STUDIES WITH PASTURE GRASSES ON THE BLACK CRACKING CLAYS OF THE CENTRAL HIGHLANDS 1. SPECIES EVALUATION

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ABSTRACT

A range of grasses was evaluated for establishment, persistence, soil covering properties and yield on the heavy black self-mulching open downs soils of central Queensland in a series of row and sward plantings. Bothriochloa insculpta *cv. Hatch was shown to be a potentially useful grass. Following rainfall after planting, reasonable stands of* Cenchrus ciliaris *cv. Nunbank,* Panicum coloratum *var.* makarikariense *cv. Pollock,* Urochloa mosambicensis *and* Dichanthium aristatum *were also obtained.*

The establishment of these grasses was satisfactory, resulting in post-harvest ground cover of 50–60 *per cent, thirty months after planting. The initial total ground cover, before harvesting, of* B. insculpta *was outstanding at* 82 *per cent four months after sowing. Observations on ground cover were recorded in* 1977 *after burning and in* 1978 *after grazing.*

B. insculpta *produced the highest yield of dry matter with* 17,000 *kg per hectare in* 1974 *and the highest total yield of* 26,500 *kg per hectare for the three years* 1972–1974. C. ciliaris *produced the highest yields of dry matter in* 1972 *and* 1973 *with* 6,500 *and* 5,250 *kg per hectare respectively.*

The highest yield response to applied nitrogen was shown by B. insculpta, *with yield increases of* 26 *and* 12 *per cent in* 1973 *and* 1974, *respectively.*

INTRODUCTION

The most commonly cultivated soils in the Central Highlands are the black self-mulching, cracking clays, locally known as "open downs". They are almost treeless, have a rolling topography and are easily eroded by water following periods of cultivation.

The depth of these black cracking clays varies from 20 to 140 cm. They are derived from basalt and other basic volcanic rocks and have a fine, granular, self-mulching surface layer 25–50 mm deep.

The pH is neutral to mildly alkaline at the surface and increases with depth. Blue grasses (*Dichanthium* spp.) were originally dominant but as a result of heavy grazing over a number of years, these have been replaced by less desirable species such as native millet (*Panicum decompositum*), Yabila grass (*P. queenslandicum*), white spear grass (*Aristida leptopoda*) and feather-top (*A. latifolia*) (Story *et al.* 1967, Gunn *et al.* 1967). Perennial and annual weeds have also increased with cultivation.

Pastures are required for soil stabilization as the exploitation of virgin land for cropping increases. Species should have good establishment ability, ground cover and persistence. Fodder production is of secondary importance, but could become relevant if it provides economic returns on the shallow, steep and rocky soils which are presently at the greatest risk from erosion or are difficult to cultivate.

The introduction of a grass phase into a rotation based solely on cash cropping could become important as a means of improving soil structure and fertility, alleviating 'long fallow disorder' and controlling perennial weeds.

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Leslie (1965) in his work on similar soils on the Darling Downs area of Queensland showed that seedling emergence was the major problem. In this environment and with shallow or surface sown seed, germination and establishment could be important and although the significance of emergence on crusting soils was recognized it was hoped that this could be overcome by species selection and/or seedbed modification.

The climate of the area is subhumid tropical to subtropical with an annual rainfall for Emerald of 630 mm, of which 72 per cent falls from October to March. The amount and distribution of rain vary considerably from year to year. Temperatures are mild in winter with some frosts (light frosts average 11 per year and heavy frosts 2.6 per year), whilst summers are hot with the maximum temperatures exceeding 32.2°C on 125 days per year, and 37.8°C on 19 days. Evaporation exceeds rainfall every month of the year, varying from 63.5 mm in June to 267 mm in January (Bureau of Meteorology, 1962).

The aim of this study was, primarily, to select grasses capable to establishing and persisting on this soil for use in soil stabilization and, secondly, to measure dry matter production and response to applied nitrogen.

