Persistence and productivity of eight accessions of *Desmanthus virgatus* under a range of grazing pressures in subtropical Queensland

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Abstract

The persistence and productivity of 8 accessions of *Desmanthus virgatus* were compared under grazing at 5 levels of presentation yield in subtropical subcoastal Queensland from 1989 to 1996. Presentation yields ranged from approximately 0.5 to 5.0 t/ha as measured at the end of the growing season. Apart from the year of establishment, annual rainfalls were below the average figure of 712 mm. Cultivar Marc and a similar line, CPI 78382, were the most productive at all levels of presentation yield. These lines also maintained a higher plant density than the other lines, although their density fluctuated from year to year. Their persistence is attributed to their ability to set seed under grazing, even in dry years. The lines which flowered late, and required a longer period of favourable soil moisture to seed, set only a small amount of seed. Thus, their density declined steadily as seedling recruitment could not compensate for death of original plants. It is suggested that commercial pastures sown to Jaribu desmanthus, which is a mixture of early-, mid- and late-flowering cultivars, could gradually become dominated by the early-flowering cv. Marc under similar rainfall conditions.

Introduction

Desmanthus virgatus is native to the Americas and the Caribbean, but has naturalised in many tropical and subtropical environments (Burt 1993). It has been used in many countries as a pure legume stand in cut-and-carry systems, but in Queensland has been commercialised primarily for use in legume-grass pastures on clay soils. Three cultivars, which are sold commercially as a mixed line ("Jaribu"), were released in Queensland in 1991. Their selection was based on the results from small plot studies, which often ran for less than 4 years (Cook *et al*. 1993; Clem and Hall 1994; Jones and Clem 1997). However, contrasting lines had not been compared under a range of grazing pressures and very little was known about long-term persistence of desmanthus.

This experiment examined the persistence of 8 accessions of desmanthus, 2 of which are components of "Jaribu", under 5 grazing pressures over a 7-year period.

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Methods

Site and treatments

The experiment was located on clay soils on the Narayen Research Station (25°41′S, 150°52′E) in subcoastal subtropical Queensland. The site, originally a brigalow (*Acacia harpophylla*) forest, was cleared in 1937 and sown to rhodes grass (*Chloris gayana*). From 1968 to 1985, it was part of a long-term grazing study, described by McDonald *et al*. (1995). McDonald *et al.* give further details of land history and soil properties.

Eight accessions of desmanthus (Table 1) were sown into separate plots within each of 5 paddocks. There were 2 replicates of each accession, in a randomised block layout, within each paddock. Paddock sizes ranged from 0.5 to 1.25 ha so that, when grazed by a single animal yearlong, there were 5 stocking rates (0.8, 1.1, 1.4, 1.7, and 2.0 head/ha).

Table 1. A brief description of the accessions of *D. virgatus* sown in the trial.

Accession	Origin	Characteristics
CPI 38351 [1]	Venezuela	Tall, late-flowering
CPI 40071	Brazil	Medium height, mid-flowering
CPI 55719	Venezuela	Tall, late-flowering
cv. Marc (CPI 78373) [2]	Argentina	Short-medium height, ascending, early- and rapid-flowering
CPI 78382	Argentina	Very similar to cv. Marc
CPI 79653	Cuba	Decumbent, mid-flowering
CPI 85178	Mexico	Decumbent/prostrate, short, early-flowering and heavy-seeding
cv. Uman (CPI 92803) [2]	Mexico	Decumbent, long stems, late-flowering

[1] CPI = Commonwealth Plant Introduction Number.

[2] More detailed descriptions of these cultivars are given by Cook *et al*. (1993).

In February 1989, the desmanthus accessions were surface sown at 4 kg/ha into a fully cultivated seedbed, with good subsoil moisture, which was then rolled. All seed was scarified to give approximately 50% germinable seed and inoculated with *Rhizobium* strain CB1397. The companion grasses were rhodes grass cv. Pioneer and green panic (*Panicum maximum* var. *trichoglume*) cv. Petrie, each sown at 2 kg/ha. These grasses were already present, to varying degrees, in the experimental area. Owing to an error when planting, desmanthus in the treatment to be stocked at 1.7 head/ha was sown at twice the correct rate.

