Growth and persistence of 17 annual medic (*Medicago* spp.) accessions on clay soils in central Queensland

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Abstract

Seventeen accessions of annual medics were evaluated on clay soil sites at Emerald, Theodore, Biloela and Mundubbera, central Queensland. Successful medics could have a role in both permanent and ley pastures. However, these are marginal areas for medics with winter (June–August) rainfalls of 80–100 mm. The accessions were selected on the basis of results in southern Queensland, a more favoured area for medics. There were 9 accessions of *Medicago truncatula* (barrel medic), 4 of *M. scutellata* (snail medic), 2 of *M. polymorpha* (burr medic) and 1 each of *M. aculeata* (keg medic) and *M. orbicularis* (button medic). Lucerne (*M. sativa*) cv. Trifecta was sown at 3 sites. All sites except Theodore were irrigated in the year of establishment (1993). The medic seedlings at Theodore died in 1993 and the trial was resown in 1994. Measurements were made of seed set in the first year and whenever it occurred in later years, seedling density in most years and yield when there was adequate growth. Selected measurements were made of soil seed reserves. Measurements ceased in 1998.

Despite moderate to high levels of seed production in the first year at all sites except Theodore, vegetative yields in subsequent years were very low until 1998 at Mundubbera. This was primarily due to well below average winter rainfall. During 1994–1997, there was no seed set at Mundubbera and only low levels of seed set at Theodore and Biloela. There was no single best line of barrel medic although Paraggio and SA11292 were consistently poorer. *M. orbicularis* SA8460 sometimes yielded as well as the better barrel medics and had the highest seed reserves in all 4 sites at the end of the experiment. At the end of the trial, the density and soil seed reserves of snail medic were low at all sites, with cv. Sava snail medic being as good as or better than the other accessions of snail medic. Lucerne did not persist into the second year at any site. Based on yields and soil seed reserves measured in 1998, the better medic lines showed good promise of persisting in the long term at Biloela and Mundubbera, and possibly Theodore, but their potential at Emerald is lower. The results showed the importance of achieving a substantial seed set in the year of sowing in these marginal subtropical environments with low and unreliable winter rainfall where there can be consecutive years without any seed set.

There is potential for some of the current barrel medic cultivars to persist in marginal medic environments in central Queensland. *M. orbicularis* SA 8460, with its early flowering, high seed set and relatively slow rate of hard seed breakdown, warrants consideration for release so that it could be included as one component of a mixture of annual medics for use in this region.

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Introduction

There are about 15 M ha of clay soils in northern New South Wales and southern-central Queensland which have potential for cropping or sowing improved pastures. Throughout this region there is considerable concern about run-down in total soil nitrogen in cropping systems which is resulting in a decline in wheat yield and quality (Dalal *et al*. 1991). In areas sown to pasture, often after clearing of brigalow (*Acacia harpophylla*), there is a run-down in available nitrogen over time (Myers and Robbins 1991) which results in reduced animal production (Jones *et al.* 1995). One way of overcoming this problem is through the use of legumes, either in leys or permanent pastures. Successful legumes could assist in maintaining soil fertility, improve the yield and quality of cereal crops in rotations and provide higher quality forage for animals (Lloyd *et al.* 1991).

There has been considerable work on the roles of lucerne (*Medicago sativa*) and annual medics (*Medicago* spp.) in northern New South Wales and southern Queensland (Lloyd *et al.* 1991) and 3 lines of snail medic (cvv. Kelson, Essex and Silver) have been released primarily for use in leys in southern Queensland. However, there has been relatively little evaluation of annual medics in central Queensland (defined here as between the Darling Downs and the Tropic of Capricorn). As southern and central Queensland have a summer-dominant rainfall, with decreasing cool season rainfall with lower latitude, there has been extensive evaluation of tropical legumes in this region (*e.g*. Jones and Rees 1996; Pengelly and Conway 1998). In particular, butterfly pea (*Clitoria ternatea*) is showing considerable promise as a tropical ley legume in central Queensland. However, there is still a possibility that medics, with their ability to respond to cool season rainfall, could also play a useful role in this region by enhancing soil N and/or producing high quality feed when companion grasses are slow-growing or frosted.

