b] 76 mm of irrigation was applied during April 1998 at Stephenville in addition to 8 mm rainfall that month. Totals for April through August: Stephenville, 1998 = 363 mm, 1999 = 217; Rosepine, 1998 = 320, 1999 = 679.

Desmanthus plants were counted in late June and August and average plant heights were measured in August of the establishment year using every plant in the plot. *Desmanthus* dry matter yield was also assessed in August of the following growing season of each planting in the switchgrass.

Analysis of variance on data from bermudagrass pastures was conducted using a model that included location, year, plant entry, seedbed preparation, and multi-factorial interactions. Due to interactions involving location and years, data from the 2 sites were subsequently analyzed separately for each year. A year by plant entry and seedbed preparation interaction was also measured for the switchgrass trial at Stephenville so all results are presented by year. Significant ($P \leq 0.05$) differences among treatments were separated with least significant difference (LSD) procedure. Analysis of data from the switchgrass was similar to that of bermudagrass stands except location was not included in the model.

RESULTS

Bermudagrass Study

Rainfall amounts and distribution substantially affected seedling emergence and survival at both locations (Table 2). Moisture limitations at Rosepine were severe during the 1998 establishment period, despite slightly greater total rainfall than at Stephenville the same year. In 1999, inadequate rainfall was particularly detrimental at Stephenville. These rainfall patterns were associated with location by year interactions ($P < 0.05$) with the seedbed preparation and entry treatments ($P < 0.05$).

Rosepine

At Rosepine in 1998, frequent observation of the planting revealed a few emerged seedlings during the initial month; however, these seedlings failed to survive longer than 2 or 3 d. During subsequent periodic observation dates through the 1998 growing season and the following year, no *Desmanthus* plants were found in this field. Spring and early summer rainfall at Rosepine was much more favorable in 1999 than in 1998. Initial emergence, assessed in late June, was greatest for the 2 rayado bundleflower entries and least for velvet bundleflower (Table 3). From an initial emergence of about 25% of the planted seeds of the 2 rayado bundleflower entries, live plants in October represented about 10% of the initial seeds. These 2 entries maintained the most plants through the establishment year, and their height in October was greater than that of the other 2 entries. Regeneration in the following growing season was minimal for all entries, even though the number of plants of Illinois bundleflower did not decline from the previous October.

Differences among seedbed treatments at Rosepine in 1999 were evident throughout the establishment year (Table 3). The tilled seedbed consistently supported more plants in the year of planting than in any other treatment. This treatment also produced taller plants than all other treatments except the 45-cm-wide herbicide desiccated band. No differences were detectable among treatment plant numbers in the second growing season, even though several treatments had no surviving plants.

Stephenville

The Stephenville 1998 planting resulted in substantial seedling numbers for all 4 entries at the initial assessment date (Table 4). Following this early seedling count, rayado bundleflower 90857 had greater plant numbers in the establishment

TABLE 3

Seedling emergence, survival and height of Desmanthus *spp. sown in 1999 at Rosepine, Louisiana (all entry and treatment responses at this location were 0 for the 1998 planting).*

Treatment	Number of Plants: Jun 1999	Aug 1999	Oct 1999	Jun 2000	Plant height Oct 1999
	plants per 5-m [a] row				cm [a]
D. virgatus 90906	9	5	4	0	7
D. virgatus 90857	10	6	4	0	9
D. velutinus	2	0	0	0	0
D. illinoensis	6	3	1	2	3
P value	< 0.01	< 0.01	0.02	0.13	<0.01
LSD (0.05)	3	2	2		3
Control	5	1	1	0	1
15 cm herbicide	5	4	2	0	4
30 cm herbicide	6	2	2	0	5
45 cm herbicide	7	3	2	1	6
45 cm herbicide tilled	13	9	7	2	9
P value	< 0.01	< 0.01	< 0.01	0.30	0.05
LSD (0.05)	3	3	2		4

[a] Conversions: 1 m = 3.3 ft; 1 cm = 0.4 in.

year and taller plants in October compared to the other entries. The following spring, however, Illinois bundleflower regenerated the greatest standing crop.