Experimental grazing commenced in February 1990, but prior to that all paddocks were periodically grazed in common. It became apparent by August 1990 that the designated range of stocking rates were too low in good conditions and yet could possibly be too high in sustained dry conditions. The treatments were then altered to 5 levels of grazing pressure (GP), based on presentation yield, rather than 5 fixed stocking rates. Although each plot was usually grazed by a single animal, an extra animal was added or the single animal was removed for varying periods so as to achieve the target presentation yields at the end of the growing season. The target yields in late autumn from May 1991 onwards ranged from *ca*. 5000 kg/ha at the lightest grazing pressure (GP1) to *ca*. 500 kg/ha at the highest (GP5). Decisions on the addition of an extra animal or removal of animals were subjective and based on feed on offer, current soil moisture and current and likely pasture growth rates. Animals were replaced each May with yearling heifers of approximately 200 kg liveweight which reached some 350–400 kg by the following May.

Measurements

Seedlings of desmanthus and the sown grasses were counted in April 1989, 6 weeks after the main emergence event. Thereafter, plant density was measured every spring, using a minimum of 10 quadrats (1 m × 0.5 m or 0.5 m × 0.5 m) per plot. Any seedlings which had emerged since the previous winter were counted separately. In 1996, plants were recorded either as being very small and from seedling recruitment the previous May, or as larger and older plants. Yield and botanical composition were estimated every autumn, with the estimated yields corrected using a regression of estimated *vs* actual yields in cut quadrats chosen to cover the range of yields recorded in the field estimations.

Ten fixed quadrat positions of 1.0 m × 0.5 m were marked out in all plots sown to CPI 78382. All original plants were marked in the autumn of the establishment year (1989) and their survival was monitored. Survival of 5 seedling cohorts of CPI 78382 in GP4 was monitored from 1992 to 1994 using the same quadrats.

Soil seed reserves were measured annually from 1990 to 1996 in all plots of the GP4 paddock, taking 30 soil cores of 7 cm diameter and 5 cm depth per plot. The plots sown to cv. Marc and CPI 78382 in the remaining grazing pressures were sampled for seed reserves in spring of 1990, 1992 and 1996 at the same intensity. Seed was recovered using the method described by Jones and Bunch (1988a).

Regular notes were taken of attributes such as vigour, flowering, seeding and damage from native psyllids. When some desmanthus leaves appeared yellow early in the 1995–96 Summer, plants were dug up and the roots washed to check for presence of nodules and topgrowth samples were analysed for N and S. Daily rainfall and terrestrial minimum temperatures were measured approximately 0.5 km from the experimental site.

Results

Rainfall and minimum temperatures

Rainfall was below average in all years except the year of establishment (1989) (Table 2). In 3 of the 7 years from 1990 to 1996, rainfall was less than 475 mm, which is equivalent to decile 2.5 (Cook and Russell 1983). Summer rainfall was also below average in each of these 7 years. Moisture stress during the 1995–96 late summer–autumn was greater than the seasonal totals indicate as there was no effective rain between January 10 and May 1. On average, there were 31 "frosts" each winter (ground temperatures below zero), similar to the long-term average (32.5). The lowest terrestrial temperature in each year, *ca.* –5° C, was also similar to the long-term average (Table 2).

Table 2. Seasonal rainfall data for summer (Dec-Feb), autumn (Mar-May), winter (Jun-Aug) and spring (Sep-Nov) at Narayen, with corresponding long-term averages. Also listed are the total number of occasions when the terrestrial minimum fell below zero and the lowest temperature recorded in each winter. Bold type indicates rainfall below the corresponding long-term average.