METHODS AND RESULTS

The experiments were carried out on a site, 2 km east of Emerald, representing Unit 2 of the Oxford Land System (Story *et al.* 1967, Gunn *et al.* 1967). Annual rainfall varied from 488 to 929 mm over the experimental period (Table 1). The soil was a Ug 5.12 (Northcote 1974). The site had a slope of one per cent and the soil depth varied from 60 to 90 cm. Soil analysis of the top 10 cm showed the following results:

	Nov. 1970	Aug. 1973	
Applied N (kg ha^{-1})	Nil	Nil	100
pH	7.1–7.7	7.5	7.0
Acid extractable P (p.p.m.)*	21–42	28	32
Extractable K (m. equiv. %)	0.20–0.40	0.39	0.42
(NO_3)N–(p.p.m.)	3–6	3	6
Total N (%)	0.03–0.05	0.05	0.05

* Kerr and von Stieglitz (1938).

TABLE 1

Monthly and annual rainfalls (mm) for Emerald for the years 1969-74 and long term average

Month	1969	1970	1971	1972	1973	1974	Average 1883-1974
January	179	91	78	63	98	420	108
February	10	142	158	168	38	55	100
March	64	3	30	74	68	47	71
April	0	3	15	1	13	22	34
May	43	0	11	24	26	34	28
June	2	7	6	4	27	6	36
July	2	0	22	0	99	1	27
August	0	12	99	5	28	42	22
September	0	49	14	0	38	30	24
October	78	19	4	12	22	26	37
November	32	101	24	79	110	70	57
December	114	139	79	59	285	174	87
Total	524	566	581	489	850	927	631

Experiment 1. *Preliminary studies*

On 19th November, 1969, a range of grasses was planted in unreplicated plots, each consisting of two rows 0.36 m apart. The rows were 6.7 m long and each pair was separated by a gap of 1.1 m. Seed was sown by hand after dusting with an insecticide (B.H.C.) and a fungicide (thiram) and covered with 10 mm of fine soil. The grasses planted, with numbers of accessions in parentheses, were *Dichanthium aristatum* (5), *D. annulatum* (1), *D. sericeum* (3), *Dactyloctenium giganteum* (2), *Da. aegypteum* (1), *Panicum coloratum* (4), *P. maximum* (4), *Bothriochloa insculpta* (1), *Cenchrus ciliaris* (2), *Urochloa mosambicensis* (1), *Eragrostis abyssinica* (3) and *Astrebla lappacea* (1). A second planting was made on 1st December, 1970 when seed became available, with *P. maximum* (3), *Da. giganteum* (2), *P. coloratum* (1) and *C. ciliaris* (1). The plots were sprayed with 2,4,5-T for broadleaf weed control.

Results

The grasses which established and persisted best were *Panicum coloratum* var. *makarikariense* cvv. Bambatsi, Burnett and Pollock, *Dichanthium aristatum, Urochloa mosambicensis, Panicum maximum* cv. Gatton, *Bothriochloa insculpta* cv. Hatch, *Dactyloctenium giganteum* Q10091 and *Astrebla lappacea.* The latter was killed when sprayed with 2,4,5-T.

Experiment 2

Eight grasses (Table 2) were planted in 6 m × 1 m plots in a four replicate randomized block design on 11th November, 1970. Plots and sowing technique were as described for Experiment 1. Sufficient seed, based on pure live seed, was sown to give 100 viable seeds per plot. Established plants were counted on 22nd January and 18th November, 1971, except for *B. insculpta* at the second count. Percentage total ground cover was estimated on 25th May and 18th November, 1971, using a 10-point quadrat; five quadrats (50 points) were taken per plot. Plots were harvested, by autoscythe, to 7 cm on 12th March, 1971 for dry matter yield, except for *B. insculpta* which was not cut because of its prostrate growth habit.

