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Response of *Desmanthus* to clipping on a phosphatic clay mine-spoil

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Abstract

Defoliation treatments of 1, 2, and 3 harvests annually were imposed on three *Desmanthus* accessions established on a phosphatic clay mine-spoil to evaluate yield and quality of edible forage and seed production. Total dry matter (leaf + stem) yields from 2 and 3 harvests annually were 26.2 and 16.0 t/ha ($P<0.01$), respectively, across all accessions. However, annual yield of the temperate perennial *D. illinoensis* (Illinois bundleflower) from 1 harvest was only 7.1 t/ha compared with 37.1 and 53.2 t/ha for the tropical *D. virgatus* accessions IRFL 1857 and IRFL 1854, respectively. The proportion of leaf decreased ($P<0.01$) from 50 to 10% with decreasing frequency of harvest. Mean leaf crude protein (CP) content for the 2 and 3 harvests averaged 22.4% but decreased ($P<0.05$) to 20% for the single harvest. The average stem CP declined ($P<0.05$) from 8.0 to 5.4% with maturation. Contrary to the expected trend, leaf *in vitro* organic matter digestibility (IVOMD) of all accessions was low (34–41%) and increased ($P<0.05$) with decreasing harvest frequency, perhaps as a result of a dilution of tannins with later growth. No appreciable amount of seed was produced under the most frequent harvest schedule. Highest annual seed yield (845–3380 kg/ha at 12% moisture, depending on year) for Illinois bundleflower was obtained with 2 harvests per year and for *D. virgatus* accessions (369–900 kg/ha) with 1 harvest per year. These data suggest that differential clipping schedules are required to optimise forage quality and seed produstion from the various *Desmanthus* accessions. Also, because of the low leaf IVOMD, feeding trials are needed to ascertain the feeding value of *Desmanthus* forage to livestock. Both temperate and tropical *Desmanthus* species were productive on this subtropical phosphatic clay site, with herbage and seed production occurring during the warm season for both species.

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Introduction

Desmanthus spp. are naturally distributed over diverse sites in tropical and warm temperate climates. Edaphic suitability of the genus ranges from sandy soils to clays (Skerman 1977) with a pH requirement ranging from 5–7. Additionally, the genus is adapted to a range of moisture regimes from semi-arid to wet equatorial conditions. Skerman (1977) reviewed the available information on *D. virgatus* and concluded that it is a palatable, productive forage tolerant of defoliation. Skerman (1977) cited research from Hawaii where *D. virgatus* persisted under 4 harvests per year when cut at the early pod stage to a 5 cm stubble. There was no plant mortality but yields decreased during the second and third years. Both maximum annual yield (24 t/ha) and leaf crude protein (22.4%) were lower than obtained for *Leucaena leucocephala*. More recently *Desmanthus* accessions were found to establish faster and to outyield 4 other tropical legumes in a preliminary evaluation on phosphatic clay in Florida (Adjei and Pitman 1990).

In some situations, however, *Desmanthus* accessions have not persisted under clipping, with yield reductions and death of large plants following repeated defoliation (Michaud *et al.* 1989). Keoghan (personal communication) suggested that, even though survival of tall, woody *D. virgatus* plants at the mature seed stage is poor following defoliation, plants browsed at earlier stages can survive as herbaceous plants under fairly close defoliation. Keoghan attributed the improved survival under defoliation at earlier stages of growth to enhanced viability of basal buds, suggesting that basal buds senesce over extended periods of subjection to apical dominance.

While *Desmanthus* accessions have shown potential on the extensive Florida spodosols (Pitman *et al.* 1988), growth of a range of *Desmanthus* germplasm on colloidal phosphatic clay mine-spoil has been particularly impressive. These sites are highly fertile with only nitrogen limiting growth of many crops. These clays are deposited in a slurry often exceeding 10 m in depth with internal water content persisting for decades. Thus, nitrogen is the primary limitation to pasture productivity on these sites. An estimated 40 000 ha of such mine-spoil currently exists in Florida (Marion 1986). Despite recognition of its suitability for these mine-spoil and other clay sites, information regarding appropriate management of *Desmanthus* is essentially unavailable. Thus, research was conducted to evaluate responses in forage yield and quality, seed production and stand survival of *Desmanthus* accessions on phosphatic clay mine-spoil subjected to 3 harvest frequencies over a 2-year period.

