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Effect of tree clearing and seedbeds on the establishment, growth and population dynamics of siratro, green panic and signal grass oversown into a speargrass pasture in south-east Queensland

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Abstract

The high cost of establishing improved pastures over large areas using cultivated seedbeds, and the unreliability of surface sowing, have prompted research into alternative, low cost techniques of pasture establishment. Seed mixtures of siratro (*Macroptilium atropurpureum*) and green panic (*Panicum maximum* var. *trichoglume*) or siratro and signal grass (*Brachiaria decumbens*) were either broadcast into live speargrass (*Heteropogon contortus*) pastures, into dead speargrass pastures that had been sprayed with herbicide, or sod-seeded into live speargrass pastures with minimal disturbance. The 3 seedbeds were imposed on native pastures that had been cleared of trees for 6 years, had the trees killed at sowing or where live trees remained. The establishment, growth and survival of seedlings, together with yield and botanical composition of the swards, were studied over 4 years.

Pasture establishment was highest in the herbicide-treated seedbeds without live trees and lowest where seed was broadcast into undisturbed speargrass pastures where trees had been cleared 6 years before sowing, and in all seedbeds where live trees were present. In the herbicide seedbeds without live trees, lower levels of plant competition led to better seedling survival and resulted in pastures with a greater proportion of sown species. Even though siratro set seed each year, and there were a number of seedling recruitment events, after 4 years, over 97% of the siratro population was composed of survivors from the initial emergence.

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Resumen

*Los altos costos asociados con el uso de camas cultivadas para el establecimiento de pasturas mejoradas en areas extensas, y la falta de confiabilidad de las siembras hechas en la superficie han motivado la investigación de alternativas, técnicas de bajo costo para el establecimiento de las pasturas. Las mezclas de semillas de siratro (*Macroptilium atropurpureum*) y green panic (*Panicum maximum *var.* trichoglume*) o siratro y pasto señal (*Brachiaria decumbens*) fueron sembrados ya sea al voleo en pasturas vivas de speargrass (*Heteropogon contortus*), o en pasturas muertas de speargrass previamente asperjadas con herbicida, o sembradas en franjas en pasturas vivas de speargrass con un mínimo de disturbio. Las tres camas de siembra fueron impuestas en pasturas nativas en las cuales los árboles fueron removidos ya sea 6 años previos a la siembra, o eliminados al momento de la siembra, o permanecieron vivos. Durante 4 años se estudió el establecimiento, el crecimiento y sobrevivencia de las plántulas, el rendimiento y la composición botánica de la pastura.*

El establecimiento de la pastura fue mayor en las camas tratadas con herbicida y sin árboles, y el menor fue cuando se sembró la semilla al voleo en speargrass sin disturbio donde los árboles fueron eliminados 6 años antes de la siembra, y en todas las camas con árboles. En las camas tratadas con herbicida y sin árboles, los niveles bajos de competencia entre plantas resultaron en *una mejor sobrevivencia de plántulas, una alta proporción de las cuales fueron de las especies sembradas. A pesar que el siratro produjo semilla cada año y hubo una numerosa incorporación de nuevas plántulas, después de 4 años más del 97% de las poblaciones de siratro fueron compuestas de plantas sobrevivientes de la siembra inicial.*

Introduction

The speargrass region of southern and central Queensland is an important beef cattle raising area containing some 25% of the beef cattle in the state. The region comprises largely open eucalypt forests and woodlands with a dense understorey of grasses, dominated by black speargrass (*Heteropogon contortus*). Tree killing or clearing has long been an accepted method of increasing herbage production from native pastures, but while such practices increase grass productivity and hence carrying capacity, only small gains in animal growth rate are achieved (Tothill 1974). Grazing trials on low fertility granitic soils in south-east Queensland have demonstrated that sown pastures comprising green panic (*Panicum maximum* var. *trichoglume* cv. Petrie) and siratro (*Macroptilium atropurpureum* cv. Siratro), when fertilised with superphosphate, can increase animal production per hectare another 5-fold through increases in both carrying capacity and animal growth rates (Coates and Mannetje 1990).