To evaluate annual medics for their potential to persist in central Queensland, 17 accessions were sown at 4 sites and their persistence monitored from 1993–1998. Lucerne was included as a control.

Materials and methods

Sites and accessions

Four sites were selected in central Queensland covering the geographical area and soil types where medics were likely to be grown. Details of the sites are given in Table 1. Emerald is the most marginal site in terms of rainfall and temperatures. The mean monthly maximum and minimum temperatures at Emerald from May–October are about 1–2°C higher than those at Theodore and Biloela which were in turn about 1–2°C higher than Mundubbera, as illustrated by the September maximum temperatures in Table 1. The 17 accessions of annual medic sown (Table 3) comprised 9 accessions of *Medicago truncatula* (barrel medic), 4 of *M. scutellata* (snail medic), 2 of *M. polymorpha* (burr medic) and 1 each of *M. aculeata* (keg medic) and *M. orbicularis* (button medic). They included some commercial cultivars and the other accessions were included on the basis of their performance in southern Queensland (D.L. Lloyd and E.J. Weston, personal communication), with

Table 1. Details and properties of the 4 experimental sites.

Site details	Site			
	Mundubbera	Biloela	Theodore	Emerald
Location	Narayen Res. Stn	“Roann”, Jambin	Brigalow Res. Stn	Emerald Res. Stn
Latitude	25° 41’ S	24° 10’ S	24° 50’ S	23°28’ S
Longitude	150° 52’ E	150° 23’ E	149° 46’ E	148° 09’ E
Mean annual rainfall (mm)	707	696	677	637
% rainfall in winter[1]	15	14	14	13
Mean winter rainfall (mm)	106	97	95	84
Mean Sep max. temp (°C)	25.1	27.0	26.5	28.3
Soil type[2]	Dr4.1	Ug5.15	Ug5.16	Ug5.12
Topsoil texture	clay loam	silty medium clay	light–medium clay	medium–heavy clay
Soil depth (cm)	80	>150	>150	70
Topsoil (0-10 cm) pH	7.1	7.0	8.1	7.3
Former vegetation	brigalow	brigalow	brigalow	open treeless downs

[1] Winter = (June–August).
[2] Soil type as described by Northcote (1977).

particular importance given to aphid resistance, early maturity and ability to set large quantities of seed under moisture-limiting conditions. Lucerne (cv. Trifecta) was also sown at Mundubbera, Biloela and Emerald. There were 3 replicates in a randomised block design.

All accessions were sown into cultivated soil at Theodore on May 6, 1993, Emerald on June 17, 1993, Biloela on June 15, 1993 and Mundubbera on June 9, 1993. Seed was inoculated with Group A *Rhizobium* and hand broadcast on to the soil surface at a rate of 10 kg/ha. The surface of the soil was then lightly harrowed or rolled to cover the seed with a thin layer of soil, except at Emerald where irrigation was applied immediately after sowing without any soil disturbance. All sites except Theodore were then irrigated to enable establishment but no irrigation was applied thereafter. The sowing at Theodore failed and it was resown on April 22, 1994. Plots were 16 m^2 at Emerald and Theodore, 9 m^2 at Biloela and 4 m^2 at Mundubbera; the small plot size at Mundubbera was due to the limited irrigation facilities.

No fertiliser was applied at any site. The following companion grasses were sown with the medics at 4 kg/ha: rhodes grass (*Chloris gayana*) at Mundubbera, resown in 1994; sabi grass (*Urochloa mosambicensis*) at Biloela; buffel grass (*Cenchrus ciliaris*) at Theodore; and native Queensland blue grass (*Dichanthium sericeum*) at Emerald. The trials were intermittently grazed by cattle during the warmer months, except for the Emerald site that was not grazed but slashed once or twice a year. The sites were not sprayed for control of aphids.

Data collection and analysis

Seedling density at all sites was measured following emergence in the year of sowing, using 4 quadrats of 0.5 m^2 or 0.25 m^2 in each plot or, where density was very high, 4 quadrats of 0.04 m^2. Seedling recruitment in major emergence events was measured in subsequent years. In this environment, with heavy soils and irregular and low cool season rainfall, there are few major seedling emergence events of medics in each year, sometimes only 1.

