could be considered as relatively susceptible. However, cv. Hunter River, and its derivative, cv. Trifecta, showed lower disease levels than other cultivars and lines except UC 1249 and UC 1250. Every line showed substantial variation for disease reaction, suggesting that recurrent selection for *Stemphylium* resistance would be possible. Such a programme is currently in progress for the Queensland bred lines Trifecta and Sequel, which are both known to have a broad genetic base (Clements *et al.* 1984).

ACKNOWLEDGEMENTS

Officers of Agriculture and Plant Pathology Branches, Queensland Department of Primary Industries, provided collections of diseased material and seed of some lucerne lines. Mr. T. Woodroffe and Mrs. M. Stirling gave excellent technical assistance. Partial funding was received from the University of Queensland—CSIRO collaborative research fund. All of this assistance is gratefully acknowledged.

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(Accepted for publication, September 4, 1985)

ESTABLISHMENT OF *STYLOSANTHES* SPP. AND SIRATRO IN DRIER (< 750 MM ANNUAL RAINFALL) INLAND AREAS OF CENTRAL QUEENSLAND

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ABSTRACT

The establishment success of nine Stylosanthes *accessions and Siratro (*Macroptilium atropurpureum*) was recorded from nine plantings in drier (500–750 mm rainfall) areas of central Queensland during 1976–79. In five plantings, 2% or less of the viable seed of* S. scabra *cv. Fitzroy established compared to 4 to 44% of the Siratro seed. Fitzroy was slower to germinate in laboratory tests and took about 5 days to reach 50% germination compared to 2.6 days for Siratro. Establishment of all* Stylosanthes *accessions was worse on clay compared to sandy loam soils. Factors affecting establishment are discussed. Recovery of weathered seed in gauze bags suggests the problem in drier environments may be poor survival of the very young seedlings rather than germination failure. Establishment of perennial stylos could be improved by sowing late in summer, to avoid rapid soil-drying conditions, and using seed that has been treated to increase the proportion of soft seed.*

INTRODUCTION

Pasture legumes are required in central Queensland to improve production from sown grass pastures and for integration with cropping to form stable production systems. Preliminary studies (Graham *et al.* 1982) show that *Stylosanthes scabra* cv. Fitzroy has potential for achieving these objectives. However, there have been many experiences of poor establishment from both experimental and commercial plantings in central Queensland. In contrast, establishment of 30% or more of the germinable seed has been reported (Mott *et al.* 1976; McIvor 1983) for sowings of perennial stylos in tropical areas of northern Australia. The sub-tropical, sub-humid to semi-arid climate of central Queensland differs from the northern tropics in that rainfall appears to be highly variable and less reliable (Nix 1977). Early summer rain mainly results from localized thunderstorms and wet spells associated with moist air masses are not expected until January–April. The establishment of small seeded pasture species can be unpredictable in drier areas because success depends on the safe transition through five phases—softening, imbibition, germination, seedling emergence and early seedling growth (Cook 1980; McKeon and Mott 1984).

This paper discusses, in terms of climate and plant attributes, the establishment performance of Fitzroy compared with other species using the experience from nine sites where various legume seeds were broadcast onto rough, cultivated seedbeds in an environment where average annual rainfall is less than 750 mm.

MATERIALS AND METHODS

Nine experimental sites were sown in the Dawson-Callide area (24°20′–24°50′S; 149°17′–150°45′E) of central Queensland during the period December 1976–1979. The sites have been grouped, according to species and sowing date, into three series (Table 1). The soil type, seedbed preparation, species used, seeding rate and germination characteristics of the seed sown are included in Table 1. The Verano and Fitzroy seed planted at sites 4 to 9 was heat treated (80°C for 48 hours) prior to sowing to reduce the proportion of hardseed. All (9 sites) legume seed was inoculated.

Series A

Seven *Stylosanthes* species and accessions (Table 1) were compared in 0.4 ha plots on two soil types. All plots were off-set disc ploughed twice just prior to sowing to prepare a clean, roughly cultivated seedbed. The legume seed and sawdust carrier were surface sown, following 21 mm of rain, at 14 kg of mixture ha^{-1}. The whole area was oversown with buffel grass (*Cenchrus ciliaris*) cv. Biloela at 2 kg seed ha^{-1} using a drum-seeder and trailing fluted-roller. Establishment was recorded by counting seedlings in eighty 1 m^2 quadrats per 0.4 ha, on February 1, 1977, eight weeks after planting.