The relatively high cost of establishing improved pastures over large areas using cultivated seedbeds has prompted research into alternative, lower cost techniques of establishment (Cook 1984). The success of these strategies depends on their capacity to limit competition between the seedling and the native pasture species, and their cost. Surface sowing is less expensive, but competition from native species limits seedling survival (Cook and Dolby 1981; Thomson *et al.* 1983; Cook 1984). Killing the native grasses with herbicide can reduce plant competition (Campbell 1974; Cook 1985), but is expensive. Sod-seeding without herbicide, while more expensive than surface sowing, may offer greater establishment reliability because of the better conditions created for germination and early seedling growth.

Native pastures become denser and more competitive as growth increases after tree removal. Establishment from surface sowing is therefore significantly less than where tree clearing and sowing are conducted simultaneously (Cook 1984). However, it is not known whether these short term establishment benefits are translated into longer term benefits to the pasture. Nor is it known whether it is possible to establish improved pasture species among live trees in the sub-coastal areas of south-east Queensland.

Grasses having more vigorous seedlings that are better able to withstand competition, or that can grow and compete better than green panic under low fertility conditions, may survive better when oversown into low fertility native pasture situations (Cook 1980). Signal grass (*Brachiaria decumbens* cv. Basilisk) appears to satisfy these criteria and has shown promise in previous oversowing experiments (Cook 1984). A field experiment was conducted to determine whether productive pastures of green panic and signal grass, with siratro, could be developed by broadcasting or sod-seeding seed into a speargrass pasture, accompanied by different tree clearing strategies.

Materials and methods

Experimental site

The experiment was conducted at the Narayen Research Station (25°41'S, 150°52'E, altitude 280 m) in the speargrass region of southern Queensland. Seventy per cent of the mean annual rainfall of 716 mm falls in the summer months. On average, evaporation exceeds rainfall in all months, with the rainfall deficit being least during January and February.

The experimental site was originally a narrow-leaved ironbark (*Eucalyptus crebra*) forest with 600 to 1800 trees per hectare, larger trees being present in more open areas and smaller trees in densely wooded areas. Black speargrass was the dominant species of the summer-growing native perennial grass understorey. Part of the area was cleared of trees by bulldozer in 1972, and cleared and uncleared areas were grazed by cattle until 1976 when the experimental area was fenced. The soils are slightly acid (pH 6.0) podzolics with a granitic sand surface soil (Dy2.22) overlying a clay sub-soil at about 30 cm. They are deficient in phosphorus, sulphur, molybdenum and nitrogen.

Experimental design and treatments

A mixture of siratro and grass seed was oversown into native pasture using 3 seedbeds. Two grasses (green panic and signal grass) and 3 seedbeds were factorially combined within each of 3 blocks and imposed on native pasture in each of 3 conditions of tree clearing. Tree clearing and seedbed treatments were as follows:

Tree clearing:
- Cleared — area cleared of trees 6 years prior to sowing.
- Killed — trees killed at sowing.
- Live — live trees.

Seedbeds:
- Broadcast — seed broadcast into undisturbed native pasture.
- Sod-sown — seed sown into cultivated strips. The strips, 8 cm wide, 2–3 cm deep and 40 cm apart, were cultivated at sowing. Seed was broadcast into the strips and worked into the soil.
- Herbicide — seed broadcast into native pasture which had been sprayed with 0.9 kg a.i./ha of glyphosate 3 weeks prior to sowing.

Individual plots measured 3 m by 2 m.

Plots were sown on January 9, 1979 with 4 kg siratro and 4 kg grass seed per hectare. After sowing, all plots were sprayed with insecticide to minimise seed theft by ants. Molybdenised superphosphate (9.6% phosphorus, 10% sulphur, 0.02% molybdenum) was broadcast on all plots at 100 kg/ha. Thereafter, annual dressings of superphosphate at 100 kg/ha were applied in December of 1979, 1980, 1981 and 1982. The experiment was completed in June 1983.

Sward management

Grass on the experimental area was burnt in October 1978. Between burning and sowing, grass in the broadcast and sod-sown plots was mown to a height of 4 cm whenever sward height exceeded 10 cm. Dry conditions meant that mowing was required only twice.