Results

Following seven consecutive wet days in December, 1970, all grasses germinated and established. *D. aristatum* and *B. insculpta* gave best establishment and earliest effective (> 50%) total ground cover. Twelve months after sowing ground cover of *B. insculpta* was 82 per cent and *Urochloa mosambicensis* and *D. aristatum,* 66 per cent. *U. mosambicensis* and *Dactyloctenium giganteum* produced highest yields of dry matter and protein (Table 2). *Da. giganteum,* an annual, did not regenerate, although, like the other grasses, it flowered well.

Experiment 3

There were various reasons for the choice of species and cultivars in this experiment. Some were chosen as a result of their performances in Experiments 1 and 2. The *P. coloratum* cultivar Pollock was chosen because seed was readily available. *C. ciliaris* was included in Experiments 2 and 3, despite the fact that it had not performed well in Experiment 1, because it was the only exotic grass species being used to any extent in the area. The cultivar Molopo was used in experiment 2 because it is considered by some graziers to be the best buffel grass for grazing. When it established poorly in Experiment 2 and was by far the worst in an establishment test with seven buffel cultivars (unpublished data) it was dropped in favour of Nunbank, which appears to establish better than others on heavy black soils.

This trial was a 5 × 5 latin square split for nitrogen. Five grasses (Table 3) were planted on 20th December, 1971 in 8.25 m × 5.6 m plots. The seed (after fungicide and insecticide treatment) was mixed with damp sawdust prior to hand broadcasting on a well prepared seedbed and covering by cross harrowing. Before planting, superphosphate at 100 kg ha^{-1} was drilled in over the whole trial area to a depth of 5 cm.

TABLE 2

Grasses sown, seeding rates, mean populations, ground cover estimates, dry matter yields and protein yields in Experiment 2

Grass	Seeding Rate (kg ha⁻¹)	Plants m^{-2} 22 Jan 1971	Plants m^{-2} 18 Nov 1971	% Ground Cover 25 May 1971	% Ground Cover 18 Nov 1971	Dry matter (kg ha⁻¹) 12 Mar 1971	Protein (kg ha⁻¹) 12 Mar 1971
Cenchrus ciliaris cv. Molopo	1.9	0.49 (1.85)"	0.49 (1.85)	5	14	1 700	210
Dactyloctenium giganteum Q10091	0.3	0.65 (2.09)	0.00 (0.00)	22	0=	4 300	550
Astrebla lappacea	4.3	1.14 (2.71)	0.94 (2.47)	8	14	2 100	290
Panicum coloratum var. *makarikariense* cv. Pollock	1.6	0.78 (2.27)	1.00 (2.55)	10	26	1 800	260
Urochloa mosambicensis cv. *Nixon*	1.2	1.62 (3.20)	1.33 (2.91)	40	66	4 800	600
Dichanthium aristatum (commercial seed ex Bloomsbury)	1.2	3.75 (4.80)	2.92 (4.25)	60	66	2 200	210
Panicum maximum cv. Gatton	1.4	1.35 (2.93)	1.28 (2.86)	18	34	3 000	370
Bothriochloa insculpta cv. Hatch	2.9	3.36 (4.55)	+ +	68	82	S	S
L.S.D. (P=0.05)		(0.85)	(0.75)	9	11	974	124

" Transformed by x + 0.05 on a plot basis of 6 m²
+Too difficult to count
=Failed to regenerate
S Not possible to cut in a comparable way to other entries

At the same time, three levels of nitrogen as ammonium nitrate (0, 50 and 100 kg N ha^{-1}) were drilled into the split plots. The main plots were split lengthways to give three 8.25 m × 1.9 m subplots and the nitrogen levels applied at random. Only the first fertilizer application was made in this way; in April, 1973 and on 5th March, 1974 the centre subplot in each main plot was fertilized with 100 kg N ha^{-1} as ammonium sulphate and the outer two subplots were left unfertilized.

Emerged plants were counted on 24th January, 1972 in five 0.92 m × 0.92 m quadrats per subplot. Total ground cover was determined in each plot on 10th April, 1972 at ten stations of a 10-point quadrat. Cover was determined, by the same method, after yield harvests on 16th March, 1973, 13th February, 1974 and 8th July, 1974.