Series B

Three legume species (Table 1) were planted at four sites. The experiment at site 3 was a split-plot (2 superphosphate levels (0 and 250 kg ha^{-1}) × 3 legume species as sub-plots) in a randomized block design with three replicates. The 8 m × 15 m plots were established in a pasture of buffel grass cv. Gayndah following two cultivations with an off-set disc plough which prepared a roughly cultivated seedbed with some grass clumps remaining. Establishment was determined by counting seedlings in ten 1 m^2 quadrats per plot, on May 25, 1977, thirteen weeks after planting.

The experiment at site 4 was a split-plot (3 seedbed treatments × 3 legume species as sub-plots) in a randomized block design with four replicates. The legumes (Table 1) were surface sown in 5 m × 5 m plots on May 30, 1978, the day after the wheat was sown at 39 kg seed ha^{-1} with a combine planter. On completion of the legume sowings, all plots were oversown with buffel grass cv. Biloela at 2 kg seed ha^{-1}. The three seedbeds, all worked to a fine tilth, were:- wheat seedlings hand weeded—(Wd), wheat retained—(Wh), wheat retained plus pasture seeds covered by hand raking—(Ra). Establishment was determined by counting in ten 0.5 m^2 quadrats per plot on August 18, 1978, eleven weeks after sowing.

Sites 5 and 6 were planted to the same experimental design as site 4 but were surface sown in summer into seedbeds prepared from the trash and wheat stubble remaining after the grain harvest in October, 1978. All ploughing treatments removed or incorporated most of the trash. Shallow penetration of the soil by the blade plough resulted in an open, compact seedbed compared to the loose, rough, cloddy seedbed from chisel ploughing. The rotary hoe cultivated a fine, clean, friable seedbed. The three seed beds were:- blade ploughed once—(Bl), chisel ploughed twice—(Ch), rotary-hoed once—(Ro). Establishment counts, the same procedure as for site 4, were taken on January 23, 1979 (6 weeks after the December planting) and February 16, 1979 (3 weeks after the January planting).

Changes in seed germination following field weathering were monitored at site 6. This was done by placing fibre-glass mesh (2 mm) bags of 12 × 12 cm size containing 50 viable seeds on the soil surface and lightly surrounding the bags and seed with sieved soil. Bags placed in each legume sub-plot of the Ch and Ro treatments were retrieved

TABLE 1

Site description, identification, sowing rate and seed test of ten legumes sown over nine sites

Site		Seed bed preparation	Species and accessions	Sowing Rate		Seed germination tests		
Location	Soil*			Total	Viable	Soft	Hard	Rate
				gm^{-2}	seed m^{-2}	% of viable seed		days**
SERIES A								
1. Brigalow Research Stn	Duplex (Db1, Dr2), Sandy loam surface	RC, harrowed clean	S. viscosa CPI 34904	0.30	149	43	57	–
			S. guianensis CPI 40294	0.17	66	35	65	–
			S. hamata cv. Verano	0.30	82	10	90	–
			S. guianensis cv. Graham	0.17	50	24	76	–
2. Brigalow Research Stn	Clay (Ug5) heavy clay surface	RC, harrowed clean	S. scabra cv. Fitzroy	0.30	88	11	89	–
			S. scabra CPI 34925	0.30	106	3	97	–
			S. scabra cv. Seca (all sown at both sites)	0.30	123	8	92	–
SERIES B								
3. Wirranda	Duplex (Db1), sandy loam surface	RC, Gayndah buffel	Verano	0.52	118	27	73	–
			Fitzroy	0.52	207	5	95	–
			Macroptilium atropurpureum cv. Siratro	0.52	25	82	18	–
4. Brigalow Research Stn	Duplex (Db1), sandy loam surface	FC, Weeded (Wd)	Verano	0.46	100	32	68	3.1
		FC, Wheat (Wh)	Fitzroy	0.40	100	33	67	6.2
		FC, Raked (Ra)	Siratro	1.36	100	52	48	3.6
5. Brigalow Research Stn	as for 4	WS, Blade (Bl)	Verano	0.36	100	35	65	2.1
		WS, Chisel (Ch)	Fitzroy	0.37	100	57	43	5.0
		WS, Rotary (Ro)	Siratro	1.30	100	65	35	2.5
6. Brigalow Research Stn	as for 4	as for 5	as for 5		as for 5			
SERIES C								
7. Clovernook	Duplex (Dy3), sandy clay loam surface	RP, Native pasture	Verano	0.50	89	54	46	3.0
			Graham	0.50	160	19	81	3.5
			Fitzroy	0.50	136	50	50	3.9
			Siratro	0.50	38	53	47	1.7
8. Bayfield	Clay (Ug5), medium clay surface	FC, clean	S. humilis	0.50	149	56	44	3.9
			S. guianensis var. intermedia cv. Oxley	0.50	40	50	50	4.8
9. Newhaven	Red-brown clay loam	RC, Gayndah buffel	(all sown at each site)					

*Northcote (1971) **Time (days) to 50% germination of soft seed.
RC—rough, cultivated twice with off-set disc just prior to sowing.
FC—fine, cultivated fallow and prepared for crop.
WS—wheat stubble and trash after October 1978 harvest.
RP—rough, chisel plough twice just prior to sowing.

on February 16 and May 25, 1979, and after counting seedlings the remaining seed was tested for % germination (Graham and Muller 1979).