Yield of medics in 1993 at Mundubbera, Biloela and Emerald, and in 1998 at Mundubbera only, was measured by harvesting all medic in a 0.25 m^2 quadrat that was considered to be representative of the whole plot. Where there was sufficient growth on other occasions, herbage yield was rated visually on a 1–9 scale. After top-growth had senesced in the year of sowing, the number of pods was counted at all 4 sites in a representative quadrat of 0.25 m^2 or 0.04 m^2 depending on pod density. Similar measurements were made at Biloela and Theodore in 1995, the only instances of further seed set. Seed from a random sample of 30 pods from each plot was counted so that seed number/m^2 could be calculated. Similar measurements were made from 3 of the most productive lines at Mundubbera at the end of the 1998 growing season.

Soil samples of 0–5 cm depth were taken in June–July 1996 at Mundubbera, Biloela and Theodore for measurement of medic soil seed reserves of 5 accessions (listed in Table 5), using 15 cores of 7 cm diameter per plot at Mundubbera and 12 cores of 4.4 cm diameter at the other sites. Further samples were taken in June–July 1998, sampling all plots at Mundubbera and Biloela — except those sown to lucerne — and a restricted range of only 6–7 accessions (listed in Table 5) at Theodore and Emerald. Thus, it was possible to relate seed set in 1993–1995 to soil seed reserves in 1998 and to seedling emergence from 1994–1998.

Results

Rainfall

June–September rainfall in 1993 at Mundubbera, Biloela and Emerald was close to or above average (Table 2) but, based on the failure of the non-irrigated sowing at Theodore, we believe there would probably have been poor establishment, growth and seed set without the use of supplementary irrigation. June–September rainfall at Theodore was only 99 mm in 1994, the year of resowing, but was enough to ensure limited establishment and seed set. June–September rainfall was, with 1 exception, below average at the 4 sites in every year from 1994–1997. Rainfall in 1998, after most measurements had ceased, was above average.

Associated vegetation

There was little grass at the Mundubbera site and the main associated species were climbing saltbush (*Rhagodia nutans*) and *R. linifolia* in summer and peppercress (*Lepidium bonariense*) in the cooler months. The site was well grazed each year. In contrast, the Emerald site was dominated by Queensland blue grass which formed a dense sward. The Theodore site was eventually dominated by blue grass, with some buffel grass, and the Biloela site by *Bothriochloa bladhii* and sabi grass. However, as the Theodore and Biloela sites were regularly grazed, the grass was not as dense and competitive as that at Emerald.

Dry matter yields

In the first year, with the aid of irrigation, the dry matter yields of the higher yielding accessions exceeded 3000 kg/ha at Mundubbera and Biloela and 1000 kg/ha at Emerald (Table 3). Yields were very low thereafter until 1998 when the better accessions yielded over 2000 kg/ha at Mundubbera. There was no consistent ranking in the yields of the better barrel medic accessions at

Table 2. Cool season rainfall (June–September) at 4 sites from 1993–1998 with corresponding long-term averages.

Year	Site			
	Mundubbera	Biloela	Theodore	Emerald
	(mm)			
1993	118	153	124[1]	152
1994	27	23	99	1
1995	55	55	47	40
1996	75	220[2]	101	78
1997	67	73	29	28
1998	201	180	145	314
Long-term average	134	128	133	106

[1] 62% of this rainfall fell in September after most medic seedlings had died.
[2] 72% of this fell in September after most medic seedlings had died.

Table 3. DM yields of 17 annual *Medicago* accessions and of lucerne measured or rated [using a 1 (lowest) –9 (highest) scale] at Munduberra (Mu), Biloela (Bi), Theodore (Th) and Emerald (Em) from 1993–1998.

