Pasture Investigations in the Yalleroi District of Central Queensland

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Price: Three Shillings

University of Queensland Papers

Department of Agriculture

Volume I Number 4

THE UNIVERSITY OF QUEENSLAND PRESS

St. Lucia

5 June 1964

WHOLLY SET UP AND PRINTED IN AUSTRALIA BY
WATSON FERGUSON AND COMPANY, BRISBANE, QUEENSLAND
1964

REGISTERED IN AUSTRALIA FOR TRANSMISSION BY POST AS A BOOK

FOREWORD

The so-called "desert" country of Central Queensland has filled a useful role through the years when light rain has given a pasture response on the sandy soils but not on the adjacent Mitchell grass downs. Sheep have been moved to this region to take advantage of such short-term feed to relieve the pressure on the downs.

Unfortunately, the useful forage is short lived and the benefit rather ephemeral. Perennial forage is of poor quality, due chiefly to the very low fertility level of the soils, their poor water holding capacity, and the irregular nature and summer incidence of the rainfall.

With the encouragement and financial assistance of the late Mr. R. L. Davidson of "Manfred", Longreach, a consistent friend of this University, Professor L. J. H. Teakle in 1951 decided to initiate trials which might lead to greater productivity from this area. Mr. Davidson made his property, "Ryandale", situated on the Blackall-Jericho railway, available for the experiment and offered hospitality and assistance to the research workers, who were successive post-graduate students studying for higher degrees.

Messrs. E. F. Henzell, L. A. Edye and L. R. Humphreys undertook the continuing work, the results of which are made available in this publication.

Although the results do not reveal any ready economic means by which productivity can be greatly increased, the strategic use of buffel grass (*Cenchrus ciliaris* L.) can lead to improvement in the existing low carrying capacity of the area.

P. J. Skerman
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1 July 1963

PASTURE INVESTIGATIONS IN THE YALLEROI DISTRICT OF CENTRAL QUEENSLAND

SUMMARY

The object of the investigations was to find means of improving the low carrying capacity of the pastures in the Central Queensland "desert" country. Field trials were conducted on a sandy soil carrying spinifex (*Triodia pungens*) and cabbage gum (*Eucalyptus papuana*) near Yalleroi; associated laboratory studies were carried out in Brisbane. The main findings were:

1. White clover responded to additions of phosphorus, potassium, lime ($CaCo_3$) and zinc when grown in the Yalleroi soil in pots. Phosphorus and nitrogen were the chief nutrients limiting the establishment and growth of buffel grass in the field. Native spinifex pasture and buffel grass pasture showed similar increases in yield when an NPK fertilizer was applied.

2. Cultivation, especially deep ploughing, assisted the establishment of buffel grass in spinifex pasture.

3. A pasture of West Australian buffel grass produced 5,420 lb of dry matter per acre during a single wet summer when fertilized with phosphorus and nitrogen. Unfertilized plots yielded 550 lb per acre during the same period. Unfertilized spinifex pasture yielded only 330–340 lb of dry matter per acre per annum at Yalleroi.

4. Dry storage improved seed germination in most varieties of buffel grass. The germination of freshly harvested buffel grass seed was improved by acid scarification, but a field trial with treated seed during a summer of erratic rainfall showed that rapid germination can be a disadvantage in practice.

5. In a pot experiment with seedlings, the Gayndah and Biloela varieties of buffel grass survived wilting better than varieties which find their chief use in arid areas, such as Cloncurry and West Australian buffel grass and Birdwood grass.

The prospects for pasture improvement in the Central Queensland desert are discussed.

Introduction

In 1951 the University of Queensland began a series of pasture investigations near Yalleroi in the Central Queensland "desert". The term "desert" is used in that region for areas of open eucalypt forest with light sandy soils in which surface water is scarce. It is not true desert, the average rainfall being about 20 in per annum.

The aim of these investigations was to improve the very low carrying capacity of the desert pastures. First, an attempt was made to improve the native pasture by addition of fertilizers. But when it was found that fertilizers had little effect on the chemical composition of the native grasses during winter, attention was transferred to the introduction of new pasture plants of higher nutritive value for use in sown pastures.

The Yalleroi District

The Central Queensland desert lies to the east of the towns of Barcaldine, Aramac, and Hughenden, stretching along the Great Divide between 20° and $24\frac{1}{2}$° S with an average width of more than 70 miles. The whole area forms a tableland at an altitude of 1,000 to 1,600 ft, with basins of internal drainage along its axis in the north (Lakes Buchanan and Galilee). There is little surface drainage in the southern part of the desert.

Yalleroi lies near the southern end of the desert country, and is situated between Jericho and Blackall on a branch of Queensland's central railway line. Ryandale station, the site of the field experiments, lies 2 miles north-east of Yalleroi.

1. *Climate*

There are no reliable rainfall records for Yalleroi, but comparison with the nearest meteorological stations indicates a mean annual rainfall of about 20 in with a marked summer incidence. The rainfall variability is high, so that occasional years of abundant rainfall as well as periods of prolonged drought can be expected. Two consecutive months of effective rainfall in summer occur in 28 and 36 per cent of years at Barcaldine and Blackall, respectively (Everist & Moule, 1952). Barcaldine has a mean maximum temperature in January and February of 95.4°F and a mean minimum in June and July of 46.5°F. Frosts may occur at Yalleroi during June, July, and August.

