THE INFLUENCE OF FLOWERING TIME AND GROWTH HABIT ON THE PERFORMANCE OF TOWNSVILLE STYLO (*STYLOSANTHES HUMILIS*) IN TROPICAL AND SUB-TROPICAL QUEENSLAND

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ABSTRACT

Eighteen lines of Townsville stylo differing in flowering time and growth habit were compared in small sward experiments at five sites in Queensland (Normanton (17°42′*S*, 141°05′*E*), *Parada* (17°08′*S*, 145°15′*E*), *Mackay* (21°09′*S*, 149°09′*E*), *Rodds Bay* (24°*S*, 151°30′*E*), *and Eskdale* (27°07′*S*, 152°12′*E*)) *over two or three years.*

The main findings of this study were:—

(1) *At the three tropical sites, dry matter yields of lines differed significantly at each harvest. Earlier flowering lines performed relatively well at two of these sites where the seed production of later flowering lines was reduced by severe plant moisture stress during March of the first growing season. Flowering time also influenced yields directly with later flowering lines being more responsive to high yielding environments than the early lines. Lines with erect growth habit were generally higher yielding than the prostrate lines, particularly in the presence of associated grass and weed species.*

(2) *At the subtropical sites, yields differed significantly for only one of the five site/year combinations and the general yield response of lines across all site/year combinations was similar. In the third growing season all lines produced dense swards at Rodds Bay but failed to regenerate at Eskdale.*

The general adaptation of Townsville stylo in Queensland is discussed and recommendations given for the use of three cultivars in tropical and subtropical areas.

INTRODUCTION

The distribution of the annual legume Townsville stylo (*Stylosanthes humilis*) in Queensland encompasses a considerable latitudinal and annual rainfall range (12–28°S and 500–300 mm respectively). Agronomic studies of Townsville stylo near Townsville (lat. 19°40′S) showed that flowering time and growth habit had important effects on dry matter production (Cameron 1967*c*). When soil moisture was not limiting, late flowering lines continued vegetative growth towards the end of the growing season while early lines were flowering and seeding. Lines with erect growth habit had the highest yields and seemed to compete better with sown grasses than prostrate lines. In this paper these studies of the agronomic importance of flowering time and growth habit have been extended to other sites representative of regions of Queensland suitable for the development of Townsville stylo pastures.

MATERIALS AND METHODS

Sites

Small sward experiments were sown at five sites (Table 1). Three were located in the 17–21°S latitudinal range which includes most of the areas of naturalized Townsville stylo in Queensland. The fourth site at Rodds Bay in central Queensland is close

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to the southern limit for successful development of Townsville stylo pastures while the fifth site at Eskdale was chosen to test for adaptation to south-east Queensland where there had been little success with commercial sowings.

Townsville stylo lines

The 18 lines (Tables 3 and 4) for the present experiments comprised 13 lines selected for high dry matter yield from the set of 34 lines grown at Townsville (Cameron 1967*c*) together with three previously untested lines and two unselected bulk populations (Carpentaria A and Katherine). Limited seed supplies restricted representation of the lines to 15 at Rodd's Bay and Eskdale, 12 at Parada, 11 at Mackay and 10 at Normanton. Eight lines were common to all sites.

Design and Management

Plots of 4 m × 5 m (Rodds Bay and Eskdale) or 4 m × 4 m were arranged in a randomized block design with three replicates. The experimental area was clean cultivated and fertilized to correct known nutrient deficiencies (see Table 1) and the plots were sown with 28 kg ha^{-1} of Townsville stylo pods and 2.2 kg ha^{-1} of Rhodes grass during the 1965/6 summer. No companion grass was sown at the Normanton site because problems of access during the wet season meant that control of grass growth would have been difficult or impossible. The hard seed content of the Townsville stylo pods had been reduced (and germination enhanced) by a heat treatment of one month in an oven set at 60°C (Cameron 1967*a*). To simulate the lenient grazing which is common commercial practice in dry areas, swards were usually not harvested until the end of the growing season. However, at Mackay the swards were cut once during the growing season in each year to reduce dominance of the legume by associated species. At each harvest, two quadrats (1 m × 0.4 m) in each plot were cut with hand shears to ground level. Harvested material was sorted into Townsville stylo and other species, dried for 24 hours and weighed. After harvesting, plots were mown at a height of 5–7 cm and raked off. Pod yields were measured at Parada on July 11, 1966 in samples of plant material and ground sweepings taken from a 1 m × 0.4 m quadrat in each plot. Cleaned pod samples were air dried and weighed.