Species	Accession	Site and year						
		Mu ’93	Mu ’98	Bi ’93	Bi ’95	Bi ’96	Th ’95	Em ’93
		(kg/ha)	(kg/ha)	(kg/ha)	(1–9)	(1–9)	(1–9)	(kg/ha)
M. aculeata	SA 8944[1]	1910	T[2]	3530	3	2	1	530
M. orbicularis	SA 8460	1750	1750	2250	2	7	4	1290
M. polymorpha	Circle Valley	4170	540	1770	4	6	2	290
M. polymorpha	Santiago	680	250	1550	3	6	3	430
M. scutellata	Kelson	1300	0	3320	4	2	3	920
M. scutellata	Sava	2670	30	4280	8	8	8	1450
M. scutellata	SA1868 (Silver)[4]	1370	T	3140	7	6	7	580
M. scutellata	SA3310 (Essex)	1630	T	2470	6	2	3	550
M. truncatula	Caliph	2800	2520	3800	5	8	2	1460
M. truncatula	Cyprus	3360	1730	2320	4	6	3	750
M. truncatula	Jemalong	3160	1010	2110	4	7	2	890
M. truncatula	Parabinga	4620	3370	2950	5	5	3	790
M. truncatula	Paraggio	2100	40	2390	2	4	2	1050
M. truncatula	Sephi	2800	480	3530	4	7	2	650
M. truncatula	SA 11292	270	T	1900	2	2	2	220
M. truncatula	Z 274	3130	2000	3510	4	7	1	610
M. truncatula	Z 914[1,5]	1900	540	1160	3	6	1	830
M. sativa	Trifecta	1530	0	630	2	1	na[3]	310
LSD (P<0.05)		1330	1010	2280	2	3	2	360

[1] SA= South Australian Department of Agriculture; and Z = a bred line from that organisation.
[2] T= trace, <10 kg/ha.
[3] na = not applicable.
[4] Snail medics SA1868 and 3310 have been released as cvv. Silver and Essex but are not yet registered as such (E.J. Weston, pers.com.).
[5] Z 914 has the provisional cultivar name of cv. Jester.

Mundubbera in 1998 and Biloela in 1995 and 1996 although cv. Paraggio and SA 11292 were the lowest at both sites. By 1998, yields of all snail medic accessions were negligible at Mundubbera whereas yields of button medic SA 8460 were similar to the best barrel medics and better than the 2 accessions of burr medic. Aphid populations were usually negligible and would not have affected plant growth or development. The worst damage from aphids was at Emerald in 1993, particularly on *M. truncatula* Z 274 and SA 11292.

Plant density

Establishment in the year of sowing was highest at Biloela (range 29–313 seedlings/m^2) and Emerald (31–261 seedlings/m^2), followed by Mundubbera (10–147 seedlings/m^2) and Theodore (1–45 seedlings/m^2) (Table 4). In 1998, there were 6 accessions at Mundubbera and 7 accessions at Biloela with a seedling density >50 seedlings/m^2. There were no snail medic or burr medic accessions in this group at either site. In contrast, seedling densities at Theodore and Emerald were very low, with the best accession having 6 seedlings/m^2. There had also been consistently higher seedling numbers at Mundubbera and Biloela during 1994–1997, with 10 accessions at Mundubbera and 9 at Biloela having an annual emergence of over 100 seedlings/m^2 (Table 4). Lucerne did not persist into the second year at any site.

Seed set and soil seed

Seed set in the first year was highest at Mundubbera and Biloela with 9 accessions at Mundubbera and 8 accessions at Biloela setting more than 5000 seeds/m^2 (Table 5). Seed set was much lower at Emerald, except for button medic, although plant densities were similar to or higher than those at Mundubbera and Biloela. Seed set was far lower at Theodore. Seed set of snail medics at Emerald was reduced by pod-boring insects, including the green vegetable bug (*Nezara viridula*). The poor seed set at Theodore is attributed to dry conditions, unlike Emerald where the experiment was adequately irrigated and had above average rainfall. Snail medic set less seed per plant than barrel, button or burr medic.

Seed set between 1994 and 1997 was infrequent and was much lower than in the year of sowing (1993). More seed was set by Sava snail medic than by any of the barrel medic accessions (Table 5).

The levels of soil seed in 1998 were very low at both Theodore and Emerald, although button medic had the highest levels at both sites. Button medic also had the highest seed reserves at Mundubbera and Biloela. Soil seed reserves of all snail medic accessions were negligible at Mundubbera and lower than most of the barrel or burr medic accessions at Biloela.

