AGRONOMIC VARIATION IN *MEDICAGO SCUTELLATA* AND *M. ORBICULARIS* IN SOUTH-EASTERN QUEENSLAND

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ABSTRACT

The variation in hardseededness, phenology, dry matter yield and nitrogen fixation capacity of a total of 29 introductions of snail medic was studied in a series of experiments.

Considerable variation was found in the degree of hardseededness between introductions. The degree of hardseededness was greater at the distal end of the pod.

The time from germination to specified developmental stages also varied greatly between introductions, with the time to flowering varying from 49 to 111 days. Plant yield was highly correlated with time to flowering under glasshouse conditions, but not in the field. Many introductions had greater yields than commercial snail medic under field conditions and differences in seasonality of growth were indicated.

The mean apparent nitrogen fixation by five snail medics and one button medic in the glasshouse during a 128-day growth period was equivalent to 200 kg N ha^{-1}, of which 25% was associated with the root/soil fraction. A highly significant positive relationship was obtained between dry matter production and apparent nitrogen fixation.

INTRODUCTION

Annual *Medicago* species commonly grown on the eastern Darling Downs in Queensland include *M. polymorpha* (burr medic), *M. truncatula* var. *truncatula*, cultivars Jemalong and Cyprus (barrel medics), and *M. scutellata* (snail medic). These species exhibit reasonable persistence in sown and native pastures in the cooler, inland sub-tropics of Queensland where the mean winter rainfall (April-September, inclusive) exceeds about 210 mm. Loader (1974) has outlined the advantages of using annual winter medic species as fodder crops in preference to forage oats and the advantages of snail medic compared to other annual *Medicago* species.

Barrel medics, however, have consistently outyielded snail medic (Russell, 1969; Jones and Rees, 1972; Mackenzie and Glasby, pers. com.) although a peak yield of 8400 kg ha^{-1} year^{-1} has been recorded for snail medic swards following a summer fallow (Jones and McLeod, 1971).

Nursery observations of a number of snail medic introductions on a black earth soil at Cambooya (Loader, pers. com.) indicated that there was considerable variation in time of flowering, growth habit, growth periodicity and yield amongst these accessions. Such variability may allow selection of lines that outyield commercial snail medic, as well as lines which are better adapted to specific environments, and thus extend the area of usefulness of snail medic.

This paper describes some preliminary studies on germination behaviour, phenology, dry matter production and nitrogen fixation of a number of accessions of snail medic.

MATERIALS AND METHODS

Germination studies

A study of the degree of hardseededness of snail medic accessions was prompted by variable germination from pods planted in the field. The seed of all 26 accessions reported in Table 1 had been stored at ambient room temperatures since collection from nursery rows in the field in the previous year.

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The germination procedure adopted was to place seeds in Petri dishes at a constant 23°C for 7 days. Seeds which failed to show any signs of imbibition in this time were deemed hardseeded. The testas of these seeds were then pricked and the germination of both categories was followed for a further 23 days. In experiments 1 and 2, which examined variability in hardseededness and the effect of seed age on the degree of hardseededness, respectively, samples of 100 seeds were used; whilst in experiments 3 and 4, which examined the relationship between seed position within the pod and hardseededness, respectively, samples of 50 seed pods were used. In these latter experiments seed positions within the pod were numbered with reference to the calyx end of the pod.

Phenology

Ten seeds of 19 introductions of snail medic and one introduction of button medic were planted in plastic lined pots which contained 1320 g (oven-dry weight) of a black clay soil. Seeds, inoculated with *Rhizobium*, were planted on June 18, 1970 and the first two seeds which germinated were retained for recording the time to reach thirteen pre-defined developmental stages from cotyledon emergence to cessation of flowering under glasshouse conditions.

Plant tops were harvested on October 20 (128 days from cotyledon emergence), oven-dried at 80°C for 48 hours, weighed and the nitrogen content (including seed pods) analysed using a micro-Kjeldahl digestion and automated indophenol blue colorimetric procedure.