Year	Rainfall					Temp < 0.0° C	
	Summer	Autumn	Winter	Spring	Total	No.	Lowest
	(mm)						
1989	359	255	125	**163**	902	40	−5.3
1990	**68**	307	**62**	**143**	**580**	42	−5.5
1991	**181**	**65**	**49**	**62**	**357**	30	−4.7
1992	**258**	**140**	**45**	**126**	**569**	23	−3.8
1993	**201**	**15**	**58**	**160**	**434**	5	−2.0
1994	**230**	**108**	**21**	**83**	**442**	47	−6.5
1995	**201**	**73**	**26**	377	**677**	27	−6.5
1996	**188**	**144**	**34**	171	**537**	35	−6.6
Long term[1]	302	148	101	166	717	33	−4.7

[1] Long-term data from Cook and Russell (1983).

Establishment

Desmanthus and sown grass seedlings emerged in late March and early April 1989. In April, average densities of desmanthus, rhodes and green panic were 10, 8 and 2 seedlings/m^2, respectively. The desmanthus density averaged 8.0 seedlings/m^2 in GP1, GP2, GP3, and GP5 and 15 seedlings/m^2 in GP4, which had been sown at double the intended sowing rate.

Rainfall (>160 mm) in April 1989, after seedling emergence, produced vigorous grass growth while grazing was delayed to avoid excessive pugging and damage to legume seedlings. This resulted in severe competition for the establishing legume seedlings from the vigorous grass.

Yields and grazing pressures

The concept of controlling grazing pressure to achieve a range of presentation yields was introduced in late 1990. However, the actual stocking rates imposed in the first 3 years, calculated on a grazing days/ha/year basis from February 1990 to August 1992, were equivalent to 1.0, 1.3, 1.6, 1.7 and 1.9 head/ha for treatments with the highest to the lowest presentation yields, respectively. These stocking rates were similar to those originally nominated, although some values may be a combination of higher stocking rates during periods of active growth and some destocking during winter. Owing to below average rainfall and the loss of rhodes grass at the higher grazing pressures in 1991, these stocking rates could not be maintained. The calculated stocking rates for the period August 1992 to August 1996, the last 4 years, were lower and with less difference between the treatments; 0.6, 0.6, 0.6, 0.8 and 0.9 head/ha from the highest to the lowest presentation yields.

Total dry matter (DM) yields in autumn of each year and averaged over desmanthus accessions are listed in Table 3. Differences in pasture yield between the 5 grazing pressures were least in the first year of grazing. Although the targeted linear range of presentation yields from 0.5 to 5.0 t/ha was not achieved in every year after 1990, yields at the highest and lowest grazing pressures from 1991 to 1996 averaged 0.7 and 4.7 t/ha, respectively (Table 3).

Table 3. Total dry matter yields in late autumn in paddocks sown to 8 accessions of desmanthus at 5 grazing pressures. The r^2 of the regression between the desired and actual presentation yields is also given, with values in bold type from a quadratic regression where this was significantly better than that from the linear regression.

Desired yield	Actual pasture yield						
	5/90	5/91	5/92	3/93	4/94	4/95	3/96
	(t/ha)						
5.0	4.2	5.7	5.1	4.3	5.5	3.7	3.6
3.9	5.5	4.7	3.2	1.8	6.2	2.9	3.1
2.8	5.8	4.0	0.9	1.3	3.5	1.1	2.3
1.7	2.4	0.3	0.4	0.6	3.5	1.3	1.7
0.5	2.7	<0.1	<0.1	0.4	2.0	0.7	0.8
r^2	ns[1]	0.90	**0.98**	**0.96**	0.82	0.86	0.99

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[1] Not significantly correlated.

Botanical composition

Although all paddocks were originally dominated by rhodes grass, rhodes grass failed to persist beyond 4 years at the higher grazing pressures. By Autumn 1994, the fifth year, the per cent rhodes grass in GP1–GP5 was 63, 60, 5, 0 and 0%, respectively. This did not change appreciably over the next 2 years with the corresponding percentages in 1996 being 61, 43, 11, 0 and 0%. There was only a patchy occurrence of green panic, averaging 5% over all treatments in 1996. In 1996, the percentage of unsown species, mainly *Urochloa panicoides* and *Rhagodia* spp., ranged from 36% in GP1 to >99% in GP5.