In order to control growth of native grasses and minimise competition to establishing seedlings, the native grasses were slashed to a height of 8–10 cm whenever sward height exceeded 25 cm, from sowing until onset of the first winter (June 1979). Thereafter, all pastures were slashed to a height of 10–15 cm following each yield and botanical composition determination in years 2, 3 and 4, cut material being returned to the plots. However, pastures were not slashed following the sampling immediately preceding onset of winter to maximise seeding of sown species.

Sampling procedure

The first day on which sufficient rain fell to cause seedling emergence (February 10, 1979) was designated the starting date (day '0'). During the first 4 months, the sampling procedure was specifically designed to measure pasture establishment. In the subsequent three growing seasons, population dynamics, production and botanical composition of pastures were measured.

Pasture establishment. Seedling emergence and seedling survival were estimated 16, 37, 58, 79 and 100 days after initial germinating rains by counting the number of siratro and grass seedlings in 10 quadrats (50 x 20 cm) in each plot. Quadrats were placed at random in the broadcast and herbicide plots. In sod-sown plots the three inner strips, out of the total of five, were sampled. Establishment was expressed as a percentage of viable seed sown.

Yield of green herbage in each plot was estimated by the "botanal" technique (Tothill *et al.* 1978) on February 14, 1979 (day 4) to provide an index of plant competition. Soil water potentials at depths of 5, 10 and 30 cm, were monitored in replicates one and two of the sod-sown and herbicide plots using gypsum blocks. Measurements were made at 2- to 3-day intervals over the first 60 of the 100-day establishment period.

Population dynamics. Two fixed quadrats, each 1 m by 0.5 m, were established in each plot in replicates one and two. Grass and legume seedlings present on day 18 (February 28, 1979) were tagged with coloured wire and their survival monitored until June 1983. They were checked every 2–4 weeks until the first winter, after which sampling was carried out at 4- to 6-weekly intervals during the growing period (October–May). New seedling cohorts were tagged with different coloured wire and their survival studied. Median size of tagged seedlings in each quadrat was estimated on day 100 (May 22, 1979).

Yield and botanical composition. Yield and botanical composition of the pastures were estimated by the "botanal" technique on 10 occasions between February 28, 1980 and June 1, 1982. Three or 4 estimates were made each growing season, the first estimate for the season being made after there had been 6–8 weeks of growth following the last frost (October). Estimates were then made at 8-weekly intervals throughout the growing season until frosts were encountered during the next winter (June). Ten quadrats (40 x 40 cm) were taken in each plot.

Statistical analysis

All variables were analysed by analysis of variance after suitable transformation of data. Protected least significant differences (Snedecor and Cochran 1980) were used to examine differences between treatment means, and back-transformed means are presented in all tables and figures.

Results

Results are presented in two sections. The first section deals with the establishment phase, and covers the period from seedling emergence to onset of the first winter (February 10–May 23, 1979). The second section deals with development and production aspects of the pastures, and covers the 4-year period from May 1979 to the end of the experiment.

Pasture establishment phase

Weather conditions. At sowing (January 9, 1979), conditions were dry. With the exception of 4 small falls of rain, which yielded a total of only 6 mm, hot dry conditions continued for the remainder of January. During this period daily maximum temperatures ranged from 28 °C to 40 °C. Seedling emergence was triggered by a 55-mm rain event on February 10, 1979. Another 28 mm of rain was received 7 days later. Rainfall for the establishment phase was close to the long term median values with monthly totals of 99, 66, 25 and 18 mm being recorded for February, March, April and May respectively; the 94-year median monthly values being 73, 62, 33 and 29 mm, respectively. This rainfall resulted in periods of adequate soil water punctuated by periods of stress of varying lengths, depending on the tree and seedbed treatments.

Competition during the establishment phase. Competition for the establishing seedlings came from the green component of the native pasture biomass in the cleared and killed tree areas and from both live trees and green native pasture in the area with live trees. Therefore, while the yields of green native pasture (Table 1) are a good indicator of the amount of competition present at emergence in the cleared and killed tree areas, they reflect only part of the competition where live trees were present. On the other hand, soil water potentials reflect the competition present in the sod-sown and herbicide plots (not measured in broadcast) in all tree treatments, even though they do not account directly for competition for nutrients.