More seedlings emerged in the tilled bermudagrass seedbed at Stephenville in 1998 compared to other treatments, except the 45-cm-wide (18-in) herbicide desiccated treatment. This advantage only persisted over the control and the 15-cm-wide (6-in) herbicide desiccated treatment by the end of the initial growing season (Table 4). Bermudagrass recovered more quickly and invaded the tilled strips more rapidly than it did in the 30- and 45-cm-wide (12- and 18-in) sprayed strips. Plant height was greatest in the 45-cm-wide (18-in) sprayed strip in October of the planting year. Standing crop resprouting the following growing season was greatest in the tilled treatment (Table 4). Responses revealed consistent enhancement of *Desmanthus* establishment and growth from the control through the progressively wider strips of Coastal bermudagrass desiccated by herbicide in 1998.

Desmanthus emergence in the Coastal bermudagrass at Stephenville was substantially less in 1999 than in 1998 (Table 4). Illinois bundleflower had the greatest emergence, although seedlings of all entries died by August 1999. Emergence in the tilled treatment was greater than that in the 15- and 30-cm-wide (6- and 12-in) sprayed treatments than in the control, while both the 30- and 45-cm-wide (12- and 18-in) sprayed treatments had greater emergence than did the control.

TABLE 4

Seedling emergence, survival, plant height, and standing crop of Desmanthus *spp. as affected by seedbed preparation in a bermudagrass during two growing seasons at Stephenville, Texas.*

Treatment	1998 planting					1999
	Plant number			Plant height	Herbage dry matter	Plant number
	Jun	Aug	Oct	Oct	Aug 1999	Jun
	plants per 5-m[a] row			cm[a]	g[a] per 5-m row	plants per 5-m row
D. virgatus 90906	25	11	5	18	0.0	0
D. virgatus 90857	33	21	12	30	1.2	1
D. velutinus	30	17	4	9	0.0	2
D. illinoensis	28	17	4	8	3.1	6
P value	0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
LSD (0.05)	4	4	2	5	1.1	1
Control	20	5	1	2	0.1	0.0
15 cm herbicide	25	13	4	10	0.1	1
30 cm herbicide	28	19	7	24	0.9	2
45 cm herbicide	33	22	10	27	2.0	4
45 cm herbicide tilled	38	22	8	19	2.4	4
P value	< 0.01	< 0.01	< 0.01	< 0.01	0.03	< 0.01
LSD (0.05)	5	5	2	6	1.3	1

[a] Conversions: 1 m = 3.3 ft; 1 cm = 0.4 in.; 1 g = 0.04 oz.

Switchgrass Study

Stephenville

In the switchgrass at Stephenville, year by treatment interactions were significant for *Desmanthus* establishment (Table 5). Although all entries had similar seedling numbers in June, by August fewer plants of rayado bundleflower 90906 survived than of the others. At this time, rayado bundleflower 90857 was the tallest entry, with Illinois bundleflower taller than the other 2 entries. Forage yield of Illinois bundleflower in the second growing season was greater than that of the others, reflecting a superior stand. Seedbed treatments did not affect plant numbers in switchgrass in 1998, but plant height in August of the establishment year and forage yield in the second growing season produced an evident trend toward superiority of the tilled treatment.

In 1999, *Desmanthus* seedling emergence in switchgrass was much less than in 1998. Illinois bundleflower produced the best stands and tallest plants in the establishment year and the most forage in the following year (Table 5). The tilled treatment provided the best initial stands and the tallest plants in August, even though plant numbers did not differ among seedbed treatments by August 1999 and second-year forage yields did not differ.