2. *Geology and soils*

The desert is predominantly an area of Tertiary rocks, chiefly sandstones. There is strong evidence that the whole area is covered by a weathered layer derived from the truncation of an old laterite profile. Red plateaux where vesicular laterite persists are found in the area, and the characteristic red and brown sandy soils usually contain ferruginous gravel (thought to be derived from higher in the old laterite profile) with a mottled clay at depth.

TABLE 1

CHEMICAL ANALYSIS OF A SOIL PROFILE FROM RYANDALE, YALLEROI

DEPTH	DESCRIPTION	pH	SALTS	CHLORIDES	AVAILABLE P_2O_5*	EXCHANGEABLE CATIONS											NITROGEN
						Ca	Mg	Na	K	H	Total	Ca	Mg	Na	K	H	
in.			%	%	p.p.m.	m — equiv./100g						% of total					%
0–6	Dark brown sand with humus	6.3	0.028	0.009	6	2.19	0.66	0.04	0.28	1.10	4.27	51	15	1	7	26	0.032
6–9	Dark brown and brownish-red sand with some humus	6.1	0.024	0.007	<1			—						—			0.022
9–21	Red loamy sand	6.0	0.015	0.004	<1			—						—			0.016
21–30	Red sandy loam, slightly mottled	5.8	0.026	0.009	3	1.22	0.69	0.01	0.44	0.08	2.44	50	28	<1	18	3	0.015
30–32	Yellow and bright red sandy loam, mottled	6.0	0.020	0.005	<1			—						—			0.015
32–38	Yellow sandy clay loam, slight red mottling, some iron-stone gravel	5.6	0.025	0.008	<1			—						—			0.012
38–60	Grey and red sandy clay, heavy iron-stone gravel	5.7	0.019	0.007	<1	0.92	0.99	0.04	0.18	1.68	3.81	24	26	1	5	44	0.010
60–72	Grey, yellow, and red mottled sandy clay, some iron-stone gravel	6.2	0.026	0.011	3			—						—			0.015
72–82	Bluish grey and red mottled stiff clay on hard sandstone	6.1	0.024	0.009	<1	2.09	8.51	1.22	0.36	1.36	13.54	15	63	9	3	10	0.009

*By extraction with 0.01 N sulphuric acid

The main features of a soil profile near Ryandale homestead are shown in Table 1. This particular soil type, similar to the one on which most of our experiments were carried out, would be classified as a Red Earth, but a large part of the Central Queensland desert is covered by sandy Solodics (Isbell, personal communication). The available phosphate content of this profile appears to be lower than at the actual experiment sites. Analyses of twelve samples (0–6 in) collected from the site of Experiment I showed a mean available P_2O_5 content of 22 p.p.m. (range 13–48 p.p.m.). Nevertheless, all these figures are very low.

3. *Vegetation*

The open eucalypt woodland in the Yalleroi district consists of three communities:

(a) The Box community. Poplar box (*Eucalyptus populnea*) is dominant on the low-lying areas, often with budda (*Eremophila mitchelli*) as an associated species. *Bothriochloa ewartiana* (desert blue) is the dominant grass.

(b) The Iron-bark community. Silver-leafed iron-bark (*E. melanophloia*) occurs on slightly higher country with a diversity of grasses, such as *B. ewartiana*, *Enneapogon intermedius*, *Themeda australis* and *Aristida* spp. Legumes, e.g. *Glycine tabacina* and *Vigna lanceolata*, are minor components of the pasture, but numerous dicotyledonous herbs occur, the most common being *Helichrysum ramosissimum*, *Justicia procumbens*, and *Goodenia glabra*.

(c) The Cabbage Gum–Bloodwood community. Cabbage gum (*E. papuana*) and bloodwoods (*Eucalyptus* spp.) occur as sparse stands with desert oak (*Acacia coriacea*) and prickly pine (*Bursaria incana*). The dominant perennial grass in the cabbage gum–bloodwood community is spinifex (*Triodia pungens*), a species found throughout the arid tropics of Australia (Burbidge, 1953). When burned regularly, spinifex exists as small tussocks with a considerable amount of bare ground between them. At Yalleroi several coarse