The yield of green herbage at day 4 was higher in the cleared area than in areas where the trees were killed or live trees remained (Table 1). In the absence of live trees the amount of green native grass was significantly higher ($P < 0.05$) in the broadcast and sod-sown than in the herbicide plots; only in the cleared area was it higher in broadcast than in sod-sown (Table 1). In the

Table 1. Yield of green native pasture present 4 days after the start of establishment rains and the percent green of the total herbage biomass.

Seedbed	Trees					
	Cleared		Killed		Live	
	Yield	Green	Yield	Green	Yield	Green
	(kg/ha)	(%)	(kg/ha)	(%)	(kg/ha)	(%)
Broadcast	804	95	222	97	114	94
Sod-sown	663	93	197	96	87	96
Herbicide	258	25	20	8	28	5

5% LSD — between tree treatments: yield 178, % green 10
— between seedbed treatments: yield 106, % green 10

Table 2. Number of days in which soil water potentials at 2 depths in the sod-sown and herbicide seedbeds fell within the 3 ranges during the first 60 days of establishment.

Soil water potentials	Depth	Trees					
		Cleared		Killed		Live	
		Sod-sown	Herbicide	Sod-sown	Herbicide	Sod-sown	Herbicide
(MPa)	(cm)	(Number of days)					
> −0.7	5	36	44	48	50	31	25
	10	45	49	52	54	41	33
−0.7 to −1.5	5	10	6	8	7	15	15
	10	7	6	5	5	11	23
< −1.5	5	14	10	4	3	14	20
	10	8	5	3	0	8	8

cleared tree area a significant number of speargrass seedlings established in the herbicide plots after light falls of rain, which fell between spraying the herbicide and emergence. This resulted in significantly higher grass competition in the herbicide plots of the cleared area than in the herbicide plots of the killed and live tree areas (Table 1).

Soil water potentials have been grouped into three categories: those in the 0 to −0.7 MPa range, where plant growth would be expected to occur; those in the −0.7 to −1.5 MPa range, where little growth would be expected; and those less than −1.5 MPa, where severe stress and seedling death might be expected. Frequency and intensity of moisture stress were greater in sod-sown than in herbicide plots of the cleared tree area ($P<0.05$), particularly at a depth of 5 cm. Soil water potentials remained higher for longer in the killed tree area, and there was no difference between sod-sown and herbicide plots. Potentials remained low in all seedbeds where live trees were present (Table 2).

Seedling establishment. Seedling numbers of siratro and both grasses were generally highest where the trees were killed at sowing and lowest where there were live trees present. They generally reached a maximum after 16 days and then progressively declined. The exception to this trend was siratro in the herbicide plots in the two areas without live trees, where numbers increased by about 10% between days 16 and 58 (Figure 1).

On average, pasture establishment at day 16 was highest in sod-sown plots and lowest in broadcast, establishment in herbicide plots being intermediate (Figure 1).

The decline in seedling numbers between days 16 and 100 was most rapid in the broadcast and sod-sown plots where trees had been cleared, and in all seedbeds where there were live trees. Siratro survived better than the two grasses in all treatments, except for the broadcast plots of the live and cleared tree areas, where all seedlings died. Siratro survived better in sod-sown plots where trees were killed at sowing rather than where they were cleared 6 years prior to sowing (Figure 1). Despite the poor overall establishment of signal grass, its seedlings survived better than those of green panic.

Pasture development and production phase

Seasonal weather conditions. Both summer and autumn rainfall were below average during the first 2 growing seasons and above average in the remaining 2 growing seasons. Spring rainfall was about average for all years except that of 1982–83 which was dry.

Population dynamics of the pastures. Survival of the original siratro plants over 4 years was influenced by both tree and seedbed treatments ($P<0.05$). Best survival was recorded in the herbicide plots of the cleared and killed tree area, with 70–80% of plants surviving until June 1983 (Table 3). On the other hand, none of the original siratro plants survived in broadcast plots of the cleared tree area and survival was relatively poor in all seedbeds where live trees were present. Survival of siratro in sod-sown and broadcast plots was significantly better where the trees were killed at sowing than where they were cleared 6 years before sowing (Table 3).