Nitrogen fixation

Following the harvest of plant tops in the phenological study, the soil (including roots) in which five snail medics (N243, Q9156, PE507, CPI12620 and CPI28398) and one button medic (CPI14530) had grown, together with six pots in which plants had not grown but had otherwise received identical treatment, were air-dried and ground to pass a 1 mm mesh sieve. Total soil nitrogen, including nitrate nitrogen, was determined by the method of Bremner (1965). The difference in total soil nitrogen between the planted and unplanted soils thus provided an estimate of nitrogen fixed by the plant which remained in the root/soil fraction.

Field growth

Whole pods of 19 introductions were planted in 30 cm rows with 15 cm spacings within rows in 4.65 m^2 unreplicated plots on a moderately acid Ruthven clay loam (Thompson and Beckmann, 1959) at Toowoomba. A basal fertilizer application of 500 kg ha^{-1} superphosphate, 125 kg ha^{-1} muriate of potash and 1250 kg ha^{-1} of lime was applied prior to planting. Peat *Rhizobium* inoculum was mixed with the seed pods at planting on May 9, 1968.

Plots were irrigated to prevent water stress. Swards were not defoliated during the study but 0.36 m^2 areas were random sampled monthly, from July to October inclusive.

RESULTS

Germination studies

In experiment 1, hardseededness varied between 40 and 96% (Table 1), with only 38% of all accessions having less than 80% hardseededness. In addition, the level of hardseededness recorded in the laboratory was significantly related ($r = 0.685$, $P < .001$) to the percentage of pods which produced a plant in the field experiment.

Where commercial snail medic seed was stored under ambient room conditions for a further year (experiment 2) the level of hardseededness decreased from 80 to 8% whilst seed viability decreased from 100 to 91%. This resulted in an increase in the germination percentage from 20 to 83%. In experiment 3, where seed was left in the pod, germination depended on its position in the pod. The proportion of hard seeds in commercial snail medic increased from 64 to 95% from the calyx to the

TABLE 1

The viability and hardseededness of one-year-old seed of a number of snail medic accessions

Introduction number*	% Germination	% Hard seed	% Non-viable
Commercial	20	80	—
SA617	23	77	—
SA776	24	72	4
WARI5278 (syn. SA655)	13	87	—
WARI5279 (syn. SA656)	13	87	—
Hely 30	19	80	1
PE506	29	71	—
PE507	27	73	—
Q9156	17	83	—
Q9157	36	64	—
N242	44	56	—
N243	7	93	—
N320	60	40	—
CPI12509	26	74	—
,, 12620	4	96	—
,, 12659	10	90	—
,, 12859	2	96	2
,, 13911	33	67	—
,, 15330	17	83	—
,, 26119	14	86	—
,, 26121	1	95	4
,, 26123	4	94	2
,, 26126	19	79	2
,, 26130	8	92	—
,, 28397	11	89	—
,, 28398	16	84	—
Mean	19·1	80·3	0·6

*C.P.I.—Commonwealth Plant Introduction
S.A. —South Australia
Hely —Collection of Mr. F. Hely
Q —Queensland
N —University of Western Australia
PE —Prefix not known—obtained from C.S.I.R.O. Div. Trop. Crops and Pastures.

distal end of the pod (Table 2a). There were however a large number of 'soft' seeds whose radicles failed to emerge from the pods and later deteriorated; the saturated state of the pods may have prevented radicle elongation. Seeds separated from the pod (experiment 4) showed the same trend in hardseededness as those within the pod (Table 2b). Less reliance can be placed on the degree of hardseededness obtained for seed positions 5 and 6 because of the smaller sample size.

Phenology

Considerable phenological variation occurred between accessions of button and snail medics (Table 3). Less variation occurred between cotyledon emergence and first branching (34 to 46 days) than from cotyledon emergence to flowering (49 to 111 days). Most accessions completed the phase from flowering to pod formation within one to three weeks. Two accessions, N243 and CPI12620, however, took 32 and 42 days respectively. The classification of flowering time under glasshouse conditions (Table 3) agrees generally with observations recorded under field conditions (Table 5).