Based only on those accessions with seed yields of over 10 000/m^2 in 1993 (to reduce errors in calculations based on small numbers), seed reserves of button medic SA 8460 persisted for longer than seed reserves of barrel medic. At Biloela, 22% of the (1993+1995) seed set of button medic was still present as a soil seed bank in 1998, contrasting with a range of 1–10% for the remaining 5 accessions in this category. At Mundubbera, 8% of the 1993 seed set remained as a soil seed reserve in 1998, contrasting with 1–3% for the 6 other accessions in this category. Seedling emergence in 1998 expressed as a percentage of (1998 soil seed reserves + 1998 seedlings) also gives an indication of the hardseededness of the 1998 seed bank. At Mundubbera, only 5% of the button medic seed reserve in autumn 1998 emerged as seedlings in that year compared with 17–71% for the barrel medics. Corresponding values for Biloela were 1% compared with 4–25%. Furthermore, allowing for 1994–1998 seedling emergence and 1998 soil seed reserves, only 71% of the 1993 seed set of button medic was unaccounted for at Munduberra compared with 78–85% for 6 accessions of barrel medic. Corresponding figures at Biloela were 59% for button medic compared with 77–92%.

Following the good rains at Mundubbera in 1998, 3 of the most promising lines, Cyprus, button medic and Parabinga, set between 40 000–60 000 seeds/m^2 (data not presented).

Discussion

The failure of lucerne to persist into the second year at the Mundubbera site is atypical (R.M. Jones, unpublished data) and is largely attributed to low rainfall in the year of sowing.. However, lucerne usually persists for only 2 years or less in most central Queensland soils (M.J. Conway, unpublished data).

At both Mundubbera and Biloela, button medic, the 2 burr medics and most of the barrel

Table 4. Plant density of 17 accessions of annual *Medicago* spp. and lucerne in the year of sowing (1993 at 3 sites and 1994 at Theodore), average density per year for the next 4 years (1994–1997) at 3 sites and 3 years (1995–1997) at Theodore, and for the final year (1998) at all sites.

Species	Accession	Mundubbera			Biloela			Theodore			Emerald		
		93	94–97	98	93	94–97	98	94	95–97	98	93	96	98
		(plants/m^2)											
M. aculeata	SA 8944	23	28	3	137	17	5	12	1	1	114	0	0
M. orbicularis	SA 8460	24	116	74	313	131	65	23	6	6	275	29	0
M. polymorpha	Circle Valley	70	801	23	205	130	11	45	20	1	214	0	0
M. polymorpha	Santiago	20	159	9	89	208	11	43	12	2	125	T	0
M. scutellata	Kelson	10	6	0	79	12	2	12	2	T[2]	51	0	0
M. scutellata	Sava	14	23	T	79	156	4	12	29	2	54	0	0
M. scutellata	SA 1868 (Silver)	12	12	0	36	120	13	4	14	2	49	0	0
M. scutellata	SA 3310 (Essex)	13	21	T	66	45	3	11	1	1	49	0	0
M. truncatula	Caliph	54	273	78	99	245	87	1	1	1	236	5	5
M. truncatula	Cyprus	77	799	154	160	278	80	15	6	4	200	1	T
M. truncatula	Jemalong	71	295	70	55	90	68	18	2	3	154	0	0
M. truncatula	Parabinga	57	619	92	70	285	100	18	6	5	223	3	1
M. truncatula	Paraggio	49	59	6	93	19	20	19	2	T	127	0	0
M. truncatula	Sephi	39	201	29	125	97	40	22	9	3	169	T	0
M. truncatula	SA 11292	10	10	2	67	12	8	21	2	0	31	0	0
M. truncatula	Z 274	147	778	187	158	180	79	10	1	T	261	0	0
M. truncatula	Z 914	46	137	13	29	75	50	5	4	1	217	0	0
M. sativa	Trifecta	48	0	0	201	13	0	na[1]	na	na	45	0	0
LSD ($P<0.05$)		27	225	83	141	126	73	10	10.7	3	87	20	ns[3]

[1] na = not applicable.
[2] T = trace (<0.5/m^2).
[3] ns = not significantly different at P = 0.05.

