BREEDING *CENTROSEMA PASCUORUM* FOR NORTHERN AUSTRALIA

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ABSTRACT

A breeding program was conducted with C. pascuorum *from 1976 to 1981 to improve seed and herbage yields and produce a cultivar suitable for dryland pastures in the Top End of the Northern Territory. Biparental crosses were made between accessions mainly from north-eastern Brazil. Pedigree selection methods were used in the F_2, F_4 and F_6 generations at Katherine, N.T., and a single-seed descent method was used to advance progenies through the F_3 and F_5 generations without selection. Optimum flowering date for seed production by F_2 spaced plants was late March, and selection in the F_2 and F_4 generations was for vigorous plants which flowered prolifically at about this time and which showed no above-ground symptoms of infestation by root-knot nematodes (*Meloidogyne *sp.) and other pathogens. In the F_6 generation, families were transplanted into small swards and evaluated for two years. The best F_6 families had seed and herbage yields greater than both parents. Seven families were selected for regional testing.*

INTRODUCTION

Centrosema pascuorum is an annual, herbaceous, twining tropical pasture legume from South and Central America. Five accessions collected in north-eastern Brazil and one from Ecuador were grown opportunistically in plant introduction nurseries in northern Australia during 1967–1978 (Cameron and Mullaly 1969; O'Donnell and Smith 1975; Winter 1978; Burt and Williams 1979; Anning 1982). Subsequently all six accessions were compared at three sites (Clements *et al.* 1984). The promising performance of some of them at Katherine, N.T., prompted efforts to obtain additional collections by correspondence. These efforts had proved unsuccessful by 1976, and it was decided to commence a breeding program with the aim of developing a cultivar suitable for dryland pastures in the Top End of the Northern Territory. This paper describes the breeding of improved lines of *C. pascuorum*, and includes comparative data for segregating F_2 progeny, F_6 progeny, parent lines and a few new introductions obtained during the program.

MATERIALS AND METHODS

The six available accessions of *C. pascuorum* (CPI 40060, 40063, 55697 and 65950, and Q9855 and Q10050) were crossed in all possible biparental combinations. Two crosses were unsuccessful. The six parent lines, three new accessions and F_2 progeny from the 13 successful crosses (Table 1) were planted in peat pellets, inoculated with *Rhizobium* strain CB1923, and transplanted to cultivated seedbeds at two sites early in the 1977/78 growing season. One site was at Katherine Research Station (14°28′S, 131°19′E, average annual rainfall 900 mm) on Tippera clay loam (red earth) [Northcote (1971) classification Gn 2.11]. The other was at Narayen Research Station (25°41′S, 150°52′E, average annual rainfall 720 mm) on a mottled yellow podzolic (duplex) soil [Dy 3.41]. Basal superphosphate applications were applied prior to transplanting (100 kg ha^{-1} at Katherine, 200 kg ha^{-1} at Narayen). Spacing between individual plants was 2.0 × 2.0 m. Two rows of five plants (Katherine) or six plants (Narayen) of each cross or accession were included in each of five replicates at each site in a randomised block design. Weeds were controlled by herbicides and inter-row cultivation. Herbage yield was estimated in late March 1978 from visual ratings calibrated against standards which were cut, dried and weighed. Date of first flowering was determined by inspection at intervals of 1–3 days. Seed yield at Katherine was determined from one 0.75 × 0.75 m area near the centre of each plant during the 1978 dry season. Fallen seeds were swept from the ground, and winnowing and flotation techniques were used to separate and clean the seed prior to weighing. The data obtained are presented as cross or accession means at each site.