Details of mean annual rainfall, soil type, fertilizer application, sowing and harvest dates are given in Table 1.

Statistical Analyses

Harvest cuts were taken in 1966 and 1967 at all sites and also in 1968 at Rodds Bay. Individual analyses of variance for dry matter yields were performed for each site/year combination. Eight Townsville stylo lines were grown at all sites and the adaptation of this group was examined by regression analysis (Eberhart and Russell 1966) of Townsville stylo line yield on an environmental index. This index was derived for each site/year combination as (mean yield of Townsville stylo lines) — (grand mean yield of Townsville stylo lines over all site/year combinations). A combined analysis was performed for all sites and years and separate analyses were performed for the three tropical sites (Normanton, Parada and Mackay) and the two subtropical sites (Rodds Bay and Eskdale). For these analyses a square root transformation was used to reduce the heterogeneity of variances between sites and years. The individual site/year combinations were regarded as separate and independent environments since the correlations of residuals between years were not statistically significant.

RESULTS

Normanton

Monthly rainfall at all sites during the experiment is presented in Table 2. After 40 mm of rain on December 12, 1965 there was good germination and establishment of Townsville stylo but very little regeneration of native species which consequently made little contribution to total yields at harvest. Plants were experiencing severe

TABLE 1

Site characteristics and experimental details

		Normanton (17°42'S, 141°05'E)	Parada (17°08'S, 145°15'E)	Mackay (21°09'S, 149°09'E)	Rodds Bay (24°S, 151°30'E)	Eskdale (27°07'S, 152°12'E)
Mean annual rainfall (mm)		930	710	1700	840	890
Soil type		Grey earth (Gn2·94) on quartzose sediments	Coarse sand (Ucl) on alluvium	Solodic (Dy3·43) on alluvium	Prairie-like (Dy3·22) on dioritic igneous rock	Solodic/podzolic (Dy5·42) on granodiorite
1965/6	Fertilizer	250 kg ha^{-1} Mo super, 375 kg ha^{-1} super	250 kg ha^{-1} Mo super	Nil	250 kg ha^{-1} Mo super, 125 kg ha^{-1} K Cl	250 kg ha^{-1} super
	Sowing	November 26	December 23	December 29	January 31	February 2
	Harvest	March 18	March 15	March 7, June 14	May 24	May 10
1966/7	Fertilizer	125 kg ha^{-1} super	125 kg ha^{-1} Mo super	Nil	Nil	125 kg ha^{-1} super
	Harvest	February 24	May 8	March 13	March 21	May 11
1967/8	Fertilizer	—*	—	—	125 kg ha^{-1} Mo super, 62 kg ha^{-1} K Cl	—
	Harvest	—	—	—	March 14	—

*Experiment terminated at this site.

moisture stress at the harvest on March 18 and did not make any further growth. In the second growing season dense seedling populations established in the plots of Dayboro, Carpentaria A and Greenvale but very few seedlings established in the plots of the other lines. Presumably this reflected poor seed set resulting from the severe moisture stresses encountered by the midseason and later flowering lines prior to flowering and seeding in the first growing season. Rainfall distribution was extremely sporadic during the 1966/7 growing season with four successive drought periods of 3–6 weeks duration between the end of September and early February.

In the first season dry matter yields of Carpentaria A and the erect lines (with the exception of Giru) were clearly superior to the prostrate lines Abingdon and Bloomsbury (Table 3). In the second season Carpentaria A and the erect early lines Greenvale and Dayboro gave high yields. The density of the midseason and later flowering lines did not improve during this second season. Although swards of the prostrate line, Carpentaria A, were clearly prostrate at the Parada and Mackay sites, all plots of this line at Normanton were erect in habit in both growing seasons.

Parada

Good germination of Rhodes grass and all Townsville stylo lines followed rainfall of 26 mm on January 1, 1966 but the grass seedlings suffered from a severe attack by Lawn army worm (*Spodoptera mauritia*) on January 20 leaving an almost pure stand of Townsville stylo. Severe moisture stress was evident at the harvest on March 15 and no further growth occurred. Following a 20 mm storm on November 8, 1966 only small numbers of seedlings established in the plots of the late flowering lines, Gordon and Torilla, but dense stands established in all other plots. Two successive drought periods caused severe seedling mortality in the dense stands but thereafter no visible symptoms of plant moisture stress were observed from early January through to the harvest on May 8, 1967. In this second season, Rhodes grass derived from a few surviving plants became the dominant component in some plots at the harvest.