Under glasshouse conditions total plant yield per pot (Table 3) varied considerably between accessions but was very highly significantly related ($r = 0.793$, $P < .001$) to time to first flower. At the time of harvest negligible leaf senescence had occurred in any accessions and thus it was apparent that most of the accessions which

TABLE 2

Effect of position of seed within seedpod on hardseededness in commercial snail medic

(a) *Seeds left in pods*

Seed position*	% Emergent seedlings	% Non-emergent seedlings	% Germination	% Hard seed
1	18·6	17·6	36·2	63·8
2	5·2	23·7	28·9	71·1
3	1·0	12·6	13·6	86·4
4	—	17·1	17·1	82·9
5†	—	4·9	4·9	95·1
6†	—	5·6	5·5	94·5

(b) *Seeds removed from pods*

Seed position*	% Germination	% Hard seed
1	37·2	62·8
2	27·5	72·5
3	24·0	76·0
4	20·4	79·6
5†	28·1	71·9
6†	25·0	75·0

*Counted from calyx end of pod.
†A 5th and 6th seed occurred in only 63% and 8% of pods, respectively.

TABLE 3

Time (days) from cotyledon emergence to branch initiation, flowering and seedpod formation and yield and crude protein concentration of plant tops harvested after 128 days, for accessions of snail and button medics

	Country of origin	First branching	First flower	First seed pod	Flowering classification	DM yield (g/pot)	% Crude protein
M. scutellata							
PE507		36	83	102	M†	19·5	12·4
Commercial		34	58	72	E	14·3	9·8
WARI5278	Crete	38	50	73	E	8·2	9·5
WARI5279	Crete	38	50	71	E	11·8	9·7
HELY30		34	111	*	L	19·3	12·8
HELY33		45	103	122	L	17·8	10·7
Q9156		38	49	66	E	11·2	9·5
Q9157	Malta	34	61	73	E	14·3	9·9
SA617		40	59	73	E	11·2	9·9
SA776		42	61	73	E	11·8	10·6
N242		38	49	66	E	14·7	9·5
N243		36	92	124	L	18·0	10·3
N245		34	97	122	L	18·8	11·5
N320		35	56	73	E	16·0	10·5
CPI12205		38	103	117	L	—	—
CPI12620	Israel	44	79	121	M	18·1	9·8
CPI12659	Cyprus	41	54	65	E	11·2	9·3
CPI15330	Israel	40	75	87	M	12·0	8·8
CPI28398		40	75	82	M	16·0	10·4
M. orbicularis							
CPI14530	Tunisia	33	108	124	L	19·3	8·8

*Seed pods not formed by October 20
†Accessions classified as early (E), mid (M) and late (L) flowering types.

were later flowering than commercial snail medic produced considerably higher dry matter yields.

The crude protein content of whole tops (including pods) harvested in late October varied from 8.8 to 12.8% and was significantly related to time of first flower ($r = 0.698$, $P < .001$).

Nitrogen fixation

The mean dry matter yield of medics in pots after 128 days was equivalent to 9325 kg ha^{-1}. Their presence increased the total soil nitrogen concentration from 0.097 to 0.104%, an increase of 52 kg ha^{-1} (Table 4). This added to the 152 kg ha^{-1} of nitrogen in plant tops gave an apparent nitrogen fixation of 204 kg ha^{-1}. There was

TABLE 4

Apparent nitrogen fixation by five snail medics and one button medic during a 128-day growth period

	% total soil N (oven dry basis)	Total soil N (mg pot^{-1})	Δ Soil N* (mg pot^{-1})	Plant N (mg pot^{-1})	Total apparent N fixation (mg pot^{-1})†
Mean unplanted	0·0970	1280			
Q9156	0·1011	1335	55	170	225
N243	0·1063	1403	123	295	418
PE507	0·1030	1360	80	386	466
CPI12620	0·1019	1345	65	284	349
CPI28398	0·1053	1390	110	267	377
CPI14530	0·1071	1414	134	270	404
Mean planted	0·1041	1375	95	279	373

*Difference in soil N in pots containing medic plants compared to mean of fallow pots.
†Total apparent N fixation = Δ Soil N + Plant N.

a highly significant linear relationship between dry matter yield of tops and total apparent nitrogen fixation ($r = 0.916$, $P < .01$), but no significant relationship between the distribution of this nitrogen between shoot and root/soil fractions ($r = 0.225$, n.s.).