Yields were measured from an 8.25 m × 0.92 m strip cut from the centre of each subplot by an autoscythe in 1972 and an 8.25 m × 1 m strip cut with a forage harvester modified to catch and weigh (Younger 1973) in 1973 and 1974. Cutting height was 5 cm on all occasions. Bulk samples were drawn at each harvest for nitrogen determination. Dry matter yields were measured by drawing samples from each sample cut and drying in paper bags for 48 hours at 80°C. Yields were taken twice each year from 1972 to 1974 except in 1972 when two species (*P. coloratum* and *D. aristatum*) had not grown sufficiently well to cut at the first harvest on 2nd March, 1972. Because of its early prostrate growth habit, the first harvest of *B. insculpta* was delayed until 13th March 1972. Thereafter all accessions were harvested at the same time on 20th April, 1972, 2nd February and 6th August, 1973 and 6th February and 11th June, 1974.

Seed yield was measured at optimum periods. The method of sampling was to cut the seedheads from two 0.92 m × 0.92 m quadrats in each subplot, air dry for several days, then separate the seed by hand.

Results

Rain fell on six consecutive days after sowing and acceptable stands were obtained for four of the five species sown. *B. insculpta* and *C. ciliaris* were very good but *U. mosambicensis* was sparse (Table 3). Initially, the ground cover of *B. insculpta* was outstanding but by July, 1974, all species had evened up at round 55–60% (Figure 1).

TABLE 3

Field establishment of seed used in Experiment 3

Grass	Viable Seed Sown (m^{-2})	Plants Established (m^{-2}) 24 Jan 1972	Viable Seed Established %
Panicum coloratum var. *makarikariense* cv. Pollock	756	8.5 (2.9)†	1
Cenchrus ciliaris cv. Nunbank	414	45.7 (6.7)	11
Urochloa mosambicensis cv. Nixon	77	2.6 (1.6)	3
Dichanthium aristatum	68	5.6 (2.3)	8
Bothriochloa insculpta cv. Hatch	196	57.0 (7.5)	29
L.S.D. (P=0.05)		(0.7)	

† Square root transformation used

Considering mean dry matter yields over all levels of applied nitrogen, *Cenchrus ciliaris* gave the highest total yield in 1972, significantly outyielding the other grasses ($P < 0.01$). Of the other four grasses *U. mosambicensis* and *B. insculpta* outyielded ($P < 0.05$) *D. aristatum*. In early 1973 only *D. aristatum* and *U. mosambicensis* yielded less than *C. ciliaris* ($P < 0.05$) and in 1974 *U. mosambicensis* was significantly lower yielding and *B. insculpta* significantly higher yielding than the other three

(Figure 2). For the 3-year period *B. insculpta* was the highest yielding and *D. aristatum* and *U. mosambicensis* were the lowest yielding ($P < 0.05$) (Figure 2).