TABLE 1

Origin of C. pascuorum *accessions and derivation of crosses.*

Accession*	Origin (Country, State, nearest town, latitude)
CPI 40060	Brazil, Ceará, Fortaleza, 4°S
CPI 40063	Brazil, Ceará, Iraucuba, 4°S
CPI 55697	Brazil, Pernambuco, Petrolina, 9°S
CPI 65950	Ecuador, Playas, 2°S
CPI 74827	Honduras, Zamorano, 14°N
CPI 75115	Brazil, Paraíba, Soledade, 7°S
CPI 75116	Brazil, Piauí, Alto Longa, 5°S
Q9855	Brazil, Pernambuco, Itapetim, 7°S
Q10050	Brazil, Paraíba, São João do Cariri, 7°S

Cross no.	Derivation (f × m)+	Cross no.	Derivation (f × m)
1	40060 × 40063	10	55697 × 65950
2	55697 × 40060	11	Q9855 × 55697
3	40060 × 65950	12	55697 × Q10050
4	Q9855 × 40060	13	65950 × Q9855
5	Q10050 × 40060	14	65950 × Q10050
8	40063 × Q9855	15	Q10050 × Q9855
9	Q10050 × 40063		

*Commonwealth Plant Introduction (CPI) number or Queensland Department of Primary Industries (Q) number.
+Female (f) or male (m) parent.

F_2 plants at each site were selected on the basis of herbage yield, prolific flowering, production of first flowers towards the end of March, and apparent freedom from above-ground symptoms of infestation by root-knot nematodes (*Meloidogyne* sp.) and fungal pathogens. A cycle of single-seed descent breeding in a heated glasshouse in Brisbane was used to advance these lines without selection through the F_3 generation during the 1978 winter. During the 1978/79 wet season at Katherine, 2340 F_4 plants from 278 families were grown in conditions very similar to those used for the F_2 progeny, and selection was again applied using the same criteria. Another cycle of single-seed descent was used to advance the selections through the F_5 generation during the 1979 winter.

Forty-five F_6 families and three parents (CPI 40060, 55697 and 65950) were evaluated in small plots at Katherine, together with *Stylosanthes hamata* cv. Verano and a local strain of *Alysicarpus vaginalis*. Seedlings were raised as described for F_2 plants and transplanted into a 7 × 7 plant grid with 0.5 m spacings between plants, to form plots measuring 3.5 × 3.5 m, separated by paths 2.5 m wide. There were four replicates in a randomised block design. Seedlings were transplanted in December 1979 and were irrigated during the first ten days to ensure establishment. By mid-February, three quarters of the plots had at least 70% ground cover but a few had failed to establish. Apart from these obvious failures of individual plots, only five lines (CPI 65950 and four F_6 families) were severely disadvantaged during the establishment phase. Unreplicated plots or rows of ten new accessions from Venezuela and one from north-eastern Brazil were also included, but they grew very poorly and their performance will not be considered here.

Plots were not defoliated during the first growing season, but dead material was removed during the dry season. Measurements taken during the first year included percent ground cover (estimated on two occasions); herbage yield (visual estimates calibrated against standards, on three occasions); resistance to nematodes and other pathogens (scored on a 1–5 basis, with 1 = most plants dead or dying, 3 = some death plus severe wilting and leaf yellowing, 5 = no visible symptoms); date of first flowering; seed yield (measured during the dry season from one 0.61 × 0.61 m quadrat per plot as before); and regeneration at the start of the second wet season (seedlings counted on two 0.61 × 0.61 m quadrats per plot in December 1980).

In the second growing season two replicates were grazed heavily with cattle in February 1981 and the other two replicates were cut to 3 cm height and subsampled to determine percent legume, herbage yield of legume and leaf:stem ratio of legume. All replicates were then left uncut and ungrazed until late April, when the plots that had been previously grazed were sampled for herbage yield by cutting one 1.0 × 0.5 m quadrat per plot. The replicates cut in February recovered poorly and were not re-sampled. Because there were no significant line × defoliation treatment interactions for herbage yield, the data were pooled to provide an estimate of the total yield of each line over the growing season. Seed reserves of the best sixteen lines were measured on all four replicates during the 1981 dry season by sweeping the soil surface as before.

RESULTS

Data obtained at Katherine for the set of F_2 crosses, their parents and three other *C. pascuorum* accessions (CPI 74827, 75115 and 75116) are summarised in Figure 1. One of the most important results was the relationship of seed yield to flowering date. Most accessions and crosses which flowered after the end of March had very low seed yields. CPI 40063 stood out as a line with higher than expected seed yields. Mean flowering dates of the crosses were usually intermediate between those of their parents, but mean seed yields were commonly lower than the mid-parent mean. However, there was considerable variability within F_2 populations for both characters, with scope for selection within all crosses except cross 15. Crosses involving CPI 65950 were highly variable.