DISCUSSION

The effect of year of planting on emergence and survival of *Desmanthus* at both locations and in both bermudagrass (sod) and switchgrass (bunchgrass) stands was dramatic. This year effect was primarily due to soil water. Burrows and Porter (1993) reported that natural seedling recruitment in a rayado bundleflower stand in Australia occurred primarily as distinct flushes of seedlings in association with favorable rainfall. Our use of only scarified seeds optimized opportunity for immediate establishment but also increased vulnerability of the plantings to moisture stress. Such moisture stress was a distinct limitation in both locations. Typically erratic rainfall patterns, rather than total annual precipitation, provided the major limitation to establishment of these warm-season legumes. This distinct dependence on sustained moisture is consistent with the observation of Kulakow (1999) that Illinois bundleflower grows in locally moist environments and the finding of Piper (1993) that this legume has a high water use.

The additional influence of plant competition was also in agreement with the results of Burrows and Porter (1993). Moisture-driven recruitment events in the Australian research occurred at times with grazing, but seedlings failed to establish with similar rainfall and no grazing of associated grass. Plant competition differed among treatments in the present study in association with locations in distinctly different rainfall zones, years with differing rainfall, grasses of differing growth habit, and seedbed preparation within grass swards. *Desmanthus* establishment at Rosepine, in the year with sufficient soil water for stand emergence, was subjected to dense plant competition in all treatments. Annual weeds dominated by crabgrass (*Digi-*

TABLE 5

Seedling emergence, survival, plant height, and standing crop for Desmanthus *spp. as affected by seedbed preparation in switchgrass during 2 growing seasons at Stephenville, Texas.*

Treatment	Plant number Jun	Plant number Aug	Plant height Aug	Herbage dry matter Aug (year 2)
	plants per 5-m[a] row		cm	g [a] per 5-m row
1998 PLANTING				
D. virgatus 90906	10	3	2	0.0
D. virgatus 90857	13	7	9	0.7
D. velutinus	12	8	3	0.9
D. illinoensis	11	9	5	12.0
P value	> 0.50	< 0.01	< 0.01	< 0.01
LSD (0.05)		2	3	3.9
Control	14	8	5	2.7
15 cm herbicide	10	6	4	0.7
30 cm herbicide	10	6	3	2.5
45 cm herbicide	11	7	5	2.4
45 cm herbicide tilled	13	8	8	8.6
P value	> 0.50	> 0.50	0.1	0.1
LSD (0.05)			3	4.4
1999 PLANTING				
D. virgatus 90906	1	1	8	0.8
D. virgatus 90857	0	0	5	0.2
D. velutinus	0	0	2	0.0
D. illinoensis	5	6	36	8.1
P value	< 0.01	< 0.01	< 0.01	0.05
LSD (0.05)	1	3	8	4.6
Control	0	0	0	0.7
15 cm herbicide	1	3	6	3.8
30 cm herbicide	1	0	13	5.9
45 cm herbicide	2	2	17	0.7
45 cm herbicide tilled	4	3	26	0.3
P value	< 0.01	0.35	< 0.01	0.42
LSD (0.05)	1		9	

[a] Conversions: 1 m = 3.3 ft; 1 cm = 0.4 in.; 1 g = 0.04 oz.

taria sanguinalis [L.] Scop. [Poaceae]) quickly filled gaps provided by either tillage or herbicide desiccation. *Desmanthus* establishment was more adversely affected by moisture limitations than was either the existing perennial grass or the weedy annual grasses. The bunchgrass growth of switchgrass appeared to be less detrimental to *Desmanthus* establishment than was Coastal bermudagrass during the dry 1999 summer at Stephenville. Treatments producing the greatest disturbance of the existing grass, especially tillage but to some extent the wider herbicide bands, were beneficial to establishment of *Desmanthus*.