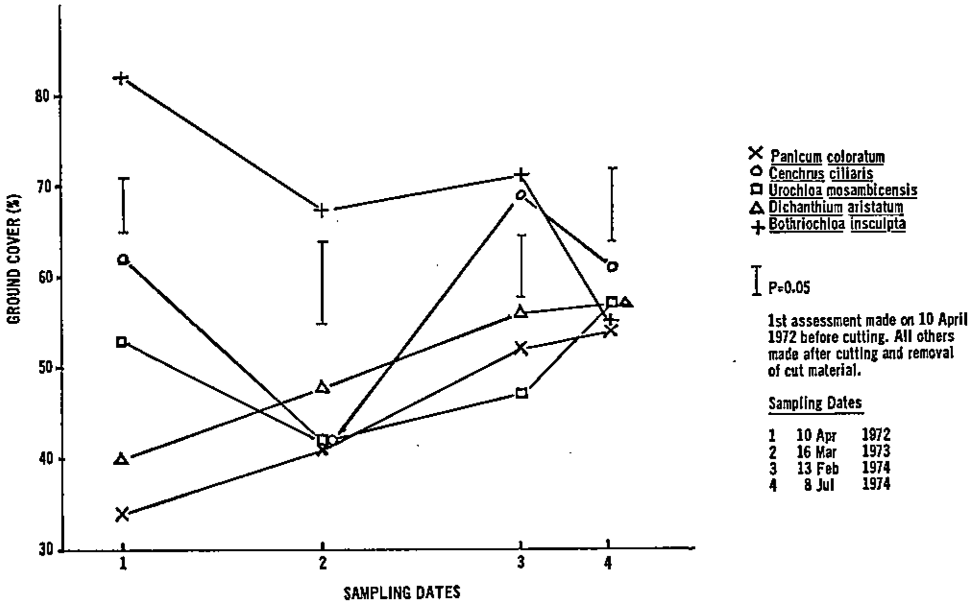

FIGURE 1

Changes in total ground cover (%) of five grasses with time (Experiment 3).

In 1972, mean N concentration was 2.4% and there were no significant responses to nitrogen, whereas in subsequent years, when nitrogen was applied in mid season at 100 kg N ha^{-1}, a significant yield response was obtained ($P < 0.05$) from *C. ciliaris, B. insculpta* and *U. mosambicensis* in 1973, and all except *D. aristatum* in 1974. Over the 3-year period the response to applied N was non-significant for *P. coloratum* and *D. aristatum* (Figure 3).

The actual responses at the harvest immediately following the 1973 and 1974 applications of 100 kg N ha^{-1} are shown in Table 4. Overall, *B. insculpta* responded most to applied nitrogen, followed by *C. ciliaris*.

Nitrogen content of the dry matter harvested in 1973 and 1974 was variable both between species and between harvests, with a consistent increase after application of 100 kg N ha^{-1} in 1974 but not in 1973. The 1974 figures were lower than those for 1973 (Table 5).

Seed yields of *B. insculpta* in July, 1973 and *B. insculpta* and *D. aristatum* in June, 1974 were increased by the application of 100 kg nitrogen per hectare (Table 6).

In mid-November, 1976, the trial was burned to test recovery of the grasses as this will be the most likely method used to remove excess growth in waterways, drainage structures, etc. The trial had not been defoliated for over two years and the burn was severe. All grasses survived with *P. coloratum, D. aristatum* and *B. insculpta* showing best recovery (> 40% total ground cover) on 3rd April, 1977.

All grasses except *U. mosambicensis* were present and providing > 40 per cent ground cover in July, 1978 after six months grazing. The *U. mosambicensis* plots had nearly been taken over by *D. aristatum* and *B. insculpta*. Whereas all other plots had been invaded to a small extent by mainly *D. aristatum* and *B. insculpta* the *B.*

insculpta plots had remained pure. All grasses had been eaten by cattle with *P. coloratum* and *C. ciliaris* more closely grazed than *D. aristatum* and *B. insculpta.*