Materials and methods

The study was conducted at the Phosphate-Mined Lands Agricultural Research facility near Bartow, Florida (27° 26′ N, 81° 55′ W). The site consisted of an 8-year old, partially dried, colloidal phosphatic clay pond. Three *Desmanthus* accessions: (1) *D. virgatus* IRFL 1854; (2) *D. virgatus* IRFL 1857; and (3) *D. illinoensis* cv. Sabine (Illinois bundleflower) were established in a randomised complete block design with 4 replicates. Four rows (0.5 m inter-row spacing) of seedlings of each accession were transplanted (25 cm intra-row spacing) on 9 m x 2 m plots in June, 1988. Very little growth occurred between September and March each year due to low winter temperatures and occasional frosts from December–February. Therefore, following successful establishment of the legumes, plants in all plots were cut back to a 15 cm stubble in March of 1989 and 1990 to remove frosted material. Three harvest frequencies: (1) 3 harvests (May, July and September); (2) 2 harvests (June and September); and (3) 1 harvest (September), annually were imposed in 1989 and 1990. Harvest treatments were imposed across 3 m strips of replicated blocks to provide a strip block design. Forage was harvested from a central 0.5 m^2 area in each 3 m x 2 m subplot with electrical shears to a 15 cm stubble according to the prescribed frequency. Harvested forage was weighed and all mature seed present was manually removed to determine seed yield. Another herbage sample of approximately 1 kg was clipped from each subplot to a 15 cm stubble and used for dry matter (DM), leaf/stem ratio and forage quality determinations. Forage samples were dried at 60 °C to constant weight, separated into leaf and stem components, weighed, ground to pass a 1 mm mesh screen and analysed for crude protein (Gallaher *et al.* 1975; Hambleton 1977) and *in vitro* organic matter digestibility (Moore and Mott 1974). Harvested seed was dried at 40 °C in a forced-draft oven for 72 hr to approximately 12% moisture, cleaned and weighed. Data on seasonal yield, forage quality, leaf/stem ratio and seed yield were analysed using the General Linear Model (GLM) procedure of SAS system (SAS Institute Inc. 1988). Means were separated by Duncan's Multiple Range Test at 0.01 or 0.05 level of probability.

Results

Forage DM yield

Annual forage yields were similar in both years, and there were no year x treatment interactions ($P > 0.05$). The total yields of stem plus leaf (average of 2 years) of 26.2 and 16.0 t/ha for the 2 and 3 harvest treatments, respectively, were similar for all 3 accessions (Table 1). However, with the single harvest, the yield of Illinois bundleflower (7.1 t/ha) was much lower than those of the *D. virgatus* accessions. Illinois bundleflower is an early maturing perennial which produced distinct determinate growth with complete foliage senescence at the time of seed maturation. Thus only dead herbage was present by the time of the single harvest in September. Two harvests per year in July and September prevented senescence during the growing season and provided the best clipping management for maximising yield of the bundleflower as compared with 1 annual harvest for the *D. virgatus* accessions.

The leaf/stem ratio of harvested forage depended primarily on the stage of plant growth at harvest. It was highest for the 3 harvests and dropped sharply with the single harvest in September (Table 2). There was a tendency for the early maturing, determinate bundleflower to produce a higher leaf/stem ratio at the most frequent harvest, but a much lower value with the single harvest when only dead herbage remained. A variable yearly response in leaf/stem ratio to harvest frequency was probably the result of variation in environmental factors such as rainfall. Generally, 30–50% of harvested forage consisted of leafy material with the 2 and 3 harvest treatments compared with less than 10% with the single harvest.