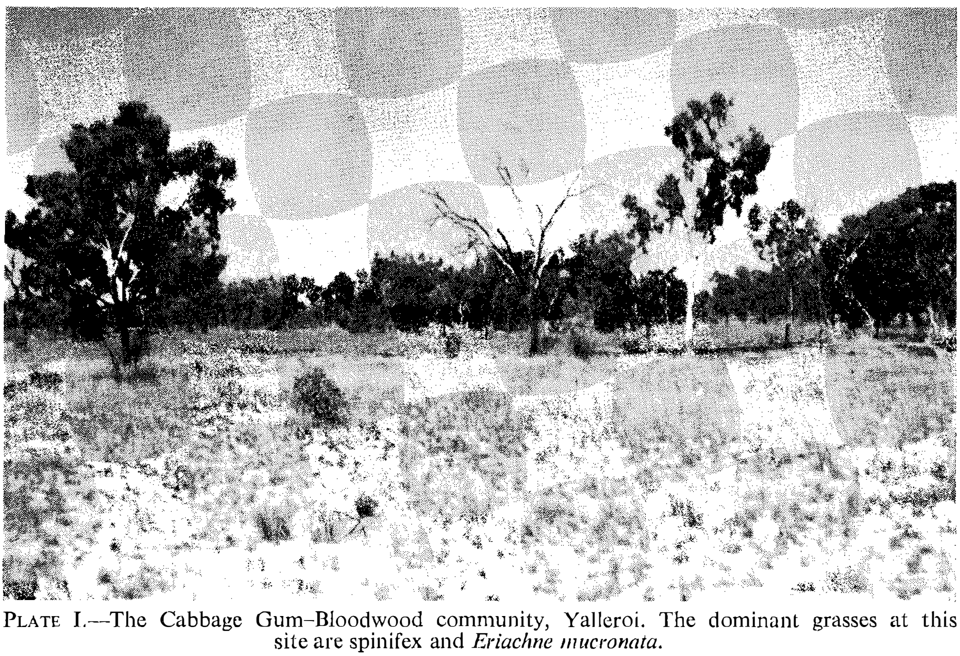

PLATE I.—The Cabbage Gum–Bloodwood community, Yalleroi. The dominant grasses at this site are spinifex and *Eriachne mucronata*.

grasses, such as *Eriachne mucronata* and *Aristida* spp., and some forbs, e.g. *Indigofera linifolia*, grow between the tussocks of spinifex. The more palatable grasses, legumes, and herbs appear to be restricted to the base of the scattered trees.

4. *Pasture problems in the Yalleroi district*

The desert pastures exhibit the same disadvantages for the nutrition of grazing animals as other native pastures in northern Australia. These pastures, which consist chiefly of summer grasses, provide reasonably satisfactory nutrition while they are growing rapidly, but their quality falls with maturity and reaches a very low level during winter. It is the poor quality of feed in winter and spring that limits production in the first place, though there is also scope for increased total production. Two possible means of pasture improvement were tested at Yalleroi: (i) Changing the management of the existing pastures by use of fertilizers, and (ii) The introduction of new plants of higher nutritive value.

Results

1. *Effect of fertilizers on the chemical composition of a spinifex pasture*

The object of the first experiment carried out at Yalleroi was to improve the native pasture by application of fertilizers (Henzell, 1953). An enclosed area of spinifex pasture in the cabbage gum–bloodwood community on Ryandale station was used. Fertilizers containing nitrogen, phosphorus, potassium, and trace elements, in various combinations, were broadcast on the plots during January 1952, and samples of the prominent pasture species were cut in March, May, and June. Material from the five replicate plots of each treatment was bulked for chemical analysis.

None of the fertilizer treatments caused any consistent change in the crude fibre or nitrogen-free-extract content of the pasture. Ammonium sulphate (at 1 cwt per acre) increased the percentage crude protein content of the grasses in March, but this effect had largely disappeared by June. Since there were no large differences in percentage crude protein between the three grasses, spinifex *Enneapogon intermedius* and *Bothriochloa ewartiana*, the results were combined; Table 2 shows the mean values, with and without nitrogen. Ammonium sulphate had little effect on the percentage of crude protein in the legume *Glycine tabacina* and in the herbs; the figures in Table 2 represent the means over all treatments. A notable feature of these results is that the grasses had a very low crude protein percentage as early as the first week of

TABLE 2

SEASONAL CHANGES IN THE PERCENTAGE CRUDE PROTEIN CONTENT OF PLANTS IN A SPINIFEX PASTURE (EXPERIMENT I)

Plant and Treatment	Time of Harvest: March (4.3.52)	May (13.5.52)	June (23.6.52)
	%	%	%
Grasses: no nitrogen	4.9	3.2	3.3
Grasses: ammonium sulphate	7.1	4.1	3.8
Glycine tabacina	18.1	10.7	12.3
Helichrysum ramosissimum	8.3	5.3	5.7
Justicia procumbens	13.8	10.3	10.5

March, whereas *Glycine tabacina* and *Justicia procumbens* (Acanthaceae) maintained relatively high levels until June. The composite *Helichrysum ramosissimum* was better than the grasses, though inferior to *G. tabacina* and *J. procumbens*. The other fertilizers used in Experiment I (superphosphate, potassium sulphate, and a trace element mixture containing magnesium, manganese, iron, copper, boron, zinc, and cobalt) did not alter the level of crude protein in the plants, but superphosphate tended to increase their phosphorus content, especially with the samples cut in March.

In general, the response to fertilizers in this experiment was quite small. There was no important change in either the percentage of crude fibre (an approximate index of digestibility) or the percentage of crude protein, when samples were harvested in June. Nor was there any obvious increase in yield. The poor feed value of unfertilized desert pasture is indicated by the results from a digestibility trial with six wethers conducted on a sample of spinifex collected near Experiment I in May 1952 (see Table 3).