Series C

Five *Stylosanthes* spp. (Table 1) and Siratro were planted in 8 m × 30 m plots. Each experiment at sites 7 to 9 was a split-plot (2 superphosphate levels (0 and 326 kg ha^{-1}) × 6 legume species as sub-plots) in a randomized block design with three replicates. Sites 7 and 9 were chisel ploughed twice just prior to sowing leaving the seedbed rough, cloddy and grassy whereas at site 8 the seedbed had been worked to a clean, fine tilth ready for planting a crop. The legume seed was hand broadcast on the soil surface and only the Siratro seed was lightly covered by hand raking. Establishment was recorded by counting seedlings in ten 1 m^2 quadrats per sub-plot on March 21, 1979 (five weeks after the February 15 planting), May 22, 1979 (11 weeks after the March 5 planting) and MaRCH 4, 1980 (10 WEEKS AFTER THE December 20 planting) at sites 7, 8 and 9 respectively.

RESULTS

Treatment effects on establishment

Establishment was assessed by counting legume plants surviving within 3 to 13 weeks after planting and expressing the establishment population as a proportion of the viable seed sown. Establishment data are presented in Table 2.

TABLE 2

Record of establishment of ten legumes over nine sites during 1976–1979 (plant numbers expressed as a % of viable seed sown)

Site, soil and seedbed	Sowing date	CPI 40294	Graham	Verano	CPI 34904	Fitzroy	CPI 34925	Seca	LSD P=0.05
SERIES A				Species establishment%					
1. Sl+	6.12.76	5.4	4.8	3.2	3.0	2.4	0.8	0.5	–
2. Cl	6.12.76	0.2	0.8	0.7	0.1	0.6	0.2	<0.1	–
SERIES B				Verano		Fitzroy		Siratro	
3. Sl	25.2.77			3.4		3.8		52.0	6.6
4. Sl Wd	30.5.78			2.1		19.6		25.8	7.8
Wh	30.5.78			3.5		26.1		25.8	7.8
Ra	30.5.78			1.3		17.0		48.1	7.8
5. Sl Bl	12.12.78			3.2		1.2		6.6	4.1
Ch	12.12.78			1.0		0.5		19.2	4.1
Ro	12.12.78			1.2		1.3		11.5	4.1
6. Sl Bl	31.1.79			0.4		0.5		4.1	4.4
Ch	31.1.79			0.0		0.1		19.1	4.4
Ro	31.1.79			0.3		0.3		11.3	4.4
SERIES C		Oxley	Graham	Verano	S.humilis	Fitzroy		Siratro	
7. Sl	15.2.79	6.3	6.5	4.9	12.3	0.8		29.7	3.6
8. Cl	5.3.79	0.1	0.4	0.5	0.1	0.2		12.6	0.9
9. Cl	20.12.79	4.6	–	6.1	25.7	2.2		43.6	8.4

+Sl—sandy loam surface
Cl—clay surface
Wd—weeded free of wheat
Wh—wheat
Ra—wheat and raked
Bl—blade ploughed once
Ch—chisel ploughed twice
Ro—rotary hoed once

Series A

In series A, the seedbed was dry at planting, but 76 mm of rain was received over the next 22 days of which 49 mm fell in one period of seven days (Fig. 1). Established plants of the *S. guianensis* lines accounted for 5% of the viable seed sown compared to 3% or less from the remaining five *Stylosanthes* spp. (Table 2). Establishment on the clay soil was much poorer than on the duplex soil. Even the most frequently encountered cultivars such as Verano and Fitzroy had less than 1% of viable seed established on the clay soil.