Forage quality

Crude protein (CP) concentration in the leaf ranged from 20–23% depending on harvest frequency (Table 3). However, stem CP was only 8% in the 3 harvest treatment and decreased to 5.4% with the single harvest.

Despite a significant year effect ($P<0.05$) on IVOMD of forage, the response to treatments was consistent over years. Although leaf IVOMD was lower for IRFL 1857 than for the other 2 accessions (Table 4), the values were generally lower for all 3 accessions than expected for tropical legumes (Skerman 1977). There was an unexpected increase in leaf IVOMD with decreasing harvest frequency. However stem IVOMD decreased with decreasing harvest frequency, as stems became more woody.

Table 1. Annual total dry matter yield (t/ha) (average of 2 years) of *Desmanthus* accessions on phosphatic clay mine-spoil at 3 harvest frequencies.

Harvests per year	Accession[2]			Mean
	1854	1857	Bundleflower	
1	53.2aA[1]	37.1aA	7.1bB	32.5
2	26.5bA	28.1abA	23.8aA	26.2
3	17.7bA	14.5bA	16.0abA	16.0
Mean	32.5	26.6	15.6	

[1]Values in columns followed by the same lower case letter and values in rows followed by the same upper case letter are not different ($P>0.05$, Duncan's Multiple Range Test). Accession x harvest frequency interaction ($P<0.05$).
[2]*Desmanthus virgatus* IRFL 1854, IRFL 1857 and *D. illinoensis* cv. Sabine Illinois bundleflower.

Table 2. Leaf/stem ratio of *Desmanthus* herbage grown on phosphatic clay mine-spoil at 3 harvest frequencies.

Harvests per year	Accession			Mean
	1854	1857	Bundleflower	
		1989		
1	0.10cA[1]	0.17cA	0.00cB	0.09
2	0.57bB	0.66bAB	0.81bA	0.68
3	1.11aB	1.15aB	1.59aA	1.28
Mean	0.60	0.66	0.80	
		1990		
1	0.09bA	0.08bA	0.00cB	0.06
2	0.70aA	0.50aA	0.50bA	0.57
3	0.61aA	0.69aA	0.87aA	0.72
Mean	0.47	0.42	0.46	

[1]Values in columns for each year followed by the same lower case letter or in rows followed by the same upper case letter are not different ($P>0.05$, Duncan's Multiple Range Test). Year x accession x harvest frequency interaction ($P<0.05$).

Table 3. Crude protein concentration (%) in leaf and stem of *Desmanthus* accessions grown on phosphatic clay mine-spoil in 1989 at 3 harvest frequencies.

Harvests per year	Accession							
	1854		1857		Bundleflower		Mean	
	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem
1	20.1b[1]	5.7	20.8a	5.9	—	4.8	20.4[2]	5.4b
2	22.8a	6.4	22.7a	6.5	20.5b	5.7	22.0	6.2b
3	23.4a	8.1	21.8a	7.9	23.0a	7.8	22.7	8.0a
Mean	22.1	6.7	21.8	6.8	21.8	6.1		

[1]Leaf values or stem means in columns followed by the same letter are not different ($P>0.01$, Duncan's Multiple Range Test). Accession x harvest frequency interaction ($P<0.01$) present for leaf crude protein only.
[2]Mean of two only.

Table 4. *In vitro* organic matter digestibility (g/100 g) (average of 2 years) of leaf and stem of *Desmanthus* accessions grown on phosphatic clay mine-spoil at 3 harvest frequencies.

Harvests per year	Accession							
	1854		1857		Bundleflower		Mean	
	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem
1	41.3a[1]	27.0b	37.3a	25.8b	—	16.7c	39.3	23.2
2	36.3b	31.4a	34.9b	27.9b	41.8a	30.0b	37.7	29.8
3	35.3b	35.3a	34.1b	33.8a	39.9a	35.4a	36.4	34.8
Mean	37.6	31.2	35.4	29.2	40.9	27.4		

[1]Values in columns followed by the same letter are not different ($P>0.05$, Duncan's Multiple Range Test). Accession x harvest frequency interaction ($P<0.05$) present for both leaf and stem.