The percentage of each desmanthus accession in the pastures from 1990 to 1996, averaged over all grazing pressures, is given in Table 4. Differences between accessions were least in the first year of grazing (1990). After 1990, plots sown to CPI 78382 and cv. Marc had the highest percentage of legume. From 1992 to 1995, they averaged about 10% of yield even though their percentage declined to 3–4% in the final year (1996). In the final two years (1995 and 1996), these lines had the highest legume percentage of all accessions at all 5 grazing pressures.

Table 4. Percentage by weight of 8 accessions of desmanthus in pastures in autumn, averaged over 5 grazing pressures, from 1990 to 1996. The percentage of desmanthus was not estimated in Autumn 1991.

Accession	Year					
	1990	1992	1993	1994	1995	1996
	(%)					
38351	4.4	13.0	2.9	4.0	1.0	0.3
40071	2.1	11.7	3.2	9.1	2.4	1.2
55719	2.6	6.2	1.1	3.1	0.2	0.0
Marc	5.8	19.9	11.5	7.6	7.2	3.0
78382	5.7	18.2	10.6	11.2	10.3	4.0
79653	0.2	4.3	0.0	0.0	0.0	0.0
85178	2.3	16.9	8.2	4.5	1.1	0.7
Uman	0.6	1.6	0.0	0.0	0.0	0.0
LSD (P<0.05)	2.7	6.6	4.8	4.7	4.7	1.1

Desmanthus density

There were significant differences between the densities of the different desmanthus accessions throughout the experiment. The density in GP4, sown at twice the rate of the other grazing pressures, was initially twice that of the other grazing pressures, but there were no accession × grazing pressure interactions. Therefore, only the annual densities of desmanthus accessions, meaned over grazing pressures, are given in Table 5. Marc and CPI 78382, followed by CPI 40071 and CPI 85178, had the highest densities towards the end of the experiment.

The densities of Marc, CPI 85178 and CPI 78382 fluctuated markedly with time, being highest in 1989, 1992, 1994 and 1996. In contrast, the density of the other lines steadily declined.

The large increase in densities in some lines from 1995 to 1996 was due to the high numbers of small plants in October 1996 that resulted from seedling recruitment in May 1996. The density of the older plants in 1996 was similar to that recorded in 1995. The density of these older plants in GP4 had increased to 2.5 times the average density at the remaining grazing pressures.

Table 5. Density of 8 accessions of desmanthus, averaged over all grazing pressures, in Autumn 1989 and in Spring from 1989 to 1996.

Accession	Desmanthus density								
	4/89	'89	'90	'91	'92	'93	'94	'95	'96
	(plants/m^2)								
38351	5.1	1.8	0.6	0.6	0.4	0.2	0.1	0.1	0.2
40071	6.6	1.4	0.7	0.7	0.7	0.8	0.8	0.4	1.1
55719	4.1	1.5	0.5	0.2	0.2	0.0	0.1	0.0	0.0
Marc	7.3	3.6	1.3	2.3	3.6	2.4	3.5	1.4	5.3
78382	4.6	2.5	1.2	1.3	4.8	3.0	6.1	2.2	8.3
79653	3.2	0.6	0.1	0.2	0.1	0.0	0.0	0.0	0.0
85178	3.1	2.7	1.1	2.5	3.2	2.0	4.5	1.4	1.0
Uman	4.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
LSD (P<0.05)	1.9	1.5	0.7	1.2	3.4	1.6	3.1	1.3	5.5

Soil seed reserves

The annual measurements of soil seed reserves in GP4 have been pooled into 3 time periods covering the early, middle and late stages of the experiment (Table 6). In the first 2 years of grazing, seed reserves of Marc were significantly higher than those of all other accessions, except

CPI 78382 and CPI 85178. After this, CPI 78382 and Marc had by far the highest seed reserves. Some of the seed reserves measured in the remaining 5 lines in later years may even have been contamination from isolated invading plants of CPI 78382 and Marc.

Table 6. Soil seed reserves of 8 *D.virgatus* accessions in grazing pressure GP4 as sampled in late winter-spring in 3 time periods (mean of: 1990 and 1991; 1992, 1993 and 1994; and 1995 and 1996 samplings) and seedling densities in May 1996.