TABLE 3

THE CHEMICAL COMPOSITION AND DIGESTIBILITY OF SPINIFEX

Fraction	Content	Digestibility
	%	%
Crude fibre	37.5	52
Nitrogen-free extract	49.5	41
Crude protein	3.8	29

While the fertilizer rates used in Experiment I were too low, in view of the results obtained in later experiments at Yalleroi (cf. Experiment V), the general conclusion that little benefit will be derived from fertilizing native pasture is probably correct. This has been the finding in other parts of Australia; the solution is to reserve the use of fertilizers for sown plants of higher nutritive value.

2. *Plant nutrient deficiencies in the Yalleroi soil*

Three pot experiments were carried out to detect nutrient deficiencies that might limit the establishment of introduced pasture plants at Yalleroi (Edye, 1955). Soil (0–4 in) was collected from an area carrying cabbage gum, bloodwood and spinifex near the site of the field experiments at Ryandale.

Experiment II was designed to test the effects of added nitrogen, phosphorus, potassium, and lime on the growth of oats. All pots received a basal fertilizer dressing containing magnesium, copper, zinc, and molybdenum. The results showed a large positive interaction between nitrogen and phosphorus (see Table 4). Without added phosphorus there was no response to nitrogen, whereas with phosphorus there was a linear increase in yield. There was a significant ($P<0.01$) response to phosphorus without added nitrogen. A dressing equivalent to 2 cwt of sodium dihydrogen phosphate per acre (equal to about 5 cwt per acre of superphosphate containing 20.5 per cent soluble P_2O_5) was sufficient for maximum yield. There was a small, significant ($P<0.05$) increase of yield from the addition of 1 cwt of potassium sulphate per acre, but no significant response to lime (calcium carbonate).

The aim of Experiment III was to test the same plant nutrients as in Experiment II for their effects on the growth of nodulated white clover. There was a spectacular response to added phosphorus (see Figure 1). In fact, most of the young clover plants died when none was applied (Plate II). A dressing of sodium dihydrogen phosphate equivalent to 15 cwt of superphosphate per acre gave the maximum yield, with a

TABLE 4

EFFECT OF NITROGEN AND PHOSPHORUS ON THE DRY MATTER YIELD OF OATS (EXPERIMENT II)

Treatment	Sodium Dihydrogen Phosphate (cwt/acre) 0	2	4
Ammonium nitrate (cwt/acre)		g	
0	1.07	2.01	2.11
1	0.99	5.26	5.26
2	0.83	8.97	9.18
Least significant	$P<0.05$	0.45	
difference	$P<0.01$	0.61	

depression at higher rates. Potassium sulphate (at 1 cwt per acre) and lime (at 5 cwt per acre) both caused significant yield increases ($P<0.01$) and there was no further response when the applications were increased to 2 and 20 cwt per acre, respectively.

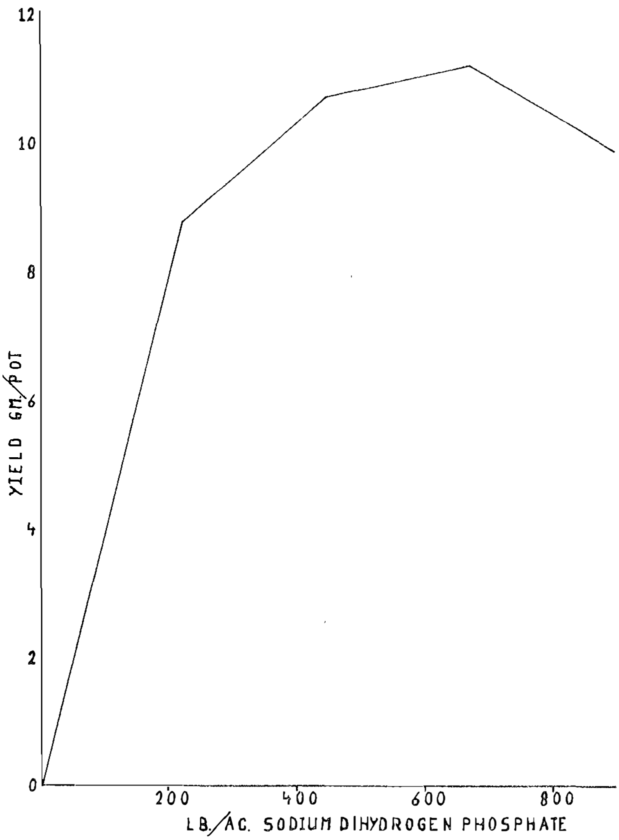

FIG. 1.—Effect of addition of phosphorus on the dry matter yield of Ladino white clover (Experiment III).

PLATE II.—Response of Ladino white clover to (reading left to right) 0, 2, 4, 6, and 8 cwt of sodium dihydrogen phosphate per acre.

Experiment IV was a trace element experiment to test the effects of copper, zinc, molybdenum, and a mixture of magnesium, manganese, iron, and boron, on growth of white clover. A basal dressing consisting of sodium dihydrogen phosphate, potassium sulphate, and lime (10 cwt per acre of ground limestone) was applied. Zinc was the only element that gave a response in this experiment, and that only in the second cut of clover. The increase in yield was significant at the 5 per cent level and just short of significance at the 1 per cent level.