The prostrate growth habit was clearly expressed in all four prostrate lines and within each maturity group the erect lines gave the highest yields. Differences in dry matter yield between the maturity groups were small in the first season (Table 3) but the pod yields of 40 and 70 kg ha^{-1} for Torilla and Gordon, respectively, were very low compared with the range of 800–1700 kg ha^{-1} for the other lines, reflecting the effects of severe moisture stress on reproductive development of the two former lines. In the second season, the yield advantage for the erect lines was even more pronounced with the plots of the early and midseason prostrate lines being dominated by the Rhodes grass component. Although plant growth was not limited by moisture stress after the rain in early January the low density of the late flowering Darwin line limited its yield potential and highest yields were obtained from erect midseason and late midseason lines.

Mackay

In both years rainfall was well distributed throughout the growing season and no plant moisture stress was observed. In the first season germination occurred in mid-January and in the second season in early November. Establishment of Rhodes grass was poor but there was substantial growth of nut grass (*Cyperus rotundus*) and other weeds.

At the first harvest in 1966 the erect lines (with the exception of Giru and Carpentaria B) were superior to the prostrate lines with no differences between the maturity groups. At the second harvest the early maturity lines were generally lower yielding. Highest yields were produced by the erect cultivars Gordon and Lawson. At the March harvest in the second season the erect, early lines Dayboro and Greenvale gave the highest yields, but following post-harvest mowing there was negligible regrowth by any line and there was no second harvest. Fisher (1973) has since shown that close cutting causes severe plant mortality in pure stands of Townsville stylo which are not defoliated until 13 weeks after germination. The combination of greater competition from

TABLE 2

Monthly rainfall totals during the course of the experiments at five sites

Locality	Year	Rainfall (mm) July	August	September	October	November	December	January	February	March	April	May	June
Normanton	1965/6	—*	—	—	—	10	92	230	157	30	4	4	0
	1966/7	0	0	60	6	118	98	112	136	—	—	—	—
Parada	1965/6	—	—	—	—	—	71	205	82	19	12	2	3
	1966/7	0	2	0	11	48	20	91	194	504	7	5	—
Mackay	1965/6	—	—	—	—	—	190	244	105	66	124	58	9
	1966/7	45	55	15	42	81	65	199	161	221	53	105	—
Rodds Bay	1965/6	—	—	—	—	—	—	87	90	33	37	18	60
	1966/7	18	74	13	19	137	21	123	25	103	38	78	224
	1967/8	12	29	0	51	75	138	123	461	179	80	—	—
Eskdale	1965/6	—	—	—	—	—	—	45	70	59	87	0	64
	1966/7	12	114	30	61	59	74	145	105	146	36	51	—

* — = Rainfall outside experimental period.

TABLE 3

Dry matter yields of Townsville stylo lines at three tropical sites

Townsville Stylo Line	Maturity type	Growth Habit	D. M. Yield (kg ha^{-1}) Normanton 1966	Normanton 1967	Parada 1966	Parada 1967	Mackay 1966	Mackay 1967
Abingdon	Early	Prostrate	1440	1320	3470	1670	2230	1260
Carpentaria A	Early	Prostrate	2810	3100	3670	1470	—*	—
Greenvale	Early	Erect	2220	2800	5220	4990	3720	2410
Dayboro	Early	Erect	2650	2840	4890	5520	3850	2720
Bloomsbury	Mid-season	Prostrate	790	800	2900	1600	1690	1090
cv. Lawson	Mid-season	Erect	2150	1140	4830	7740	5130	1360
Carpentaria B	Mid-season	Erect	—	—	4050	7640	3030	1200
Katherine	Mid & Late Mid	Erect	2760	1480	4590	6530	3950	1560
Coen	Late Mid-season	Erect	2100	640	3620	4950	4500	940
Giru	Late Mid-season	Erect	1310	830	4410	6590	2340	1530
Torilla	Late	Prostrate	—	—	2040	2650	2040	870
cv. Gordon	Late	Erect	1760	980	4590	4550	5300	1180
	L.S.D. ($P < 0\cdot05$)		1000	1460	1430	3110	1120	710

* — = not grown at this site.

associated species in the second year and a 17 (second year) versus 8 week (first year) interval from germination to midseason harvest may explain the different responses of the first and second year swards to the midseason cut.