Flowering dates at Katherine and Narayen were positively correlated ($r = 0.78$, $p < 0.01$). However, CPI 65950 flowered three weeks later at Narayen than at Katherine, and all crosses involving CPI 65950 flowered from 7–16 days later at Narayen (data not presented). Seed yield at Narayen was negligible for all lines except the early flowering accession CPI 74827.

Heterosis for herbage yield occurred in the F_2 of many crosses, with eight of the thirteen crosses outyielding both parents at Katherine and six outyielding both parents at Narayen. Although the superiority of the hybrids was often not statistically significant, it was consistent, and cross 12 significantly outyielded both its parents at Katherine (Fig. 1). CPI 40060 consistently produced heterotic progeny at both sites. The correlation between sites for herbage yield was only moderate ($r = 0.59$, $P < 0.01$) because cross 12 grew unusually well at Katherine while CPI 40060 and 74827 grew relatively better at Narayen than Katherine.

Although individual plants from most crosses were selected to produce F_3 progeny, many families were rejected at the F_4 stage and 22 of the 45 F_6 families were from cross 2. Herbage and seed yield data from the first year of the F_6 evaluation are presented in a scatter diagram (Fig. 2). Eight F_6 families had significantly greater herbage yields than all of the parent lines. Four of these families (all from cross 2) also had higher seed yields than their parents (CPI 40060 and 55697), but did not have significantly higher seed yields than CPI 65950. The failure of CPI 55697 to set seed (Fig. 2) was unexpected in view of its moderate herbage yield (2.1 t ha^{-1}) in March and April and its 78% ground cover in February (Table 2). About half of the families also had low seed yields (< 50 kg ha^{-1}) despite herbage yields of up to 6.4 t ha^{-1}. In contrast, CPI 65950, which had only 17% cover (the lowest of any line) and yielded only 1.2 t ha^{-1} of herbage, yielded 104 kg ha^{-1} seed. The better *C. pascuorum* families and *S. hamata* yielded more than 5 t ha^{-1} herbage and more than 100 kg ha^{-1} seed in the first growing season, with two families from cross 2 (2/2 and 2/1) possessing outstanding combinations of these yield characteristics (Fig. 2).

Other data obtained during the two years of the F_6 evaluation are presented in Table 2 for the controls and the seven families finally selected for regional testing. These families all established rapidly in the first year as shown by the ground cover estimates, had high nematode/disease resistance scores and flowered in mid- to late March. There were no significant differences in leaf:stem ratio (mean 1.8). With the exception of family 11/5, they re-established well in the second wet season and gave good yields of