Further evidence on the trace element status of the desert soil is provided by analyses of samples of native pasture collected from Experiment I in March 1952. The percentages of molybdenum and copper were within the satisfactory range for pastures, but spectrographic analysis showed that the levels of zinc were below normal.

3. *The effect of fertilizers and cultivation on the establishment and growth of buffel grass*

A number of varieties of buffel grass (*Cenchrus ciliaris* L.) have been introduced into northern Australia and some have shown considerable promise in the arid and semi-arid regions. Small plots of buffel grass were already growing in the Yalleroi district in 1951.

Two field experiments were laid down at Ryandale to study the effect of fertilizers and cultivation on the establishment and yield of buffel grass pasture (Edye, 1961). Both sites were on an area carrying the cabbage gum–bloodwood community. Trees were cleared from the plots before the experiments began.

Experiment V was a factorial trial consisting of nitrogen, phosphorus, potassium, lime, and zinc treatments. West Australian buffel grass seed was sown at 10 lb per acre on dry ploughed ground in February 1954, and scuffled into the soil with a rigid tine cultivator. Rain fell immediately, and the total rainfall during the course of this experiment was well above the long-term average for the district.

The establishment of buffel grass was very satisfactory and there was a significant response to nitrogen plus phosphorus when samples were cut for estimation of dry matter yield in September 1954 (see Table 5). Ammonium sulphate plus superphosphate, each at 1 cwt per acre, increased the yield from 47 to 265 lb per acre, but the experimental design does not allow the separate fertilizer responses to be distinguished. At higher rates there were significant linear responses ($P<0.01$) to both fertilizers and a significant positive interaction ($P<0.05$) between them.

TABLE 5

EFFECT OF NITROGEN AND PHOSPHORUS FERTILIZERS ON THE DRY MATTER YIELDS OF BUFFEL GRASS PASTURE (EXPERIMENT V, HARVESTED 8.9.54)

Treatment	Superphosphate (cwt/acre) 1	2	4	6	Means
Ammonium sulphate (cwt/acre)	lb/acre				
1	265	272	375	397	327
2	220	375	750	617	491
4	426	559	632	1,014	658
8	463	713	1,014	1,022	803
Means	344	480	693	763	
Yield of unfertilized control plots = 47 lb/acre					

When the pasture was sampled again in March 1955, after thirteen months' uninterrupted growth, there was still a large linear response to ammonium sulphate ($P<0.001$). The linear superphosphate response was now smaller than in September but remained significant ($P<0.05$). The yield of 6,220 lb of dry matter per acre on plots that had received 8 cwt of ammonium sulphate was approximately ten times the yield of the unfertilized control plots (600 lb per acre); of this 6,220 lb, 5,420 lb had grown between September 1954 and March 1955.

The other fertilizer treatments in Experiment V (potassium sulphate, lime, and zinc sulphate) had little effect on the growth of buffel grass.

Experiment VI was designed to test the effect of cultivation and fertilizer on establishment of West Australian buffel grass. Eight methods of cultivation were used, each with and without 5 cwt per acre of an NPK fertilizer (a 2 : 2 : 1 mixture of ammonium sulphate, superphosphate, and potassium sulphate).

The cultivation treatments were:

1. Control
2. Harrowed (discs) 1–2 in deep
3. Harrowed (discs) 3–4 in deep
4. Ploughed (mouldboard) 4–5 in deep
5. Ploughed (mouldboard) 6–8 in deep
6. Ploughed 6–8 in deep and ridged.
7. Furrows ploughed 5–6 in deep and 3 ft apart.
8. Cultivated (rigid tines) 3–4 in deep.

The cultivation treatments were carried out 11–18 December, 1953, and West Australian buffel grass seed was then sown at the rate of 5.3 lb per acre. In the case of treatments 6 and 7, the seed was sown in the furrows and left uncovered; in the remaining treatments the seed was broadcast and covered by dragging a chain across the plots. As with Experiment V, the rainfall was above average during the course of this experiment.