Rodds Bay

Dry conditions early in the season delayed land preparation and the experiment was not sown until January 31, 1966. As a result yields in the first year were low and not significantly different ($P > 0.05$). There was a slight trend, however, towards higher yields for later flowering lines (Table 4). Rhodes grass dominance of the sward in the second season was favoured by effective rainfall in June and August, 1966 and good opening rains in November followed by a dry December. No trends were evident in Townsville stylo yields in the second season. To prevent Rhodes grass dominance in the third season the plots were continuously grazed from November, 1967 to February 3, 1968 and then slashed at 10 cm. At the harvest on March 14 the swards were Townsville stylo dominant but there were no significant differences in yield between the lines.

Eskdale

Sowing at this site was also delayed until early February, 1966 resulting in low yields of Townsville stylo in the first season with no significant differences between lines (Table 4). Early rains in September/October 1966 were supplemented by follow-up rains which promoted good growth of both the Townsville stylo and Rhodes grass components of the sward. Variation both within and between plots was very high at the second year harvest with some lines producing very low yields. Significant yield differences were measured with the Greenvale line being outstanding but there was no association between growth habit or maturity type and yield. In spite of the substantial yields produced by some lines in this second year, none of the lines re-established during 1967/8 indicating that the general adaptation of these 15 lines to the Eskdale environment was no better than that of a commercial seed line of the species which had failed to persist in an earlier species evaluation experiment at this site ('t Mannetje 1967).

General Adaptation

In the regression analysis of the eight lines over all sites the Bloomsbury line showed a much poorer yield response to improved environment than the other lines but no clear patterns could be discerned in the remaining lines. However, the separate analyses for the tropical and subtropical sites revealed distinct response patterns for the tropical sites and the regressions for these separate analyses are presented in Figure 1. Line mean yields, regression and correlation coefficients and the stability index of Eberhart and Russell (1966), s^2_d (= deviations from regression mean square — pooled error mean square), are presented in Table 5.

Tropical Sites

Differences between overall line means ($P < 0.001$) and between regression coefficients ($P < 0.01$) were highly significant for the six tropical site/year combinations. Three general groups may readily be distinguished among the eight lines (Figure 1(a)). Bloomsbury shows a very slight yield response to improved environment, while Dayboro and Greenvale give the best yields in low yielding environments but are not as responsive to higher yielding environments as the remaining group of later flowering lines. While the midseason cultivar Lawson was the most outstanding line for the higher yielding environments of this study, none of the environments favoured expression of maximum yield potential by cv. Gordon (viz. good conditions for seed set followed by a long growing season with only moderate competition from associated species). Highest values for s^2_d were obtained with Bloomsbury and Giru but s^2_d was significantly greater than the pooled error ($P < 0.05$) for Giru only.

Subtropical Sites

There were highly significant differences between line means ($P < 0.001$) but the low values for Bloomsbury and cv. Lawson and the high value for Greenvale were