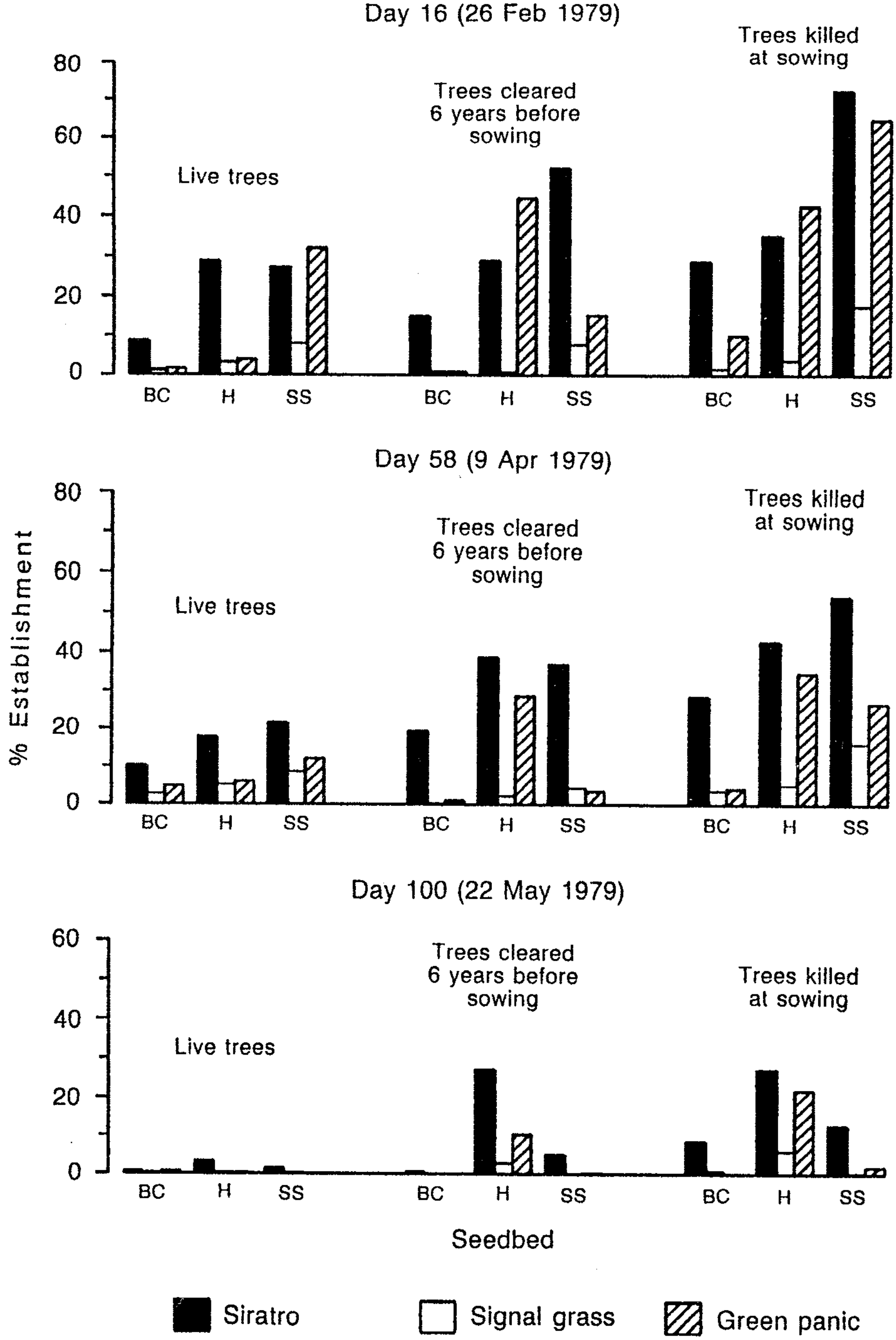

Figure 1. Establishment (% of viable seed sown) of siratro, signal grass and green panic 16, 58 and 100 days after germinating rains where seed was broadcast into either live (BC) or herbicide-treated (H) speargrass, or sod-sown into live speargrass (SS). The 3 seedbeds were superimposed on pasture where live trees were present, where the trees had been cleared 6 years before sowing or where the trees were killed at sowing.

Table 3. Percentage of original (a) siratro and (b) sown grass (average of green panic and signal grass) plants surviving 4 years after sowing (June 8, 1983).