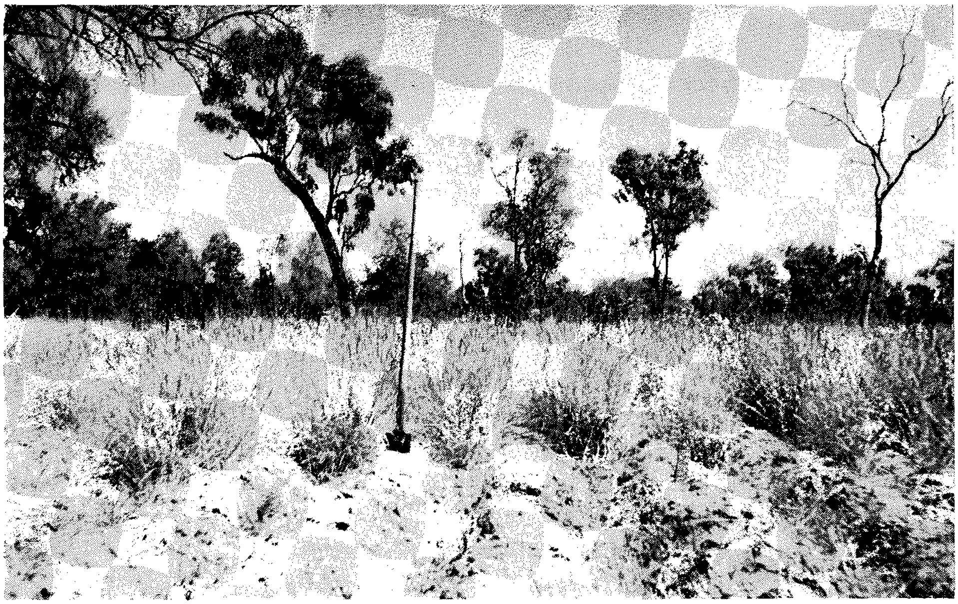

PLATE III.—Growth of West Australian buffel grass in March 1954, on plots ploughed 6–8 in deep and ridged. The plot in the foreground was unfertilized, the one behind received NPK fertilizer at 5 cwt per acre.

TABLE 6

EFFECT OF NPK FERTILIZER ON THE ESTABLISHMENT OF WEST AUSTRALIAN BUFFEL GRASS (EXPERIMENT VI)

Treatment	March 1954	March 1955
	No. of buffel grass plants/25sq. links	
Without fertilizer	8.9	8.2
NPK fertilizer	16.5	14.2

Counts made in March of 1954 and 1955 indicated that NPK fertilizer had almost doubled the establishment of buffel grass plants (see Table 6). This difference was significant ($P<0.05$). The NPK fertilizer also caused a significant increase ($P<0.01$) in the total yield of native species plus buffel grass. In samples cut during March 1955 the unfertilized plots yielded 1,050 lb dry matter per acre and the plots receiving 5 cwt per acre of NPK fertilizer yielded 2,350 lb per acre. Surprisingly, it was found that the increase in yield was about the same irrespective of whether the pasture consisted predominantly of native plants or of buffel grass.

While the cultivation treatments had no significant effect on total plant yields, they did alter the botanical composition of the pasture. Cultivation definitely favoured the establishment and persistence of buffel grass. The highest yields harvested from this grass in March 1955 were from plots ploughed 6–8 in deep. In contrast, the yields of native perennial grasses, such as spinifex, were progressively reduced by increasing intensity of cultivation. In fact, they were almost completely eliminated on the plots ploughed 6–8 in deep. Table 7 shows the botanical composition of the uncultivated controls, the plots disc-harrowed 3–4 in deep, and the plots ploughed 6–8 in deep. The results of other treatments, which have not been shown, fell within this range.

TABLE 7

THE EFFECT OF PLOUGHING, DISC-HARROWING, AND NPK FERTILIZER ON THE BOTANICAL COMPOSITION OF PLOTS SOWN TO BUFFEL GRASS (EXPERIMENT VI)

Species	Uncultivated Without Fertilizer	Uncultivated NPK Fertilizer	Disc-Harrowed Without Fertilizer	Disc-Harrowed NPK Fertilizer	Ploughed Without Fertilizer	Ploughed NPK Fertilizer
	% by weight		% by weight		% by weight	
Buffel grass	0	1	1	30	70	94
Spinifex	78	63	46	27	0	0
Other native perennial grasses	3	10	20	22	0	2
Native annual grasses	4	23	26	20	1	2
Dicotyledonous herbs	15	3	7	1	29	2

Considering the combined effects of fertilizer and cultivation treatments on the proportion of buffel grass (expressed as a percentage of total dry matter yield), the application of fertilizer had little effect on the uncultivated controls, but increased the proportion of buffel grass in the disc-harrowed and ploughed treatments. Buffel grass became dominant, i.e. its yield exceeded that of the native plants, in treatments 5 and 6 when fertilized with NPK, and only in treatment 5 in the unfertilized plots. Treatments 5 and 6 both involved ploughing the soil to a depth of 6–8 in.

A further experiment to study the establishment of buffel grass in the field (Experiment VII) was carried out at Ryandale during the summer of 1955–56 (Humphreys, 1958). The site was on spinifex pasture in the cabbage gum–bloodwood community. Six kinds of buffel grass seed were sown: West Australian buffel, untreated and acid-treated; Boorara buffel (Q2953), untreated and acid-treated; Biloela buffel, untreated and hammer-milled. The acid treatment consisted of immersion in commercial sulphuric acid (78% W/W) for thirty minutes, using the technique described in the next section.

On 11 December 1955, the seed was sown on the surface of a rough, dry seed-bed which had previously been ploughed to a depth of 5 in. A total of 0.77 in of rain fell on 19 and 21 December 1955, followed by 0.58 in on 6 and 7 January 1956. As a result some of the seed germinated, but died before effective rains commenced late in January 1956. The results of plant counts made on 22 March 1956 are shown in Table 8, and the laboratory germination of the seed samples is shown for comparison. Establishment in the field was markedly reduced by seed treatments that promoted rapid germination in the laboratory. It will be noticed that hammer-milling (at 750 r.p.m. in a Ferguson hammer-mill) impaired germination in the laboratory too.