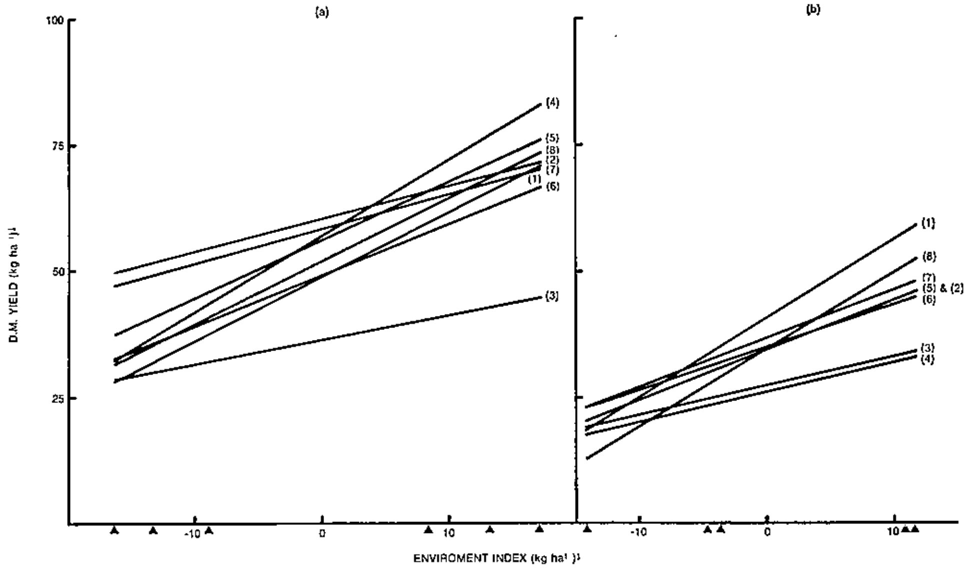

FIGURE 1

Regressions of Townsville stylo yield (square root transforms) on the environment index for eight lines at (a) Tropical sites, (b) Sub-tropical sites. Greenvale (1), Dayboro (2), Bloomsbury (3), Calbraith (4), Katherine (5), Coen (6), Giru (7), Darwin (8). Value of environment index for each site/year combination indicated by △.

attributable to the yield values obtained at Eskdale in 1967. In view of the high within and between plots variation observed at this harvest, and the failure of all lines at this site in the following season, these apparent differences in mean yield should be treated with caution. Differences between regression coefficients were not statistically significant, indicating an overall similarity of response by these lines to improved environment at the subtropical sites. s^2_d values were significantly greater than the pooled error for all lines except Dayboro and Coen.

DISCUSSION

The results for the three tropical sites support the earlier studies on the natural distribution pattern and dry matter production of Townsville stylo lines (Cameron 1967*c*). Early onset of plant moisture stress in March 1966 at both Normanton and Parada resulted in low seed production of late flowering lines. As a consequence seedling regeneration of these lines was poor in the following growing season. This poor seed production of late lines when the growing season is short is consistent with the pattern found in the natural distribution where late flowering populations were confined to areas with annual rainfall in excess of 1100 mm. The regression analysis for the tropical sites shows clearly that erect midseason and later flowering lines are more responsive to high yielding environments than are the early lines. Similar results were obtained by Ive and Fisher (1974) at Katherine, Northern Territory, Edye and Cameron (1975) at sites near Townsville and in Cape York Peninsula and Cameron and McCown (1977) at Weipa.

No relationship between flowering time and yield could be discerned at the two subtropical sites, and the regression analysis suggests a similar yield response for all lines in the subtropical environments. With the greater reliability of autumn rainfall at these sites (Coaldrake 1964) the seed production of later flowering lines was not

TABLE 4

Dry matter yields of Townsville stylo lines at two sub-tropical sites

Townsville Stylo Line	Maturity Type	Growth Habit	D. M. Yield (kg ha⁻¹) Rodds Bay 1966	Rodds Bay 1967	Rodds Bay 1968	Eskdale 1966	Eskdale 1967
Heathfield	Early	Prostrate	1040	690	2410	720	1040
Rodds Bay A	Early	Prostrate	1010	870	2720	800	2010
Greenvale	Early	Erect	960	560	2130	940	5500
Dayboro	Early	Erect	550	600	1970	950	3110
Takilberan	Early	Erect	720	740	2080	620	3580
Bloomsbury	Mid-season	Prostrate	820	390	2630	940	220
cv. Lawson	Mid-season	Erect	470	330	1790	790	550
Lower Wonga	Mid-season	Erect	1180	450	2150	950	600
Rodds Bay B	Mid-season	Erect	1300	790	1960	880	520
Katherine	Mid & Late Mid	Erect	1120	260	1600	1170	2500
Daly River	Late Mid-season	Erect	1220	540	2260	890	3430
Coen	Late Mid-season	Erect	1350	470	2250	910	1720
Giru	Late Mid-season	Erect	1540	660	2230	540	2670
Torilla	Late	Prostrate	1470	510	2000	1050	2720
cv. Gordon	Late	Erect	940	280	1980	939	3510
L.S.D. ($P < 0 \cdot 05$)			N.S.	N.S.	N.S.	N.S.	2310

TABLE 5

Performance characteristics of eight lines in tropical and subtropical environments (Analysis on square root transforms; for each line, regression and correlation coefficients relate individual site/year yields to an environment index calculated for each site/year combination).