Field growth

The growth of all accessions was slow for the three months following germination in May (0.5 and 4.3 kg DM ha^{-1} day^{-1} for May-July and July-August periods, respectively) and high growth rates were not recorded until the September-October period (123 kg DM ha^{-1} day^{-1}) (Table 5). The mean dry matter yield at the final

TABLE 5

The cumulative dry matter yield (kg ha^{-1}) of 19 snail medic introductions on four occasions during a 154-day growth period in the field.

Introduction	Country of origin	Time of harvest				Flowering classification
		10.vii	12.viii	12.ix	10.x	
Commercial		25	141	598	3187	E
SA617		11	162	713	3663	E
SA776		28	19	724	2467	E-M
WARI5278	Crete	34	151	902	7000	E
WARI5279	Crete	15	53	590	3573	E
HELY30		12	34	320	7193	L
PE506		39	127	1288	2166	E
PE507		26	61	1396	5434	E
N242		33	292	1760	4720	E-M
N320		43	354	1866	5681	E-M
Q9156		25	188	903	3839	E-M
Q9157	Malta	41	288	2702	8975	E-M
CPI12509	Spain	25	223	531	3198	M
CPI12659	Cyprus	23	139	1189	1871	E
CPI13911	Cyprus	14	210	633	5713	E-M
CPI15330	Israel	17	24	786	2734	E
CPI26119	Italy	37	243	195	3302	L
CPI26126	Turkey	67	309	416	4075	L
CPI26130	Crete	38	223	674	4660	E-M
Mean		29	171	957	4392	

harvest in October was 4390 kg ha^{-1}. Some differences in seasonality of growth were apparent amongst accessions and a number of accessions greatly out-yielded commercial snail medic.

Differences in time of first flowering were apparent and were generally consistent with flowering categories obtained in the glasshouse experiment. Sward yields however, did not appear to be closely related to flowering time in contrast to that found for plant yield in the phenological study. Five of the six accessions which produced the highest dry matter yields (*viz.* WARI5278, PE507, N320, Q9156, and CPI13911) were early to mid-flowering types, and were therefore only slightly later flowering than common snail medic, and only one (Hely 30) was a late flowering type.

DISCUSSION

It is evident that within snail medic introductions there exists considerable variability in time of flowering when grown in the southern Queensland environment. Crawford (1975), in South Australia, also found a number of accessions which were earlier flowering and earlier maturing than commercial snail medic. Potentially this characteristic may provide a greater suitability of snail medic to areas of lower winter rainfall. In the glasshouse study the earliest line flowered on July 30, and the latest on October 5 from a planting on June 18. The respective daylengths (sunrise to sunset) at these dates were 10.7 and 12.1 hours. Amongst those lines where the country of origin is known, it appears that mid- and late-flowering lines come from more northerly latitudes (Portugal, Spain, Italy and Turkey) whilst the early flowering lines come from the islands of Malta, Crete and Cyprus. Introductions from Israel, however, exhibit a fairly wide range of flowering time.

The differences in flowering time also raise interesting questions in relation to the findings of Clarkson and Russell (1975), who concluded that time to flowering in common snail medic was relatively unaffected by vernalization and photoperiod. However, as their shortest photoperiod was a variable 12 hours, this could have precluded the definition of a minimum critical photoperiod. It seems necessary to resolve (i) whether differences in flowering time between snail medic lines are basically due to differences in a critical minimum photoperiod requirement and (ii) whether the range in flowering times observed for introduction from Israel indicates that for some lines flowering might be differentially accelerated by mean daily temperature or vernalization duration.

A consistent regenerative ability is an important requirement in annual species, particularly in a semi-arid environment. This depends not only on consistent seed set but also on seed survival. The considerable variation in hardseededness amongst introductions in this experiment points to the need to examine the variation in hardseededness under more controlled conditions of maturation and storage to establish the inherent degree of variation between accessions. Crawford (1975) believes that annual *Medicago* species should have less than 80% hard seed by mid-April to ensure consistent, high density populations. Only 38% of the accessions examined met this requirement under the conditions of storage utilized.

The finding that the degree of hardseededness is dependent on the position of formation of a seed within the seedpod is consistent with the results of McComb and Andrews (1974) who found that within a number of annual *Medicago* species, seeds softened first at the calyx end of the seedpod.