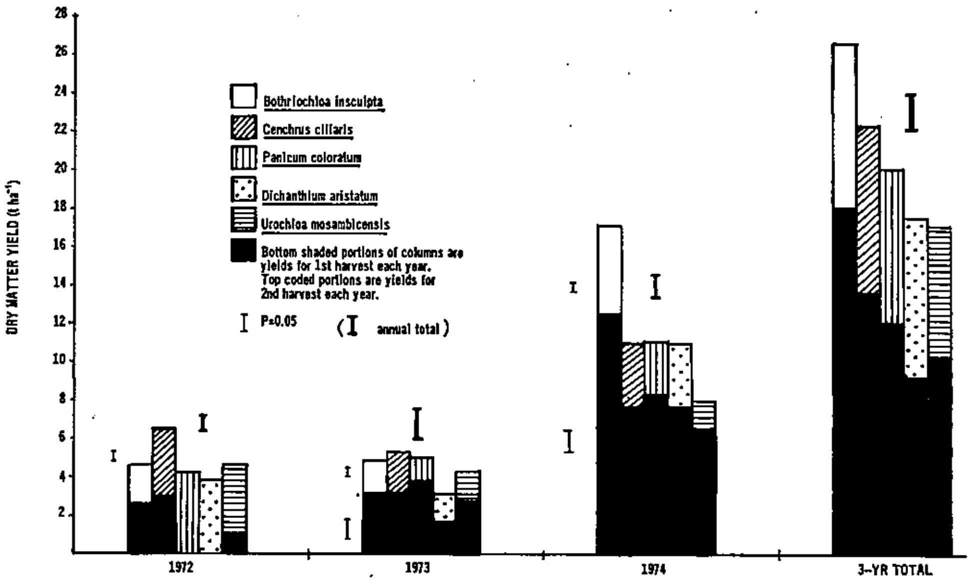

FIGURE 2

Mean dry matter yields of five grasses over all levels of applied nitrogen for 3 years (Experiment 3).

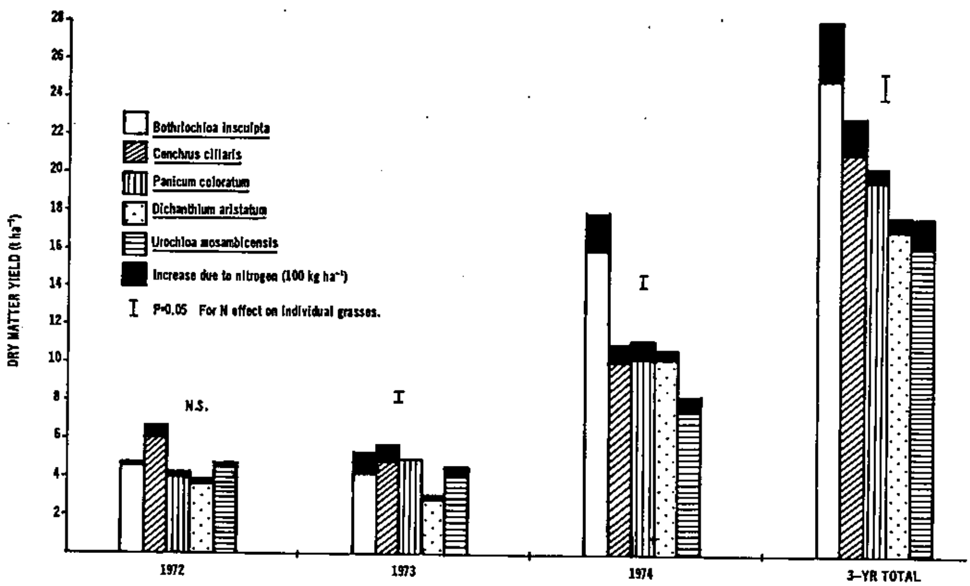

FIGURE 3

Dry matter yields of five grasses with and without nitrogen for 3 years (Experiment 3).

TABLE 4

Dry matter response to applied nitrogen for late harvests in 1973/74 in Experiment 3

Grass	6 Aug 1973				11 Jan 1974			
	N_0 (t ha^{-1})	N_{100} (t ha^{-1})	Mean (t ha^{-1})	Response to N (%)	N_0 (t ha^{-1})	N_{100} (t ha^{-1})	Mean (t ha^{-1})	Response to N (%)
Panicum coloratum cv. Pollock	1.22 (d)*	1.24 (d)	1.23	2	2.09 (ef)	3.02 (bcd)	2.56	45
Cenchrus ciliaris cv. Nunbank	1.66 (cd)	2.53 (a)	2.10	50	2.56 (de)	3.58 (b)	3.07	40
Urochloa mosambicensis cv. Nixon	1.36 (cd)	1.91 (bc)	1.64	40	1.04 (g)	1.85 (f)	1.45	78
Dichanthium aristatum	1.36 (cd)	1.68 (cd)	1.52	24	2.67 (cde)	3.20 (bc)	2.94	20
Bothriochloa insculpta cv. Hatch	1.17 (d)	2.26 (ab)	1.72	93	3.47 (b)	5.39 (a)	4.43	55
MEAN	1.35	1.92			2.37	3.41		

* Values followed by the same letter do not differ at P=0.05.