Table 5. Seed set (ss) of annual medics at Mundubbera and Emerald in 1993, Biloela in 1993 and 1995 and Theodore in 1994 and 1995 with soil seed reserves (sr) as measured in 1996 and 1998.

	Accession	Mundubbera			Biloela				Theodore				Emerald	
		93 ss	96 sr	98 sr	93 ss	95 ss	96 sr	98 sr	94 ss	95 ss	96 sr	98 sr	93 ss	98 sr
								(seeds/m^2)						
M. aculeata	SA 8944	1110	–[1]	30	530	0	–	60	5	0	–	–	0	–
M. orbicularis	SA 8460	17700	1680	1440	24420	500	9600	5520	60	130	30	50	8790	130
M. polymorpha	Circle Valley	21920	1420	680	13580	0	570	1470	350	0	50	0	330	20
M. polymorpha	Santiago	6500	–	300	21800	0	–	1740	540	5	–	–	1790	–
M. scutellata	Kelson	125	–	–	270	70	–	20	20	10	–	–	30	–
M. scutellata	Sava	675	60	10	5490	370	130	330	60	210	175	20	1310	0
M. scutellata	SA 1868 (Silver)	435	–	0	4770	120	–	350	50	90	–	–	60	–
M. scutellata	SA 3310 (Essex)	410	–	10	1580	0	–	390	10	10	–	–	0	–
M. truncatula	Caliph	11860	–	290	13840	30	–	1320	5	0	–	–	2070	40
M. truncatula	Cyprus	20720	2920	490	8490	20	1250	860	80	0	0	0	580	50
M. truncatula	Jemalong	11260	–	300	2670	0	–	1540	10	0	–	–	50	–
M. truncatula	Parabinga	17970	–	420	22100	0	–	1500	190	5	–	20	360	40
M. truncatula	Paraggio	1970	300	20	1480	10	50	200	0	0	0	0	0	0
M. truncatula	Sephi	6630	–	100	2970	0	–	730	10	0	–	–	10	–
M. truncatula	SA 11292	80	–	0	80	10	–	60	0	0	–	–	0	–
M. truncatula	T 116/Z 274	18920	–	350	14800	150	–	220	5	0	–	–	240	–
M. truncatula	Z 914	410	–	130	1820	0	–	310	10	–	–	–	20	–
M. sativa	Trifecta	0	–	–	0	0	–	0	na[2]	na	–	–	0	–
LSD (P<0.05)		1060	1500	500	1460	ns[3]	430	1220	335	80	160	ns	1760	ns

[1] – = not measured.
[2] na = not applicable.
[3] ns = not significantly different at P = 0.05.

medic accessions were able to persist through 5 years, in the sense that they had over 500 seeds/m^2 present in the soil at the start of the 1998 winter, although they had set no seed at Mundubbera since 1993 and only a small amount at Biloela. Previous evidence for successful long-term persistence of Jemalong barrel medic at the Narayen Research Station near Mundubbera had been documented by Heida and Jones (1988) who recovered almost 15 000 seeds from the soil seed bank in 1985 from a pasture that had been sown in 1976. Jemalong is still a useful component of this pasture in 1998 and Cyprus is also persisting at Narayen from sowings made 10 years earlier (R.M. Jones, unpublished data). Cyprus and Jemalong were 2 of the best 3 accessions in earlier testing in marginal areas of southern Queensland (Clarkson 1986). Thus, once an adequate seed set has been achieved, the prospects for sustaining well adapted medics in the long term at Mundubbera and Biloela are good. However, results at Emerald and Theodore were less promising.

At Emerald, only 4 early-flowering accessions (button medic, Santiago, Caliph and Sava) set more than 1000 seeds/m^2 in the year of sowing. The poorer seed set of the later-flowering accessions is not attributed to moisture stress as rainfall was above average and extra irrigation was applied. It could be due to higher temperatures during flowering and seed set at this site (Table 1). The poor seed set could also be partly attributed to insect predation. The dense grass sward at Emerald would also have reduced medic establishment, growth and seed set in subsequent years.