Initial establishment of the 4 entries generally followed similar patterns, although the rayado accessions were superior at Rosepine in 1999, and Illinois bundleflower excelled in switchgrass at Stephenville in 1999. In 1998, rayado accession 90857, the larger seeded entry, was superior to the other rayado accession in establishment in the bermudagrass sod at

STEPS FOR ESTABLISHING BUNDLEFLOWERS (*DESMANTHUS* SPP.) IN GRASS STANDS

GENERAL

- Scarify 50% of the seeds to ensure germination
- Leave 50% of the seeds unscarified to ensure range in germination dates
- Inoculate with specific rhizobia (Urbana Laboratories, St Joseph, Missouri) to ensure nodulation
- Plant 21 to 42 seeds/m (2 to 4 seeds/ft^2)
- Drill seeds 6 mm (0.25 in) depth in February-March

SWITCHGRASS AND OTHER BUNCHGRASSES

- Burn, graze down, hay, or mow existing grass prior to seeding

BERMUDAGRASSES AND OTHER GRASSES THAT SPREAD BY RHIZOMES OR STOLONS

- Burn, graze down, hay, or mow existing grass prior to seeding
- Graze grass as legume seedlings emerge but not after legumes are 7.5 cm (3 in) tall
- Spray Select (clethodim) in 61- to 92-cm-wide (2- to 3-ft) bands over the seedling rows when grass initiates growth
- Do not apply nitrogen fertilizer in or near bands!

Stephenville. Kulakow (1999) noted that large seeds were associated with plant vigor of Illinois bundleflower in the establishment year. This benefit of large seeds was achieved only under the conditions producing the highest emergence obtained in our plantings. The most consistent difference among entries was the superiority of Illinois bundleflower in the year following establishment. This superior survival reflects the winter hardiness and adaption of Illinois bundleflower in contrast to the more tropical or subtropical rayado bundleflower. Although previously reported to "survive in cold frosty climate" (Graham and others 1991), several interacting factors including extent of growth and development in the establishment season, competition, defoliation, and soil biology and chemistry appear to be critical to survival of rayado bundleflower in marginal environments.

Dovel and others (1990) reported excellent establishment of Illinois bundleflower in kleingrass suppressed by either disking or herbicide desiccation in a year with above-average rainfall. In the open stand of this bunchgrass, seedlings of Illinois bundleflower established and produced increasing stand density during a 4-y period. Low soil nitrogen and lack of recent fertilization apparently reduced competitiveness of the grass. Such reduced competitiveness of existing vegetation by grazing has been reported to enhance establishment of rayado bundleflower (Graham and others 1991; Burrows and Porter 1993). Effective limitation of plant competition is more readily obtained in plant communities of lower rainfall environments, especially when those plant communities are dominated by open-growing bunchgrasses rather than aggressive, sod-forming grasses. Timing of defoliation of switchgrass can readily increase susceptibility of established stands to invasion by other species (Beaty and Powell 1976; Haferkamp and Copeland 1984).

Illinois bundleflower appears to be the best suited of these *Desmanthus* species for plantings in latitudes approaching 31 °N and higher. Greater control of competition than that provided by the bands of tillage and herbicide desiccation evaluated will be needed for establishment in humid regions. Erratic rainfall patterns and large variation in annual precipitation predispose pasture plantings, especially interseeding, to periodic failure in sub-humid to semi-arid regions. Thus, scarification to enhance rate of germination should only be done on a portion of the seeds to provide more than 1 opportunity for establishment from a planting. Probability of successful interseeding and *Desmanthus* stand survival appears greater in appropriately managed bunchgrasses than in established sod.

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AUTHOR INFORMATION

James P Muir
Associate Professor
Texas Agricultural Experiment Station
1229 North US Hwy 281
Stephenville, TX 76401
j-muir@tamu.edu

William D Pitman
Professor
Louisiana Agricultural Experiment Station
Rosepine Research Station
PO Box 26
Rosepine, LA 70659
wpitman@agctr.lsu.edu

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