TABLE 5

Plant nitrogen percentages at early harvests (unfertilized) and at late harvests (with or without 100 kg N) in two years (Experiment 4)

Grass	Feb. 1973	August 1973		Feb. 1974	June 1974		Mean
		N_0	N_{100}		N_0	N_{100}	
Panicum coloratum cv. *Pollock*	1.63	1.39	1.69	0.81	0.61	0.73	1.14
Cenchrus ciliaris cv. Nunbank	1.03	1.16	1.12	0.79	0.66	0.87	0.94
Urochloa mosambicensis cv. Nixon	1.84	1.26	1.83	0.59	0.53	0.94	1.16
Dichanthium aristatum	1.30	1.30	1.21	0.64	0.88	1.17	1.08
Bothriochloa insculpta cv. Hatch	1.52	1.20	1.24	0.44	0.67	0.71	0.96
MEAN	1.46	1.26	1.42	0.65	0.67	0.88	

TABLE 6

Effect of nitrogen on yield of seed in kg ha^{-1} for two grasses in Experiment* 3

Grass	July 1973		June 1974	
	N 0	N 100	N 0	N 100
Dichanthium aristatum	—	—	195	395
Bothriochloa insculpta cv. Hatch	40	85	85	360

*Free from straw and foreign matter but containing empty florets, bracts and awns.

DISCUSSION

The makarikari grasses are regarded as the most reliable establishers on self-mulching heavy black soils in the 650–900 mm rainfall areas of southern Queensland and as being well adapted to them (Lloyd and Scateni 1968). They are excellent pasture grasses when well established, being drought tolerant and palatable. Their slow growth in the first year, however, is a serious disadvantage.

In these experiments *B. insculpta* cv. Hatch proved to be the outstanding grass. Its emergence is satisfactory and it quickly provides good ground cover. It responds well to water and nitrogen and is eaten by cattle (Bisset and Graham 1978). Acceptance by cattle was confirmed by observations in 1978. It produces viable seed from a main flowering in late summer which can be harvested mechanically (Bisset and Graham 1978). A locally made buffel harvester was used successfully on a seed production area at Emerald in July 1978 (C. N. Jacobsen, personal communication). A minor flowering occurs in early summer. Disadvantages from the point of view of soil stabilization are a low capacity to root at stolon nodes and poor spread from shed seed. *Cenchrus ciliaris* cv. Nunbank outyielded *B. insculpta* in the two drier years in 1972 and 1973 and cannot be dismissed as a pasture grass. Being upright in growth it does not have the same ability as *B. insculpta* to protect the soil during the early stages of pasture development.

Establishment conditions were good for both Experiments 2 and 3 with 6-7 days of wet, cloudy weather after sowing. Even so, establishment can only be rated as poor with less than 12 per cent establishment in all species except *B. insculpta*. It is probable that under harsher conditions all except *B. insculpta* would have failed. Sowing time is very important and should precede a period when prolonged rain periods can be expected. Such conditions are likely to occur from December to March.

The ground cover percentages in Experiment 3 in the first year reflected establishment and early vigor. *P. coloratum* and *D. aristatum* were slow whereas *B. insculpta* was quick to establish a network of runners on the soil surface. Ground cover after harvesting was similar for all species by July, 1974, with a marked decline in that of *B. insculpta* from 70 to 55 per cent (Fig. 1). This was due to a gradual change in growth habit with an increase in density with time and the more upright growth habit at flowering. During the early establishment period much of the stoloniferous material lay close to the ground and was left undisturbed after harvesting, but as the pasture matured and became denser, the stolons became entwined in the other leaf material and were removed by the forage harvester. The extent and duration of this early mat-forming habit depends on what bare soil is available. In Experiment 2, there was little population pressure on the *B. insculpta* [3.4 plants m^{-2} and less in all but one of the other species (Table 2)], whereas in Experiment 3 the plots were much larger and the population density greater (57 plants m^{-2}) (Table 3). This is why the *B. insculpta* plots in Experiment 2 could not be cut with the autoscythe in 1971 but could in Experiment 3 in 1972. The dense mat-forming habit of *B. insculpta* made it impossible to count the individual plants in Experiment 2 on 18th November, 1971. It is now believed that the number would not have been different from the count on 22nd January, 1971.