Accession	Soil seed reserves			Seedlings
	1990–91	1992–94	1995–96	May 1996
		(seeds/m^2)		(sdlgs/m^2)
38351	86 (1.84)[1]	186 (2.16)	269 (2.32)	0 (0.0)
40071	58(1.70)	738(2.44)	466(2.53)	10 (0.7)
55719	4(0.49)	132(1.91)	84(1.92)	0 (0.0)
Marc	3550(3.48)	7900(3.88)	5430(3.70)	83 (1.9)
78382	344(2.26)	15000(4.16)	11500(3.94)	160 (2.1)
79653	10(0.68)	483(2.24)	121(2.10)	0 (0.0)
85178	798(2.89)	2900(3.34)	1800(3.18)	10 (1.0)
Uman	121(1.85)	280(2.41)	220(2.10)	5 (0.5)
LSD (P<0.05)	(1.29)	(0.84)	(0.82)	(0.9)

[1] Transformed values in brackets are Log(X + 1).

Averaged over the remaining 4 grazing pressures, seed reserves of Marc and CPI 78382 increased from 18 seeds/m^2 in 1989 to 1270/m^2 in 1992 and 3100/m^2 in 1996. There was no significant difference between the seed reserves of these 2 accessions. Seed reserves in GP5 in 1992 (610/m^2) were significantly lower than in the remaining grazing pressures (GP1–GP3, mean 1490/m^2) and the 1996 reserves in GP5 (910/m^2) were significantly lower than the reserves in GP1 and GP2 (mean 5240/m^2).

Seedling/plant survival

Seedlings. Seedling numbers were always higher in lines with the highest seed reserves, as in the example given in Table 6.

Seedling emergence and survival of CPI 78382 in GP4 was monitored for 1 seedling cohort in 1992–93 and 4 cohorts in 1993–94. The numbers of seedlings/m^2 emerging in these 5 cohorts, and their percentage survival to the following spring (given in brackets) were: 13 (0%), 3 (0.2%), 25 (0%), 43 (0%) and 194 (15%). It was this last cohort which contributed to the increased density of CPI 78382 from 1993 to 1994 (Table 5). These measurements and other observations throughout the trial suggested that most seedling cohorts died during dry periods in the growing season during which they emerged.

Plant survival. All CPI 78382 plants which were tagged in spring of the establishment year had died after 6 years. There was a significant linear relationship between time and $\log_{10}$ plant numbers ($r^2 = 0.94$) with a plant half-life of 11 months.

Other observations

Damage from psyllids was noted periodically, but did not appear to be a major limitation. The leaves of desmanthus were usually green. When paler plants were dug up in the 1995–96 Summer, their roots were nodulated with pink nodules. Nitrogen and sulphur concentrations in the terminal 15 cm of shoots collected at the same time were 3.0% N and 0.23% S.

Discussion

The limitations of the experiment will be considered first, followed by an assessment of the desmanthus accessions and finally by some practical considerations for the use of desmanthus.

Experimental considerations

Three factors must be considered when interpreting the results of this experiment.

Firstly, GP 4 was inadvertently sown at twice the sowing rate of the other grazing pressures. This resulted in higher yields and densities of desmanthus at this grazing pressure, but there is no evidence that this affected the relative performance of the different lines. However, desmanthus yield and density in GP4 can not be directly compared with those from the other grazing pressures.

Secondly, following the wet conditions after emergence, insufficient grazing was applied to the pastures during the establishment phase. This probably decreased the survival of desmanthus during the first year. The fixed stocking rates used in 1990, when grass growth was still vigorous because of favourable moisture and mineralised nitrogen, also resulted in pasture being undergrazed. However, changing treatments to levels of presentation yield rather than fixed stocking rates provided a system of grazing which coped well with the variation in growth between high and low rainfall years. This flexibility is likely to be needed more on fertile heavy textured soils, in this instance with some 6% organic matter, than on a light textured soil. Most duplex soils have far lower levels of organic matter, and hence a lower amount of available N for grass growth in years with good rainfall.