Seed production

No appreciable seed was produced by *D. virgatus* accessions when subjected to 3 harvests per year (Table 5). Accession IRFL 1854 achieved its highest seed production of 379–887 kg/ha from a single harvest. For IRFL 1857, about 707–790 kg/ha of seed was produced with 2 harvests per year and between 369–900 kg/ha with a single harvest. Seed yield of Illinois bundleflower was highest (845–3380 kg/ha) from the 2 harvest per year treatment.

Discussion

Total (leaf + stem) yields obtained from 2 and 3 harvests per year in this study compare favourably with those reported in Hawaii (Skerman 1977). The total DM yield of 16.0 t/ha obtained with 3 harvests per year was better than the yield of 12.5 t/ha obtained earlier at a similar site (Adjei and Pitman 1990). The unusually high yields (37–53 t/ha) obtained with a single annual harvest of *D. virgatus* reflect the excellent fertility and moisture content of colloidal phosphatic clay deposits (Marion 1986) and a good climate during the growth season. Average annual yields of 30.7 and 58.5 t/ha were reported for *Desmodium cinerascens* and *Leucaena leucocephala*, respectively, on a nearby phosphatic clay site (Mislevy *et al.* 1989). The treatment harvested only at the end of the season had a full canopy for light absorption and photosynthesis. However, the highest yielding treatment produced a high proportion of woody stem. With advancing plant maturity, increased total yield but decreased leaf/stem ratio reflects the compromises between quantity and quality that must be made for efficient forage production (Ivins *et al.* 1958). The changes in plant morphology with maturity suggest that *Desmanthus* must be harvested more frequently (at the early to mid-bloom stage) (as obtained with 2 or 3 annual harvests) or even earlier for leafy forage.

Table 5. Seed production (kg/ha) by *Desmanthus* accessions on phosphatic clay mine-spoil at 3 harvest frequencies.

Harvests per year	Accession		
	1854	1857	Bundleflower
		1989	
1	379aA[1]	369bAB	196bB
2	92bB	707aA	845aA
3	0cA	0cA	0cA
		1990	
1	887aA	900aA	45bB
2	80bB	790bB	3380aA
3	0cB	0cB	47bA

[1]Values in columns followed by the same lower case letter or in rows followed by the same upper case letter for each year are not different ($P>0.05$, Duncan's Multiple Range Test). Year x accession and accession x harvest frequency interactions present ($P<0.05$).

Crude protein levels in both leaf and stem are similar to earlier records for *Desmanthus* (Muir and Pitman 1991) and other tropical legumes (Skerman 1977; Adjei and Fianu 1985). However, the low leaf IVOMD obtained from the frequently harvested plants and the increased leaf digestibility with maturity were abnormal (Adjei and Fianu 1985). The abnormal trend in IVOMD may be indicative of the presence of anti-quality factors which tend to decrease with maturity because of dilution with increased growth (Toit *et al.* 1990). Preliminary examination (Adjei and Albrecht 1993) has confirmed that leaves of *Desmanthus* contain tannins (1.5-3.1% of DM). Notwithstanding the presence of tannins, *D. virgatus* exhibited high palatability and was heavily grazed by deer and rabbits in Florida (Pitman *et al.* 1988; Muir and Pitman 1991). Further research may be needed to evaluate *in vivo* digestibility and growth rate in cattle to ascertain the feeding value of *Desmanthus*.

This experiment has demonstrated the potential for *Desmanthus* to produce 8–13 t/ha of edible leafy forage annually, with a crude protein concentration of 20–23%, on the phosphatic clay mine-spoil when clipped 2 or 3 times annually. There is also the possibility of integrating herbage with seed production during the warm season for both species in this subtropical environment.

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