Tree clearing strategy	Seedbed		
	Broadcast	Sod-sown	Herbicide
		(%)	
	(a) Siratro survival		
Live trees	3.6 Aa[1]	10.3 Aa	13.9 Aa
Trees cleared 6 years before sowing	0 Aa	14.0 Aa	79.5 Bb
Trees killed at sowing	26.9 Ba	42.3 Ba	72.4 Bb
	(b) Grass survival		
Live trees	0 Aa	8.0 Aa	9.0 Aa
Trees cleared 6 years before sowing	0 Aa	0 Aa	12.9 Aa
Trees killed at sowing	0 Aa	10.5 Aa	48.0 Bb

[1] Mean separation: *Between tree clearing strategies and within seedbeds* — means followed by the same upper case letter are not significantly different at the 5% level.
Between seedbeds and within trees — means followed by the same lower case letter are not significantly different at the 5% level.

Seven seedling emergence events occurred during the third (1980–81) and fourth (1981–82) growing seasons from seed that had been set by the original siratro plants in the killed and cleared tree areas. The number of seedlings emerging tended to reflect the number of original siratro plants surviving but this effect appeared to decline with time. Newly-emerged siratro seedlings generally survived only 2–3 months, except for seedlings which emerged during the wet summer of 1981–82; they survived 12–18 months before dying (Figure 2). By June 1983, only 3 of the 112 tagged siratro plants originating from emergence events other than the initial one survived, meaning that over 97% of the population at the end of the experiment was plants that had established and survived from the original sowing (Figure 2). In the live tree area, siratro growth was always poor, there was no seed set and no additional seedling cohorts appeared during the 4 years of the experiment.

Survival of tagged grass seedlings followed a similar pattern to siratro. The herbicide plots of the killed tree area were the only ones where significant grass survival was recorded (Table 3). No sown grass plants survived in any of the broadcast plots or in the sod-sown plots where trees were cleared. Grass survival in all other seedbeds was relatively low.

On average, signal grass seedlings survived better than did green panic seedlings ($P<0.05$) with about 10% of the original plants surviving to June 1983, compared with less than 2% of the green panic plants (data not presented). Survival of grass seedlings was generally less than that of siratro in comparable treatments and fewer seedling emergence events occurred for grass in years 2, 3 and 4, despite prolific seeding of green panic at various times. Signal grass set far less seed than green panic, and fewer seedlings emerged.

Pasture yield and botanical composition. Pasture yields during the 3 growing seasons following the establishment phase largely reflected seasonal rainfall, the presence or absence of live trees and the proportion of sown species making up the yields. In all 10 growth periods for which yield and botanical composition were estimated, the 2 areas without live trees produced between 2 and 8 times the yield of the pasture in the area with live trees ($P<0.001$ for all periods). Presentation yields of pastures averaged 850 kg/ha DM at the end of each 8-week period where there were live trees, while those without live trees yielded 3400 kg/ha, with no difference in pasture yields between the cleared and killed tree areas in any period. Initially, yields were lower in the herbicide plots of the killed and live tree areas. However, by the start of the second growing season (October–November 1980) these effects had largely disappeared, especially in the killed tree area, where the sown species were making an increased contribution to pasture yield. From that point on, the highest pasture yields were recorded in those plots with the greatest proportion of sown species (Figure 3).

On average, siratro contributed around 30% of the pasture yield in herbicide plots, but less than 10% in broadcast plots. However, the proportion of sown species contributing to the yield