TABLE 8

EFFECT OF ACID TREATMENT AND HAMMER-MILLING ON THE GERMINATION AND FIELD ESTABLISHMENT OF BUFFEL GRASS (EXPERIMENT VII)

Variety and Treatment	Laboratory Germination	Field Establishment
	% of seeds sown	
West Australian buffel grass		
untreated	8	6.4
acid-treated	52	0.3
Boorara buffel grass		
untreated	33	13.4
acid-treated	70	3.0
Biloela buffel grass		
untreated	46	30.8
hammer-milled	28	1.6

4. *Studies on the germination, emergence and early growth of buffel grass and Birdwood grass*

As an extension of the field work at Yalleroi, a series of laboratory studies with buffel grass and the closely-related Birdwood grass (*Cenchrus setigerus*) were carried out in Brisbane (Humphreys, 1958).

(*a*) *Seed dormancy and germination*

An important practical problem with buffel grass is dormancy in freshly harvested seed (Akamine, 1944). Satisfactory germination can usually be obtained after four-six months' storage (Anderson, 1953; Winchester, 1954), though Fitzgerald (1955) recommended storage for eighteen–twenty-four months before sowing West Australian buffel grass. The artificial procedures that have been described for improving the germination of buffel grass seed include treatment with concentrated sulphuric acid (Akamine, 1944), scratching the seed coat, moist chilling, and storage at an elevated temperature (Anderson, 1953).

Our experiments were designed to determine the importance of dormancy in local supplies of buffel grass and Birdwood grass seed, and to examine some of the treatments prescribed for overcoming dormancy. To be strictly correct, buffel grass "seed" and Birdwood grass "seed" really consist of fascicles, each fascicle comprising a cluster of one to three spikelets enclosed in an involucre. In the account which follows fascicles are simply described as seed, unless specific mention is made to the contrary.

Storage:

The extent of dormancy in freshly harvested seed was tested in a trial with seed of five varieties of buffel grass and one of Birdwood grass, harvested at Ryandale in 1955. The Gayndah, West Australian, Biloela, Boorara, and Cloncurry varieties of buffel grass were used. Germination was determined on moist blotting paper in an incubator at 32°C.

Except for the West Australian variety, buffel grass seed showed a steady increase in germination during eight months' storage. The average germination of the four varieties increased from less than 5 per cent up to 38 per cent. In contrast, Birdwood grass seed germinated quite well (10–20 per cent) just after it was harvested. Seed of

West Australian buffel grass showed only a relatively small improvement in germination with time, and in this experiment never reached a high percentage germination.

Sulphuric acid treatment:

Experiments were carried out to examine the effects of (1) the time of immersion, and (2) the concentration of the acid used for seed treatment. The general procedure was that seed was immersed in 20 ml of sulphuric acid in a beaker. After the required time had elapsed, the contents of the beaker were poured into 500 ml of water and the acid was then washed off the seed while it was held on a fine sieve. With 36N sulphuric acid the temperature in the beaker rose to about 32°C; there was a further sharp increase in temperature when the acid was poured into water, then the temperature fell rapidly when the contents were stirred.

In one trial seed was treated with 36N acid for periods of five, ten, and twenty minutes. Immersion in sulphuric acid significantly improved germination ($P<0.001$), but there were no significant differences between times. The five varieties of buffel grass (listed in the time of storage experiment) all responded to acid treatment. Birdwood grass did not.

A further test was carried out with buffel grass seed immersed in varying concentrations of acid for periods of five and thirty minutes. High concentrations (24N and 36N) were significantly better overall ($P<0.01$) than low concentrations (3N, 6N, and 12N), and, when fascicles were immersed for thirty minutes, 24N was significantly better than 36N ($P<0.01$). Overall, treatment for thirty minutes was more effective than for five minutes. Sulphuric acid treatment exerted most of its effect on speed of germination. For instance, treatment with 24N acid increased germination from 2 to 39 per cent after three days' incubation, and from 29 to 48 per cent after fourteen days' incubation.

Another test showed that there was no deterioration in the germination of acid-treated buffel grass seed during two months' storage.

Increased air pressure:

Seeds of buffel grass were germinated in a pressure chamber on petri dishes standing beside a beaker of caustic soda (to absorb carbon dioxide). The controls were placed in boxes at normal pressure. A trial with Biloela buffel grass showed that a pressure of two atmospheres tended to increase the germination of intact seed, but had little effect on acid-treated seed, hammer-milled seed or naked seed that had been separated from the hulls by hand. Two months after harvest, increased pressure (two atmospheres) raised the germination of naked seed of West Australian buffel grass from 5 to 23 per cent.

Moist chilling:

Moist chilling at 6°C for eight days increased the germination of naked West Australian buffel grass seed, previously incubated at two atmospheres (see above), from 23 to 89 per cent; moist chilling alone gave 45 per cent germination. When intact seed was subjected to moist chilling there was no benefit in any of the varieties of buffel grass (including West Australian), or in Birdwood grass.

Dry storage:

Dry storage at 40°C for twenty-eight days increased the average germination of five varieties of buffel grass plus Birdwood grass from 31 to 48 per cent; this difference was significant ($P<0.05$). Moist chilling conferred no additional benefit.