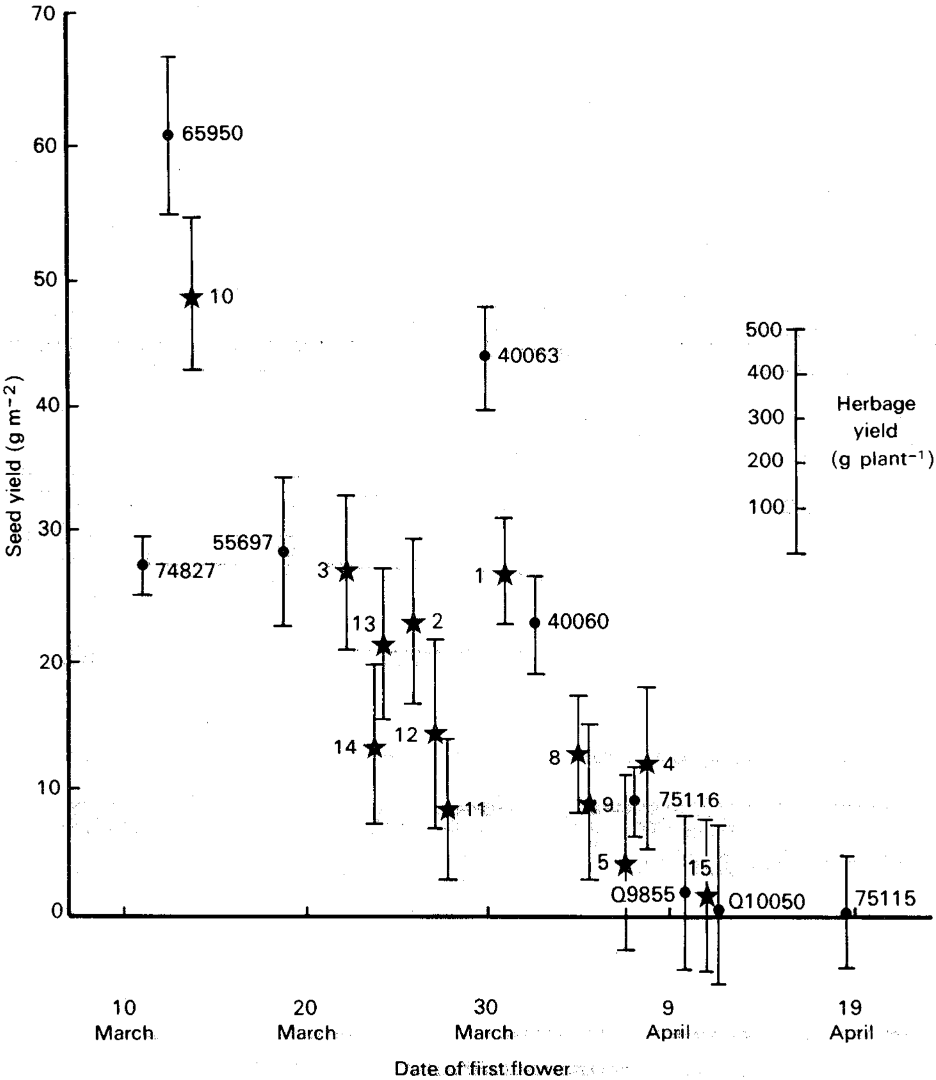

FIGURE 1

Flowering dates, seed and herbage yields of *C. pascuorum* accessions (●) and F_2 progenies (★) at Katherine. Herbage yields are shown as vertical bars and the yield scale is shown within the Figure. Numbers alongside the points refer to the accessions and crosses listed in Table 1. Least significant differences (P = 0.05) are: flowering date, 3.9 days; seed yield, 0.58 $\log_e$(yield + 1.0), or approximately 3.8 g m^{-2} at the mean yield of 19 g m^{-2}; herbage yield, 80 g.