A third important consideration in leguminous species is their ability to fix atmospheric nitrogen. In southern Queensland, Russell (1969) found that Jemalong barrel medic yielded 35 kg N ha^{-1} yr^{-1} in tops in a semi-arid environment whilst Jones and McLeod (1971) recorded a mean nitrogen yield at mid-seeding of 172 kg N ha^{-1} in a snail medic sward following a previous summer fallow. In the present study where the nitrogen associated with the root fraction was measured, a mean apparent nitrogen fixation of 204 kg N ha^{-1} was obtained, of which 25% remained in the soil. This level of fixation was comparable with that indicated in Jones and McLeod's (1971) study for commercial snail medic grown under field conditions. In addition, it is indicated that introductions which produce the highest yields of dry matter also fix the greatest amount of atmospheric nitrogen, but in contrast to the findings of Watson (1963) and Watson and Lapins (1964) where there was a constant proportionality between the nitrogen yield of tops of subterranean clover and increase in total soil nitrogen, there was considerable variability in this relationship between snail medic lines. The lower nitrogen concentration in early flowering accessions at harvest was probably due to their later phenological stage at this time. Jones and McLeod (1971) found that in commercial snail medic there was a steady decline in nitrogen concentration throughout the reproductive phase whilst maximum nitrogen yield was at mid-seeding, prior to mature pod fall.

In the field trial, although a number of introductions greatly outyielded commercial snail medic during the spring and there was some indication of differences in seasonality of growth, all introductions had very low growth rates during winter. In South Australia, Crawford (1975) found that 19 out of 68 introductions showed greater winter production than commercial snail medic. The results in this unreplicated trial suggest that further field evaluation is necessary to establish the significance and consistency of yield advantages indicated for a number of the introductions, compared with commercial snail medic. In addition, it seems necessary to resolve the different results obtained in the glasshouse and the field, with respect to the association between time of flowering and total annual dry matter yield.

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REFERENCES

BREMNER, J. M. (1965)—Total nitrogen. *In:* "Methods of soil analysis. Part 2. Chemical and microbiological properties", C. A. Black (ed.). *Agronomy Monograph* No. 9: 1149 (American Society Agronomy: Madison).

CLARKSON, N. M., and RUSSELL, J. S. (1975)—Flowering responses to vernalization and photoperiod in annual medics (*Medicago* sp.). *Australian Journal of Agricultural Research* **26**: 831.

CRAWFORD, E. J. (1975)—Data bank and genetic conservation in annual species of the genus *Medicago* L. *Australian Plant Introduction Review* **10**(3): 11.

JONES, R. M., and MCLEOD, M. N. (1971)—Changes in nutritive value throughout the growth cycle of snail medic (*Medicago scutellata*). *Journal of Australian Institute of Agricultural Science* **37**: 63.

JONES, R. M., and REES, M. C. (1972)—Persistence and productivity of pasture species at three localities in subcoastal south east Queensland. *Tropical Grasslands* **6**: 119.

LOADER, L. R. (1974)—Medics as fodder crops on eastern Downs. *Queensland Agricultural Journal* **100**: 607.

MCCOMB, J. A., and ANDREWS, R. (1974)—Sequential softening of hard seeds in burrs of annual medics. *Australian Journal of Experimental Agriculture and Animal Husbandry* **14**: 68.

RUSSELL, J. S. (1969)—Evaluation of temperate legumes on a solodic soil and a gilgaied clay soil in the southern brigalow region. *Tropical Grasslands* **3**: 123.

THOMPSON, C. H., and BECKMANN, G. G. (1959)—Soils and land use in the Toowoomba area, Darling Downs, Queensland. C.S.I.R.O. Soils Land Use Series No. 28.

WATSON, E. R. (1963)—The influence of subterranean clover pastures on soil fertility. I. Short-term effects. *Australian Journal of Agricultural Research* **14:** 796.
WATSON, E. R., and LAPINS, P. (1964)—The influence of subterranean clover pastures on soil fertility. II. The effects of certain management systems. *Australian Journal of Agricultural Research* **15:** 885.

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