Line	Tropical environments: Mean yield† (kg ha⁻¹)	b‡	r‡	$s^2{}_d$‡	Sub-tropical environments: Mean yield (kg ha⁻¹)	b	r	$s^2{}_d$
Greenvale	3410 (58·4)	0·69	0·93**	—0·16	1640 (40·5)	1·57	0·85	12·04***
Dayboro	3630 (60·3)	0·65	0·96**	—1·03	1160 (34·0)	1·00	0·92*	1·45
Bloomsbury	1330 (36·4)	0·48	0·74	2·17	740 (27·2)	0·59	0·45	17·52***
cv. Lawson	3250 (57·0)	1·50	0·98***	—0·07	680 (26·1)	0·61	0·70	4·46**
Katherine	3160 (56·2)	1·15	0·97**	—0·23	1150 (33·9)	1·02	0·91*	1·86*
Coen	2420 (49·1)	1·01	0·92**	1·97	1210 (34·7)	0·85	0·94*	0·49
Giru	2420 (49·1)	1·27	0·93**	3·35*	1350 (36·7)	0·97	0·87	2·97**
cv. Gordon	2700 (52·0)	1·25	0·96**	1·25	1290 (35·9)	1·38	0·94*	2·46*
L.S.D. ($P < 0 \cdot 05$)	(3·0)	0·52			(6·6)	N.S.		

†Back transformed data; square root transforms in parenthesis.
‡b = regression coefficient, r = correlation coefficient, $s^2{}_d$ = deviations from regression mean square—pooled error mean square.
$*P < 0 \cdot 05$; $**P < 0 \cdot 01$; $***P < 0 \cdot 001$.

restricted by severe plant moisture stress. Factors which might also have acted to reduce potential yield differences between maturity types are the lower day and night temperatures during April and May and the delayed flowering of earlier maturity types at these subtropical sites (Cameron 1976*b*).

Growth habit

Although more erect than prostrate lines were included in the site comparisons, the proportion of prostrate lines approximated that found in the natural distribution. Yields at the subtropical sites were not associated with differences in growth habit but at the tropical sites there was a consistent advantage for the erect lines with the exception of the prostrate line Carpentaria A which gave the highest yield at Normanton. This line was low yielding at Parada and, in another comparison at the Mackay site, was lower yielding than the erect Katherine line (D. I. Sillar, unpublished data). The high yield at Normanton might be attributable to the atypically erect growth of the Carpentaria A swards at this site. Torssell (1974) has noted that prostrate components of a heterogeneous Katherine population assume an erect growth habit when grown in swards of high seedling density. In a three year yield comparison of thirteen lines at Katherine, N.T., Ive and Fisher (1974) also found a clear advantage for erect lines in pure swards which were not defoliated during the growing season.

However, prostrate lines may be favoured under different ecological or management conditions. Burt *et. al.* (1973) reported an increase in the proportion of prostrate plants when a heterogeneous population was sown at sites where the environment was harsher than the site of origin although erect plants still predominated after two years. When defoliated at a height of eight cm, prostrate lines were also favoured in mixtures by reducing the interval between cuts from six weeks to three weeks (Cameron and McCowan 1977). At Rodds Bay in the present experiment, the prostrate lines were at least as productive as the erect lines after grazing in 1967/8 had altered the botanical composition of the swards from grass to legume dominance.

General Adaptation

These short-term experiments have shown clearly that short growing seasons will favour early maturity types and that later maturity types will be more productive than early types in long growing seasons. The high variability in amount and distribution of rainfall over much of the distribution range results in wide variation in length of the growing season so that these short-term experiments cannot be used to predict long term adaptation at particular sites. Fortunately, a clear pattern of long term adaptation is revealed from the natural distribution of maturity types (Cameron 1967*c*) and these data were used in conjunction with the yield trials to support the release of the cultivars Lawson and Gordon. In tropical areas cv. Gordon is recommended for areas receiving more than 1100 mm annual rainfall and cv. Lawson for areas in the 900–1100 mm rainfall range. An erect, early flowering, black seeded line selected from the Greenvale population (Cameron and Bishop, unpublished data) has also been released (cultivar Paterson) for areas with 650–900 mm annual rainfall.