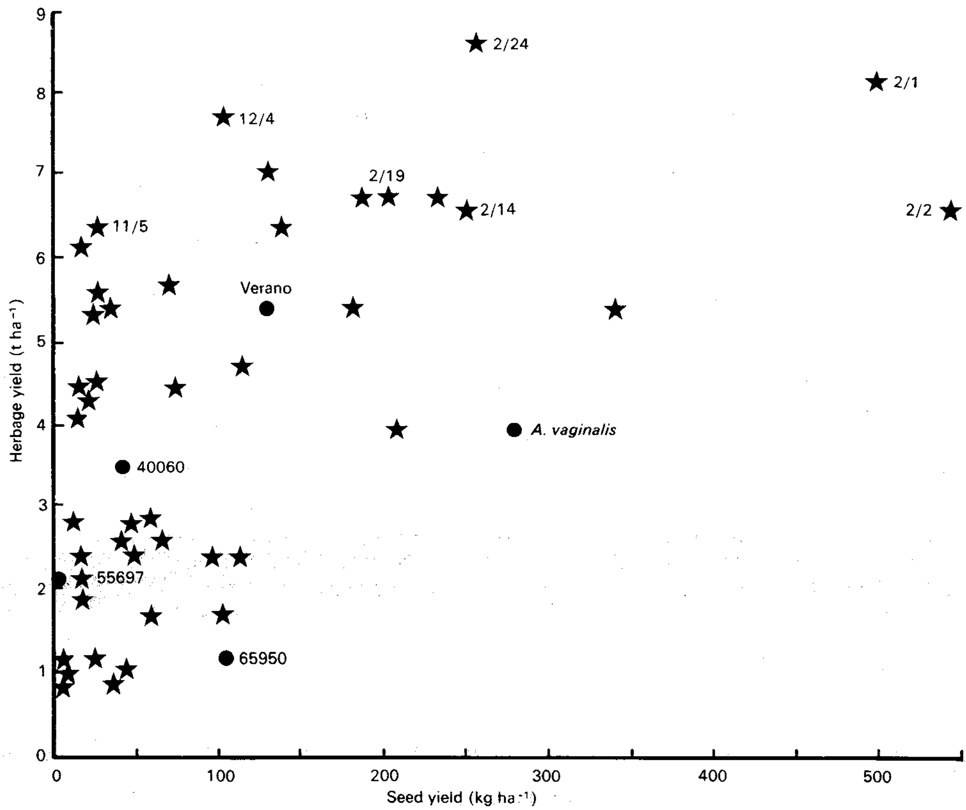

FIGURE 2

Herbage and seed yields of 45 F_6 families and three parent lines of *C. pascuorum*, and of *S. hamata* cv. Verano and *A. vaginalis*, in simulated swards during the first year of growth at Katherine. Numbers alongside the points refer to accessions (●) and families (★), coded as in Table 1 except that the first part of the family designation indicates the cross; e.g. 12/4 is a family derived from cross 12. Least significant differences (P = 0.05) are: herbage yield, 2.2 t ha^{-1}; seed yield, 2.06 $\log_e$ yield, or approximately 63 kg ha^{-1} at the mean yield of 104 kg ha^{-1}.

herbage and seed in the second year. Family 2/2 was clearly the best line in the second year while the *C. pascuorum* parent lines grew poorly and were greatly surpassed by the better bred lines.

DISCUSSION

The key result from this project was the successful production of elite F_6 families which surpassed their parents in both seed and herbage yield in the two years of testing. In interpreting this result the unexpectedly poor performance of CPI 40060 and 55697 in the simulated sward conditions must be considered, because in other experiments at Katherine they have grown and persisted very well (e.g. Clements *et al.* 1984). The failure of CPI 55697 in the second year was due to its lack of seed production in the first year, despite what appeared to be an adequate first-year plot cover and herbage mass (2.1 t ha^{-1}). In contrast, CPI 40060 set a reasonable amount of seed in the first year (42 kg ha^{-1}), re-established quite well at the start of the second wet season (22 seedlings m^{-2}), yet produced only 0.9 t ha^{-1} of herbage in the second year. Failure to produce seed has been observed previously at Katherine and is thought to be due partly to predation by sucking insects (L. J. Phillips, *personal communication*). However, we have

TABLE 2

Some characteristics of bred lines and parent accessions of C. pascuorum *and of* S. hamata *and* A. vaginalis, *during the first two years of growth in simulated swards at Katherine, N.T.*

Family or accession	Ground cover (Feb. 1980)	Resistance to nematodes and disease*	Flowering date (1980)	Regeneration (Dec. 1980)	Herbage yield of legume (1981)	Seed reserves (1981)
	%			(seedlings m^{-2})	(t ha^{-1})	(kg ha^{-1})
2/1	100 a	5.0 a	22 March bc	80 ab	3.8 ab	439 a
2/2	88 a	4.6 a	17 March cde	249 a	5.5 a	527 a
2/14	90 a	4.8 a	22 March bc	235 a	2.9 bc	410 a
2/19	100 a	4.0 abc	24 March b	287 a	3.1 b	360 a
2/24	100 a	5.0 a	24 March b	405 a	4.4 ab	333 a
11/5	75 a	4.1 ab	25 March b	4 bc	0.9 cd	89 b
12/4	90 a	4.1 ab	20 March bc	65 ab	3.3 b	343 a
F_6 mean	75	3.4	23 March	69	—	—
F_6 range	17–100	1.5–5.0	14 Mar–4 Apr.	0–405	0–5.5	0–527
40060	90 a	2.8 bc	5 April a	22 bc	0.9 cd	n.a.
55697	78 a	2.4 c	18 March cd	1 c	0.1 d	n.a.
S. hamata	83 a	—	12 March e	202 a	3.0 b	5 c
A. vaginalis	97 a	—	14 March de	534 a	3.7 ab	69 b