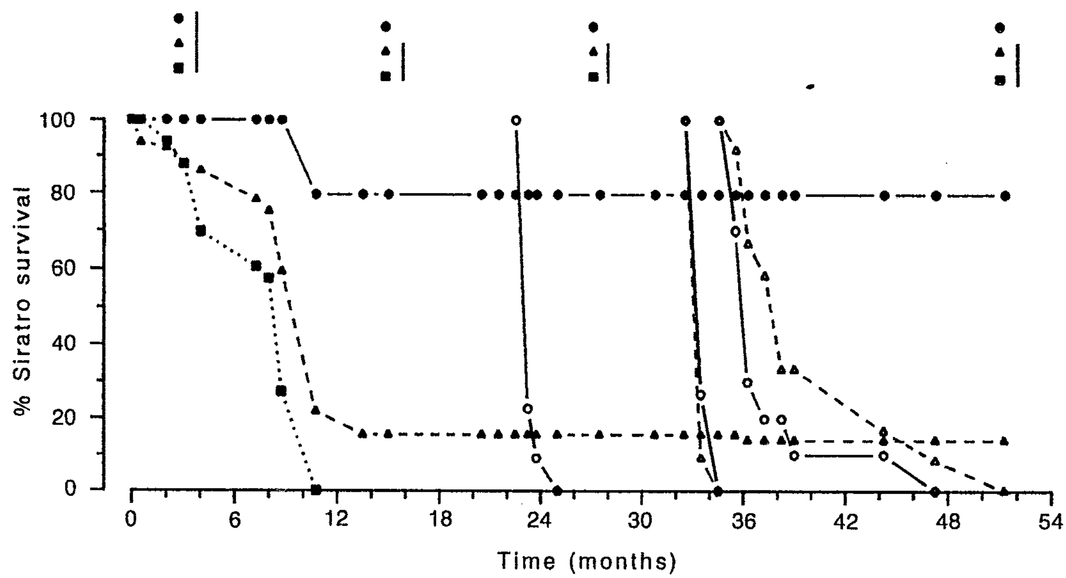

Figure 2. Population dynamics of siratro plants in 3 seedbeds (■.... ■ broadcast; ▲----▲ sod-sown; ●—● herbicide) where trees were cleared 6 years prior to sowing. Solid symbols represent initial establishment, open symbols later cohorts. Only cohorts with greater than 10 plants are shown. *Mean separation:* side-scored symbols indicate points which are not significantly different ($P<0.05$).

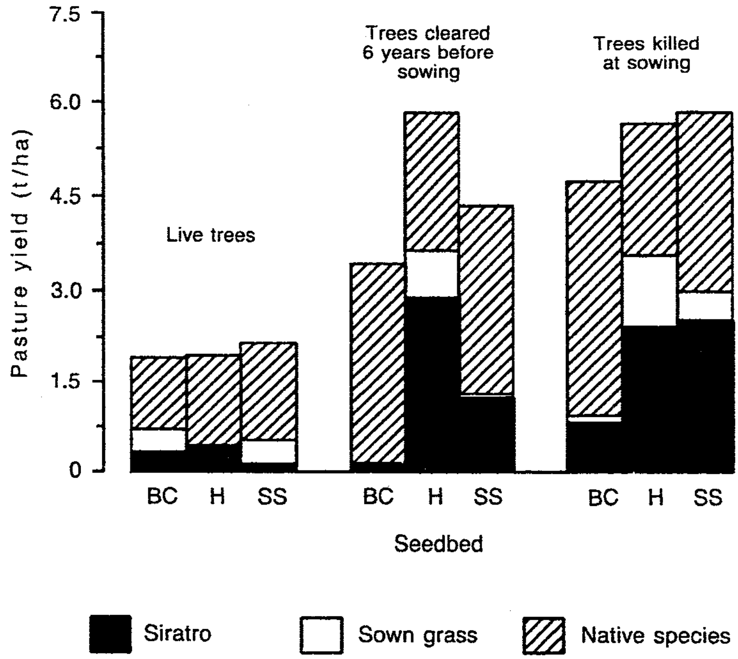

Figure 3. Siratro, sown grass and total pasture yields in the various tree-seedbed treatments for the December 1981–January 1982 growth period, 3 years after sowing.

of broadcast and sod-sown plots also depended on tree treatment, particularly during the 1980–81 and 1981–82 growing seasons, and is illustrated by the data in Figure 3.

The sown grass component increased with time in the hebicide plots without live trees and, to a lesser extent, in the sod-sown plots of the killed tree area. This resulted in sown grasses contributing about 30% of the pasture yields of the herbicide plots in these areas over the 1981–82 growing period. Over the same period, the sown grasses contributed a maximum 10% of yield in the sod-sown plots of the killed tree area, but never exceeded 5% in the other sod-sown or broadcast plots of any tree treatment. There was never any difference between green panic and signal grass in terms of their contribution to pasture yield, despite large differences in initial establishment.