Although no clear pattern emerged from the results at the subtropical sites, all five collections from south of the Tropic were of the early or midseason type (Cameron 1967*c*). Skerman and Humphreys (1975) have shown that seed formation in the field declines progressively with minimum temperature ($r = 0.981$), with complete floral abortion at about 9°C. The seed production potential of late flowering lines, which only commence flowering near the end of April, would therefore be substantially reduced by low temperature over much of south-east Queensland. This suggests that cv. Paterson or cv. Lawson should be more suited to subtropical areas than cv. Gordon.

The failure of all lines to persist in the Eskdale environment (altitude 450 m) is consistent with earlier results at this site ('t Mannejte 1967) and with general experience in coastal and subcoastal Queensland south of Bundaberg (ca. 25°S lat.). Nevertheless, persistent populations of early to midseason maturity type are located at Grantham in the Lockyer Valley, only 50 km south of Eskdale, and even further south near Boonah (28°S) indicating that Townsville stylo may serve a useful role in some parts of this southern region (25–28°S lat.).

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REFERENCES

BURT, R. L., WILLIAMS, W. T., and COMPTON, J. F. (1973)—Variation within naturally occurring Townsville stylo (*Stylosanthes humilis*) populations; changes in population structure and some agronomic implications. *Australian Journal of Agricultural Research* **24:** 703-13.

CAMERON, D. F. (1965)—Variation in flowering time and in some growth characteristics of Townsville lucerne (*Stylosanthes humilis*). *Australian Journal of Experimental Agriculture and Animal Husbandry* **5:** 49-51.

CAMERON, D. F. (1967*a*)—Hardseededness and seed dormancy of Townsville lucerne selections. *Australian Journal of Experimental Agriculture and Animal Husbandry* **7:** 237-40.

CAMERON, D. F. (1967*b*)—Flowering in Townsville lucerne (*Stylosanthes humilis*). 2. The effect of latitude and time of sowing on the flowering time of single plants. *Australian Journal of Experimental Agriculture and Animal Husbandry* **7:** 495-500.

CAMERON, D. F. (1967*c*)—Flowering time and the natural distribution and dry matter production of Townsville lucerne (*Stylosanthes humilis*) populations. *Australian Journal of Experimental Agriculture and Animal Husbandry* **7:** 501-8.

CAMERON, D. F., and MCCOWN, R. L. (1977)—Rapid changes in simple mixtures of Townsville stylo (*Stylosanthes humilis*) lines differing in flowering time and growth habit. *Australian Journal of Experimental Agriculture and Animal Husbandry* **17:** 97-104.

COALDRAKE, J. E. (1964)—The subtropical environment of eastern Australia: climate. *In* "Some Concepts and Methods in Subtropical Pasture Research". Bull. Commonw. Bur. Past. Fld. Crops No. 47: 17-26.

EBERHART, S. A., and RUSSELL, W. A. (1966)—Stability parameters for comparing varieties. *Crop Science* **6:** 36-40.

EDYE, L. A., and CAMERON, D. F. (1975)—Comparison of Brazilian and naturalised Australian ecotypes of *Stylosanthes humilis* in the dry tropics of Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry* **15:** 80-87.

FISHER, M. J. (1973)—Effect of times, height and frequency of defoliation on growth and development of Townsville stylo in pure ungrazed swards at Katherine, N.T. *Australian Journal of Experimental Agriculture and Animal Husbandry* **13:** 389-97.

IVE, J. R., and FISHER, M. J. (1974)—Performance of Townsville stylo (*Stylosanthes humilis*) lines in pure swards and with the annual grass (*Digitaria ciliaris*) under various defoliation treatments at Katherine, N.T. *Australian Journal of Experimental Agriculture and Animal Husbandry* **14:** 495-500.

MANNETJE, L. 'T (1967)—Pasture improvement in the Eskdale district of south-eastern Queensland. *Tropical Grasslands* **1:** 9-19.

SKERMAN, R. H., and HUMPHREYS, L. R. (1975)—Flowering and seed formation of *Stylosanthes humilis* as influenced by time of sowing. *Australian Journal of Experimental Agriculture and Animal Hubandry* **15**: 74-9.

TORSSELL, B. W. R. (1974)—The genetic variation in a population of Townsville stylo (*Stylosanthes humilis* H.B.K.). *Journal of the Australian Institute of Agricultural Science* **40**: 234-6.

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