The poor results at Theodore emphasise the importance of obtaining a good seed set in the first year. Given a seed set of 10 000 seeds/m^2, as occurred at Mundubbera and Biloela, there is more likelihood of retaining an effective seed bank after a number of years without further seeding than with the initial seed set of *ca*. 100 seeds/m^2 as occurred at Theodore. We consider that the very low seedling numbers and soil seed reserves at Theodore in 1998 largely reflect the poor set in the first year, rather than the site being substantially less favourable for medics.

The sequence of 4 years (1994–1997) of below average winter rainfall was ideal for evaluating the ability of annual medics to persist in permanent pastures in subtropical central Queensland. It is highly desirable for accessions to experience these adverse conditions to see if they can maintain their seed banks through several years when there is no further seed set.

Further investigations of factors affecting seed set by medics in very marginal areas close to the tropics, such as Emerald, may provide further understanding of their adaptation. Average winter maximum and minimum temperatures in central Queensland are some 2–4°C higher than in areas of southern Queensland where medics are well adapted (Clewett *et al.* 1999). Higher temperatures would exacerbate soil moisture stress and in addition could potentially affect medic development and seed set. This effect is additional to the lower winter rainfall than in the recognised medic areas where the average June–August rainfall of 110–120 mm is about 20 mm higher than equivalent averages at Biloela, Theodore and Emerald. Clarkson *et al*. (1991) also drew attention to the impact of heat during seed set of medics in marginal areas.

Of those accessions that set large amounts of seed at Mundubbera and Biloela in 1993, only button medic SA 8460 had a markedly better retention of soil seed reserves. Lloyd *et al.* (1997) have also shown that this accession had a far slower breakdown rate of hard seed than did 18 other accessions in a 3-year field experiment in south-east Queensland or under fluctuating temperatures in laboratory conditions. SA 8460 also set more seed than any of the barrel medic accessions under the very marginal conditions experienced at Biloela and Theodore in 1995. This line, with its early flowering, heavy seeding and relatively slow breakdown rate of hard seed, warrants consideration for release for sowing with a mixture of medic cultivars. Given years with favourable rainfall, it is unlikely to yield as well as the better barrel medics with the same seedling density but may have much greater ability to maintain a seed bank through consecutive years of low rainfall.

There was no consistent ranking of the better barrel medics at Mundubbera and Biloela in terms of yield or seed bank retention. Because of the high variability in cool season rainfall in this region, we recommend sowing a mixture of barrel medic cultivars, such as the shorter season Caliph and longer season Parabinga.

The proportion of initial seed set which was unaccounted for as either seedlings or residual soil seed was higher than usually recorded in experiments where seed is set or buried under more controlled conditions and/or more regular measurements made of seedling emergence (Hagon 1974; Lloyd *et al.* 1997). However, we consider it is unlikely that there were major seedling emergence events which were not recorded and the evidence points to a greater loss of seed than usually occurs in more favoured environments. Because of the complex pattern of seed softening in medics, which is affected by factors such as accession, depth of burial, rainfall and soil temperature (Taylor and Ewing 1992; Lloyd *et al*. 1997), we have not attempted to relate hard seed breakdown of the different accessions to environmental conditions.

None of the newer snail medic cultivars was superior to the early-flowering Sava in this study, although different rainfall patterns could have favoured the mid-flowering Silver and Essex or the late-flowering Kelson. Kelson may not be suited to central Queensland due to the higher temperatures it would encounter during flowering. Dry matter yields of snail medic at Mundubbera in 1998 were very low, confirming that snail medic, although a useful species in ley pastures in Queensland (Lloyd *et al.* 1997), does not persist adequately in permanent pastures.

In our experiment, we achieved a good initial seed set by using irrigation at 3 of the 4 sites. However, this is not practical in the vast majority of commercial situations where, at best, medics will be sown into a dry soil surface of a prepared seedbed with good subsoil moisture carried over from summer rains. Even if this is done, there will be years when it will not be possible to achieve good growth and seed set in the first year in these environments, as occurred at Theodore. If the medics are sown with oats, the problems of moisture stress will be exacerbated. Thus, although this study has shown that medics can persist in the more subtropical sections of central Queensland, it remains to be seen whether the input into establishing them is justified. Another potential problem is that the need for close grazing over summer to aid medic establishment in autumn-winter is in conflict with the general farm requirement to carry over feed, produced in summer and autumn, for winter and spring grazing.

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