The third factor is the almost total death of rhodes grass during dry periods at the 3 higher grazing pressures. This contrasted with the retention of good rhodes grass stands at the 2 lighter grazing pressures, particularly the lowest. This greater death of rhodes grass at higher stocking rates during dry periods has been noted in earlier studies at Narayen (Jones *et al.* 1995). The death of rhodes grass reduced the potential productivity and carrying capacities of the higher grazing pressures (GP3–GP5). This partly explains why, in the last 3 years, the actual stocking rate on the nominally lightest GP1 was similar to GP3.

Assessment of desmanthus

Under the dry conditions experienced, Marc and CPI 78382 were the outstanding accessions in terms of their contribution to the pasture and ability to build up a seed bank and successful seedling recruitment. They usually comprised more than 10% of presentation yield, averaged over all grazing pressures, at the end of the growing season. Their percentage biomass was lower in 1996, but this sampling was carried out in late March after a long dry period and when plants had been well grazed at the higher grazing pressures.

Marc, CPI 78382 and CPI 85178 frequently set seed after single isolated rainfall events and flowered early in the season. The seed reserves of Marc and CPI 78382, of more than 5000 seeds/m^2 in GP4, were similar to those of CPI 78382 measured in small plots at 2 sites in southern inland Queensland by Jones and Rees (1997). They were far higher than the reserves of 150–450 seeds/m^2 of CPI 78382 measured by Burrows and Porter (1993) at Gayndah, Queensland. However, these authors pointed out that the desmanthus growth in their study was limited by severe grass competition. Studies by Brandon *et al.* (1997) have also highlighted possible nutrient deficiencies limiting desmanthus growth at the Gayndah site.

Four accessions (CPI 38351, 55719, 79653 and Uman) set much less seed. These lines, except for CPI 79653, flowered later in the season and seed development was more protracted. They appeared to require a longer period of favourable moisture to flower and set seed. Thus, dry conditions, particularly late in the growing season, were the main factor limiting seed set of these 4 lines, but grazing pressure and frosting could also be involved. Frosting of stems over winter has a particular impact on cv. Uman which flowers so "late" that flowers appear in spring on growth from those old stems that have survived the previous winter. However, late-flowering lines could well set more seed during seasons with longer spells of favourable soil moisture, especially in the second half of the growing season when they flower. CPI 40071 set more seed than these lines but much less seed than CPI 85178, Marc and CPI 78382.

It was only at the highest grazing pressure (GP5), where presentation yield was usually less than 0.5 t/ha towards the end of the growing season, with strong competition from dense *Urochloa panicoides*, that persistence of CPI 78382 and Marc appeared to be reduced through heavy grazing pressure. This was at least partly through reduction of seed set. Observation suggested that cattle selected grass leaf in preference to desmanthus during active growing periods in summer, although desmanthus was grazed, at times quite heavily.

Individual plants of the robust and later-flowering lines such as CPI 38351, CPI 55719 and cv. Bayamo may persist better than the smaller and freer-seeding CPI 78382 and Marc (authors, unpublished data). However, in the absence of recruitment, the plant density of CPI 38351 and CPI 55719 gradually declined to low levels at the end of the trial. In contrast, the fluctuating plant densities of CPI 78382 and Marc showed clear evidence of successful recruitment of new plants. This has also been noted for CPI 78382 by Burrows and Porter (1993) and for Marc by Clem and Hall (1994). Although CPI 78382 usually had higher plant densities and seed reserves than Marc, these differences, measured at one site, were not sufficiently important to suggest replacement of Marc by CPI 78382 in the commercial "Jaribu" composite.

Uman had poorer persistence than the other late-flowering robust types as noted in other adjacent experiments at this site (authors, unpublished data). CPI 85178, despite its ability to set seed, was low-yielding in the later years of the trial, as found elsewhere by Rees *et al.* (1995). CPI 40071 was possibly the most promising line apart from CPI 78382 and cv. Marc, and could be more productive and yet set appreciable amounts of seed given years with less adverse rainfall.