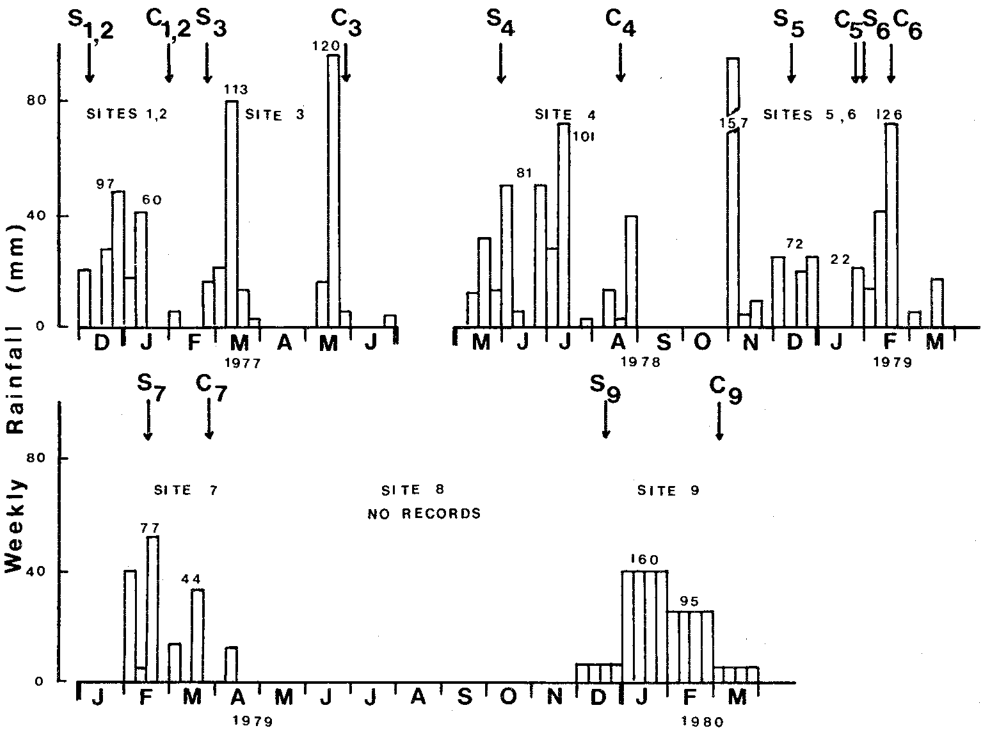

FIGURE 1
Weekly rainfall (mm) and monthly totals in figures during the experimental period. Sowings (S) and counting (C) dates are marked (↓).

Series B

Planting into a roughly cultivated seedbed in late summer 1977 (site 3) favoured Siratro. About 52% of the viable seed of Siratro established compared with only about 3–4% of the viable seed of Fitzroy and Verano (Table 2). During the 14 days following planting 118 mm of rain was received in ten falls (Fig. 1).

The following year, both Siratro and Fitzroy established well when sown in May (site 4). Climatic and seedbed conditions at planting favoured good establishment. The seedbed was moist and 31 mm of rain fell one day later. In June–July, 138 mm of rain was received over six days of a 13 day period. Winter temperatures were mild and only light frosting occurred. About 17% to 26% of the viable seed of both species established and there was an 85% increase in seedling numbers where Siratro seed was lightly covered with soil by hand raking (Table 2). Soil coverage did not improve establishment of the *Stylosanthes* spp. Verano performed badly with only about 2% of the viable seed establishing. The wheat, sown at 39 kg ha^{-1} grew into an open stand and appeared to offer little competition to the establishing pasture. By harvest time, in early October, the legume and grass seedlings were about 50 to 100 mm tall. Subsequent sowings during early (site 5) and mid-summer (site 6) (1978–79) resulted in very poor establishment of the *Stylosanthes* spp. but the Siratro was reasonably successful. Rainfall following both summer plantings was low (Fig. 1). Only 19 mm of rain was received in three falls over the five days following the December 1978 planting and only 29 mm of rain fell during the next five weeks. The January 1979 planting was followed by a wet period of 6 days during which 55 mm was received in four falls. Generally less than 1% of the viable seed of the *Stylosanthes* spp. established compared to 19% of the Siratro when sown into a cloddy seedbed prepared with a chisel plough (Table 2).

Series C

At site 7, rain fell the day after planting and 32 mm was received over three days. A further 44 mm was received in five falls prior to counting. In contrast, at site 8, it was overcast with light rain when the seed was planted into moist soil but little rain followed in the 11 weeks to time of assessment. At site 9, 234 mm of rain fell during two wet periods of six and seven days duration in early January and February (Fig. 1). Siratro was the best legume with 30 to 44% of viable seed establishing at sites 7 and 9 (Table 2). Townsville Stylo was the next best with 12 to 26% of viable seed establishing. Establishment of the other *Stylosanthes* spp. never exceeded 6% of the viable seed sown and for Fitzroy it was 2% or less.

Weathering effects on seed germination

Germination within legume sub-plots of site 6 was monitored over late summer using the gauze bag technique. Germination was highest in Siratro (88%) followed by Fitzroy (68%) and Verano (42%) (Table 3).