Within columns, numbers sharing a common letter do not differ significantly.
*Visual rating (1 = worst, 5 = best; see text) of resistance to nematodes and fungal pathogens.

no data to prove that sucking insects were responsible for low seed yields in this experiment. Re-establishment failure despite adequate seed set has also been observed previously, usually when the soil surface has a hard seal or is excessively bare. The ability of the elite F_6 families to re-establish successfully under conditions in which the parents had severe limitations suggests that they may be less vulnerable than the parents to failure at the beginning and end of each wet season, which are critical times for the success of an annual plant.

Late March was found to be the optimum flowering date for *C. pascuorum* at Katherine. The high seed yields of families which flowered at this time are in agreement with other results (Clements *et al.* 1984; Stockwell *et al.* 1986).

Although we have referred in this paper to selection for resistance to nematodes and other pathogens, the exact cause of the pathological symptoms we observed is not clear. A high proportion of the affected plants had root-knot nematode lesions (R. C. Colbran, *personal communication*). Fungal pathogens from the genera *Fusarium* and (less commonly) *Gliocladium*, *Neocosmospora* and *Macrophomina* were also isolated from affected plants (J. L. Alcorn, *personal communication*), but may have only attacked plants already weakened by nematode infestation. Susceptibility of *C. pascuorum* to nematodes has also been reported from Florida, U.S.A. (Kretschmer *et al.* 1980). Symptoms observed in our experiments included vascular discoloration, chlorosis spreading outwards in a circle from the crown of the plant, yellowing and wilting of leaves, rotting of tap roots, and death. The nature of this problem needs closer study.

The seven elite families derived from this program have been tested more widely in the Northern Territory (Stockwell *et al.* 1986), and family 2/2 was ultimately released as cv. Cavalcade.

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EVALUATION OF BRED LINES OF *CENTROSEMA PASCUORUM* IN SMALL PLOTS IN NORTH-WEST AUSTRALIA

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ABSTRACT

Seven bred lines and two parent accessions of Centrosema pascuorum *were grown for two years in a cutting trial at six sites in the Northern Territory and at one site near Kununurra, W.A.* Stylosanthes hamata *cv. Verano and* Macroptilium atropurpureum *cv. Siratro were included as controls at six sites. Herbage yield was measured towards the end of each wet season, and seed yields were measured during both dry seasons.*

In the first year, most C. pascuorum *lines yielded more herbage and seed than Verano and Siratro at most sites. Differences between* C. pascuorum *lines in mean herbage yield were small, but differences in seed yield were substantial. There were no line × site interactions for either herbage or seed yield. In the second year, however, the* C. pascuorum *lines generally gave poorer yields than Verano at each site, but again outyielded Siratro which performed poorly at all sites. There were significant* C. pascuorum *line × site interactions for both herbage and seed yield.*

One line, subsequently released as cv. Cavalcade, possessed a desirable combination of consistently high herbage yield over sites and years and good seed production, providing 22% more herbage (on average) and 118% more seed than its best parent.

INTRODUCTION

Centrosema pascuorum has been identified as a tropical pasture legume of considerable promise for the strongly seasonal rainfall areas of northern Australia (Winter 1978; Anning 1982; Clements *et al.* 1984), north-eastern Thailand (Topark-Ngarm and Moolsiri 1982) and several other countries in South-East Asia. It is an annual species native to Central and South America, first introduced to Australia in 1965. A breeding program conducted mainly at Katherine Research Station, N.T., from 1976 to 1981 (Clements *et al.* 1986) produced a number of elite lines for regional evaluation in north-west Australia. This paper describes the comparative performance of seven bred lines, the two best parent lines (Clements *et al.* 1984), and three widely-used commercial pasture legumes in cutting trials at seven sites in north-west Australia. The objective was to identify the best line for release to the pastoral industry.