Even though the failure of the later-flowering lines to maintain density relates to the lower seed reserves of these lines, they still had reserves of some hundreds of seeds/m^2 in GP4. Seed reserves of this order can maintain a productive sward of *Macroptilium atropurpureum* (*e.g.* Jones and Bunch 1988b), so why were these lines unable to maintain their density in GP4? There are 2 possible reasons.

The first is that desmanthus is very hard-seeded. Data on the rate of breakdown of hard seed presented by Burrows and Porter (1993) suggest that the half-life for breakdown of hard seed under dense cover is 60–70 months. Thus, it may take some years for a seed input to be reflected in seedling numbers. However, in GP4, there is evidence of seedling recruitment of Marc and CPI 78382 in 1990–91, 2 years after sowing, and of a substantial increase in density from seedling recruitment in the third year after sowing (Table 5).

The second and more important reason relates to the succession of dry years experienced in our study. There was often seedling emergence following isolated rainfall events but, on most occasions, all the seedlings or small plants died due to lack of follow-up rain. The high water holding capacity of the soil (*c.* 25% at 15 atmospheres) meant that, once the soil was air dry, appreciable rainfall was required to give conditions for seedling emergence and survival. The relatively high soil fertility also meant that growth of companion grasses was vigorous during the sporadic periods of favourable moisture and thus was strongly competitive for desmanthus seedlings.

Yellowing or unthriftiness of desmanthus was not a feature of this trial unlike experience at some other sites such as "Brian Pastures" Research Station (Burrows and Porter 1993), where sulphur deficiency has been measured in field and glasshouse studies (Brandon *et al.* 1997). Sulphur levels in desmanthus leaves in this study were above the tentative critical level of 0.2% S (Brandon *et al.* 1997). On the one occasion when some yellowing was observed, nodulation and sulphur did not appear to be limiting.

Practical implications

Desmanthus is sold commercially as a mixture of early-, mid- and late-flowering lines, cvv. Marc, Bayamo and Uman. We did not have Bayamo in this experiment but, in more recent sowings at Narayen, it has shown a limited ability to set seed under low rainfall, similar to CPI 55719 and CPI 38351 in this study. Thus, it is likely that, in years such as we experienced, commercial sowings will drift towards dominance by Marc, which will have far higher seed reserves and plant recruitment, as original plants of the other lines gradually die.

Although Uman has not persisted well at Narayen, it has shown more promise at other sites (authors, unpublished data; R.L. Clem, personal communication) We would not recommend that it be left out of the "Jaribu" composite on the basis of results from one site. Both Uman and Bayamo have higher yield potential than Marc and it could be desirable to keep these lines in the commercial mixture. We suggest that, when these lines are flowering and seeding following favourable conditions, grazing should be controlled to ensure that seeding is not prevented by heavy grazing. Such seed input would not be required every year; once in every 3–4 years may be adequate. Unless pastures were overgrazed, as was the case with GP5, it is unlikely that grazing pressure would have to be reduced to allow cv. Marc to seed.

During the drier years experienced, there was a "trade-off" between pasture yield and seed production — the latter being essential for long-term persistence. There may be a place for a cultivar which can seed more freely than Bayamo or Uman but with greater productivity than Marc.

The final implication relates to grazing management during the establishment phase. Higher grazing pressure should have been maintained when the companion grasses were growing vigorously during the favourable conditions in the establishment phase. However, it is also possible that this could have increased death from pugging, as has been noted by Burrows and Porter (1993).

Acknowledgements

We would like to thank Mr K.F. Gould, Officer-in-Charge, and the staff of the Narayen Research Station for their assistance in establishing and maintaining the experiment. We also thank Mr R.G. Greenfield who took many of the field measurements during the early years of the trial when assistance was also provided by Dr Bruce Pengelly and Mrs Francis Porter. The assistance of Mr C.K. McDonald and Mr G.A. Bunch is also gratefully acknowledged. During the last 4 years, the experiment was part of a joint CSIRO-DPI project partially funded by the Meat Research Corporation.

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(Received for publication April 23, 1997; accepted March 19, 1998)