TABLE 3

The percentage of hard, soft and germinated seeds in gauze bags after weathering on the soil surface for 16 (February 16) and 114 (May 25) days

	Verano			Fitzroy			Siratro			
	Initial test	Feb. 16	May 25	Initial test	Feb. 16	May 25	Initial test	Feb. 16	May 25	LSD P=0.05
			% of viable seed in gauze bags							
Hard seed	65	10	25	42	19	13	35	4	9	9.6
Soft seed	35	62	32	58	46	10	65	6	0.5	12.7
Germinated	–	24	42	–	29	68	–	88	86	12.4

DISCUSSION

In five of the seven trials in which Fitzroy and Siratro were sown only 2% or less of the viable seed of Fitzroy established compared with 4 to 44% of the viable seed of Siratro. Cultivation reduced grass competition and loosened the soil but variations in cultivation treatment had less influence on establishment of *Stylosanthes* than climatic conditions. Germinating rains following the five plantings at sites 5 to 9 provided wet periods of only three to seven days duration. This is in contrast to the much more successful plantings at sites 3 and 4 where rain periods after planting extended for up to 14 days duration. As a result, nearly all the soft seed of Siratro (48–51% of the viable seed) and Fitzroy (4–26% of the viable seed) established. Under favourable moisture conditions in north Queensland, McIvor (1983) recorded, for dehulled and scarified Fitzroy seed, mean establishments of 33% (range 15–45%) of germinable seed sown.

The perennial species *S. scabra* has been reported (McIvor 1976; McKeon and Mott 1984) to be a slow germinator. Laboratory germination tests at 25°C on seed used in these experiments indicate that the time taken for 50% of the soft seed to germinate varies from about 5.0 days for Fitzroy to only 2.6 days for Siratro (Table 1). Fitzroy seed used in these experiments consisted of single-seeded pods. Gardener (1975) has shown that in some *Stylosanthes* spp., pods around the seed can delay germination by at least one day. Also, seedlings (0–6 weeks of age) of the perennial *S. scabra* have slower early growth rates and slower radicle elongation rates than the annual *S. hamata* (Gardener 1978). Any delays in the germination phase, particularly during early summer, could subsequently expose seedlings to high risk if short rain periods of three to seven days duration are followed by hot, dry weather.

The problem period in drier environments may be the early seedling survival stage rather than germination failure. For instance, the recovery of seed in gauze bags at site 6 showed that 42, 68 and 88% of the viable seed of Verano, Fitzroy and Siratro germinated. In the surrounding plots, less than 1% of the *Stylosanthes* and less than 20% of Siratro viable seed established. Similarly, McKeon and Mott (1984) suggested that in severe environments the relatively poor establishment success of the perennial *S. scabra* may have resulted from slow germinating seed being exposed to sub-optimal environmental conditions throughout the "early seedling establishment" phase.

Soil texture can also influence the establishment of the smaller seeded *Stylosanthes*. Establishment of all *Stylosanthes* spp. was poorer on clay soils (site 2) than on sandy loam soils (site 1) (Table 2), and at sites 8 and 9 Fitzroy establishment was poor compared to Siratro. Thomson *et al.* (1983) reported poor establishment with *Stylosanthes* on clay soils and suggested surface crusting may have prevented emergence. However, poor establishment is also likely to be associated with differences between soils in available water content since more water is required to wet fine textured clay soils to a given water potential compared to coarse textured sandy loam soils (Black 1957).

The experience with legume establishment described in this paper, from nine sowings during 1976 to 1979, highlights the importance of both time of sowing and speed of germination in relation to soil moisture conditions. As discussed earlier, the less successful establishments were associated with short wet periods of three to seven days duration. These conditions are common for inland areas of central Queensland in early summer. During this period, weekly mean maximum temperatures are high, reaching 35 °C, and rainfall is highly variable since it mainly results from localized thunderstorms (Nix 1977). When sowing perennial stylos, such as Fitzroy, in drier areas of central Queensland the chance of successful establishment can be improved if two points are observed. Firstly, saarify the seed either by mechanical means or dry-heat treatment (Mott 1979; Mott and McKeon 1979) to reduce the proportion of hard seed, and secondly, plant in late summer (February–MArch) to avoid rapid soil-drying conditions. The penalty of the late sowing is that there will be very little seed set in the first year and in some areas small plants may be at risk if winter frosting is severe but the reward is likely to be greater establishment populations. Further study of the fate of sown seed in this environment is required to formulate more reliable planting techniques.

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(Accepted for publication, September 27, 1985)