It is believed that the prostrate growing habit of *B. insculpta* would be retained under frequent defoliation and heavy grazing.

The lack of response to nitrogen in 1972 (Experiment 3) was probably due to mineralization during the one year fallow (weedy) prior to sowing. This is indicated by the high average nitrogen content for all species of 2.4 per cent, for the harvested material from the first cuts in 1972, compared with averages of 1.3 and 0.8 per cent for 1973 and 1974, respectively.

The application of nitrogen (100 kg ha^{-1}) prior to the second cuts in 1973 and 1974 resulted in increases of 40–90 per cent except for *P. coloratum* in 1973 and *D. aristatum* in 1973 and 1974. This lifted production in the drier, cooler part of the growing season.

Seed production of *B. insculpta* and *D. aristatum* was noticeably increased by the nitrogen applications and, because of their habit of seeding in one main flush in June and July, were easily harvested. Grasshoppers ate the seed of *P. coloratum* in 1973 and 1974.

None of the grasses showed any increase in plant population after initial establishment either by late germination of sown seed or from seed shed from established plants and very little invasion of neighbouring plots had occurred up to the end of 1974. Any increase in ground cover in 1973/74 was mostly from the development of the original plants either by rhizomes (*C. ciliaris* and *P. coloratum*) or by stolons (*B. insculpta, U. mosambicensis* and *D. aristatum*). However, it was noticed, on 3rd April, 1977, after the experiment had terminated, that one of the *U. mosambicensis* plots had been completely replaced by *D. aristatum* and some *B. insculpta* and another partly replaced by *D. aristatum*. The severe burn in mid-November, 1976 is not believed to have been the cause of this decline.

The performance of all grasses improved in 1974, and this can be explained if the yearly rainfall is measured from October to September. Rainfall totals were 482, 585 and 1073 mm for 1971/72, 1972/73 and 1973/74, respectively. *B. insculpta* responded to this increase in rainfall with a more than threefold increase in dry matter in summer and a twofold increase for the pre-winter harvest while *D. aristatum* had a fivefold increase in summer yield and a twofold increase in pre-winter yield. The other grasses also responded but to a lesser degree (Fig. 2). Despite this overall increase in yield in 1974, the response to nitrogen was not very different; the mean response of all grasses to nitrogen as a per cent increase, being 42 in 1973 and 48 in1974 (Table 4). This may have been due to the major part of the rainfall in 1973/74 occurring before the fertilizer was applied.

All grasses survived the dry winter of 1972 when only 46 mm of rain fell in eight months from 9th March to 6th November.

The success of *Bothriochloa insculpta* could increase the importance of the genus in this area. Native *Bothriochloa* spp. are valuable pasture grasses on a range of soils and *B. insculpta* could extend this range into the black, self-mulching cracking clays. Another member of the genus, *B. pertusa,* is at present under consideration by soil conservationists in the area as an aid to soil stabilization.

It is obvious that any natural spread of grasses *B. insculpta, C. ciliaris* and *P. coloratum* cannot be anticipated in this environment and some provision must be made to ensure that initial stands are adequate to provide the type of ground cover required. This could be achieved by using high seeding rates as in Experiment 3 but a more realistic approach to improving establishment would be to find a sowing method pertinent to this type of soil and climate. A number of experiments, which looked into sowing methods, were run concurrently with this series and are described in Part 2 of this paper (Younger and Gilmore, 1978).

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