Discussion

The control or management of plant competition during the first 3 months of establishment was a key factor in determining the final pasture establishment and, ultimately, the production of the different pastures that developed. In treatments where there was a significant reduction in competition, such as in the herbicide plots of the two areas without live trees, there were better seedling growth rates (data not presented), better seedling survival (Table 3) and more productive pastures with a greater proportion of sown species (Figure 3). Sowing pastures beneath live trees in these drier sub-coastal areas of southern Queensland would appear to be a waste of time and money.

Adequate control of plant competition required the killing of both live trees and native herbage. When the tree and seedbed treatments were ranked in decreasing order of establishment and growth over the first 100 days, the following was obtained: killed herbicide > cleared herbicide > killed sod-sown > killed broadcast > cleared sod-sown > cleared broadcast > live herbicide > live sod-sown > live broadcast. Only the first 3 seedbeds produced pastures with more than 30% sown legume during peak summer growing periods, while only the herbicide plots in the killed and, to a lesser extent, cleared tree areas contained more than 20% sown grass (Figure 3). The fact that the 3 seedbeds in the area with live trees ranked second, third and fourth lowest in terms of the amount of green native grass at day 4 (Table 1) suggests that the live trees were providing the bulk of the competition in these seedbeds. Furthermore, there were twice as many days with soil water potentials less than -1.5 MPa in the herbicide plots with live trees, compared to those in the cleared area (20 *v.* 10, Table 2), despite there being almost 10 times the amount of green grass in the herbicide plots of the cleared area (Table 1).

The results of this experiment, and that of Cook (1984) have shown that it is possible to manage plant competition by strategically timing the removal of the trees and pasture sowing operations. In open forest areas, where live trees significantly limit the growth of the native grass understorey, the tussocks of the native grasses have smaller basal areas than those in areas where the trees have been cleared for some time. They also appear to be more easily killed by herbicide. The relatively large number of speargrass seedlings that established in the herbicide plots of the cleared tree area, compared with virtually none in the area where the trees were killed at sowing, suggests that the soil seed reserves of the native grasses were very low or insignificant in areas where live trees were present. This hypothesis is supported by the observation that the growth of the sown species that survived beneath live trees was always poor, with little or no seed set, even during wet years. This contrasts with the often heavy seed set in the 2 areas without live trees. Hence, not only was less competition present where the trees were killed at sowing, but less competition redeveloped in the herbicide plots after spraying, compared with the area where trees had been cleared for 6 years (Table 1).

Reduced levels of plant competition (Table 1), whether the result of herbicide treatment, strategic timing of tree clearing, or both, led to soil moisture conditions that were more favourable for seedling growth than seedbeds where higher levels of plant competition were present (Table 2). Both sown grass and siratro seedlings were significantly larger in these treatments (data not presented) and a high proportion of the seedlings survived. On the other hand, most of the smaller seedlings, especially those in the broadcast plots, either died within the first 3 months (Figure 1) or died subsequently (Table 3), a result similar to that obtained by Cook (1984).

The marked improvement in seedling emergence from sod-seeding both legumes and grasses, compared with broadcasting the seed on the soil surface, is clearly evident in Figure 1. However, in the area that had been cleared of trees 6 years prior to sowing this advantage was lost, largely because the disturbance was not sufficient to adequately control plant competition. Lowe and Bowdler (1991) suggested that at least 75% of the basal cover of the native grasses needed to be removed before reliable establishment of siratro could be expected. It is worthy of note that other successes in establishing siratro into native speargrass pastures in this environment (Tothill 1974) also occurred in a situation where the trees were killed at sowing.

The importance of achieving a good initial establishment of legumes such as siratro is emphasised by the fact that, even after 4 years, over 97% of the siratro population was made up of plants which had established and survived from the initial emergence event. Even though large numbers of seedlings emerged in subsequent years, very few of these survived (Figure 2). Reliable establishment may only be possible when there is sufficient disturbance to provide adequate control of plant competition. Similar results have been obtained in grazed pastures at Narayen (Jones and Mannetje 1986). A build-up of siratro population over time therefore appears less reliable than previously thought in these drier subcoastal environments (Cook and Dolby 1981). Nevertheless, the data of Figure 3 demonstrate that it is possible to establish productive pastures based on legumes such as siratro using low input techniques, provided that plant competition is adequately managed or controlled, even in years of below-average rainfall.

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