(*b*) *Emergence and early growth of seedlings*

The main factors that were found to limit the establishment and growth of buffel grass at Yalleroi, viz. nitrogen deficiency, phosphorus deficiency, and soil moisture stress, were further studied in pot trials in Brisbane. Only the main findings are reported here; further details can be found in the original account of this work (Humphreys, 1958).

Effect of soil moisture content on seedling emergence:

An experiment was carried out in trays of the soil (0–6 in) from Ryandale. The field capacity of this horizon is about 15 per cent and the permanent wilting point 5–6 per cent. The soil in each tray was mixed with a calculated quantity of water, then the seeds were counted onto the soil surface, covered with 0.25 in of soil, and the surface was firmed. The trays were covered with plastic lids and incubated at 32°C. Four varieties of buffel grass were used: Gayndah, West Australian, Cloncurry, and Biloela.

TABLE 9

EFFECT OF SOIL MOISTURE CONTENT ON EMERGENCE OF BUFFEL GRASS AND BIRDWOOD GRASS

Initial Soil Moisture Content	Final Soil Moisture Content	Emergence
%	%	% of seeds sown
3.0	0.9	0
5.0	1.4	0
7.0	4.1	16
9.0	5.9	31
11.0	7.2	39

In all the varieties there was no emergence when seed was sown in soil below the permanent wilting point, and emergence increased with increasing soil moisture content above the wilting point (see Table 9). The difference in emergence between the two high moisture levels and the next lowest was significant ($P<0.01$). Other results not included in Table 9 showed that treatment of seed with sulphuric acid (36N for five minutes) improved seedling emergence significantly ($P<0.01$) in Biloela buffel grass under these conditions. The mean emergence was raised from 26 to 55 per cent, though this effect was least at the highest soil moisture content. Hammer-milling improved emergence at the intermediate moisture content, but not at the two highest moisture contents.

Effect of sowing depth on seedling emergence:

A pot experiment with the four varieties of buffel grass listed above, and Birdwood grass, showed that these grasses emerged best when the seed was sown at a depth of 1 in. There was good emergence from seed sown at 2 in, but not from that sown at 4 in (Table 10). Other results showed that acid treatment again improved the emergence of Biloela buffel grass significantly ($P<0.01$), the values being 50 per cent (untreated) and 78 per cent (acid-treated).

Effect of nitrogen and phosphorus nutrition on seedling growth:

A pot experiment (Experiment VIII) was carried out in the glasshouse to measure the effects of nitrogen and phosphorus nutrition on the growth of buffel grass and Birdwood grass seedlings. The plants were grown in pots containing 2 kg of soil (0–6 in). All pots received a basal dressing containing lime (calcium carbonate), potassium, magnesium, sulphur, copper, zinc, boron, manganese, and molybdenum. The experiment was harvested forty-five days after the seedlings emerged.

TABLE 10

EFFECT OF DEPTH OF SOWING ON SEEDLING EMERGENCE
COUNTS TAKEN TWENTY-EIGHT DAYS AFTER SOWING

Sowing Depth	Emergence
in.	% of seeds sown
0.25	57
1.0	64
2.0	51
4.0	2

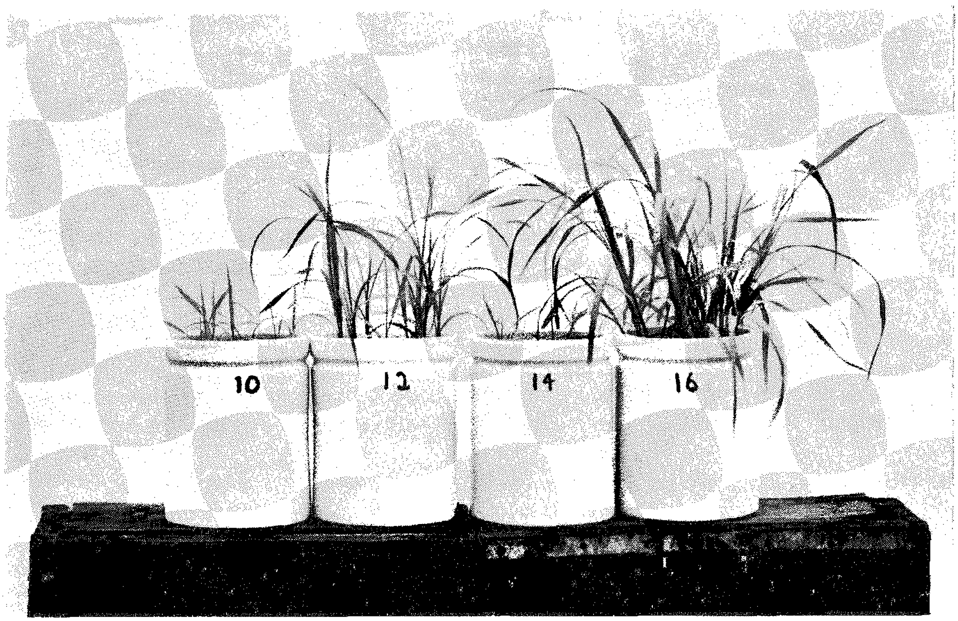

PLATE IV.—Effect of additions of phosphorus (2 cwt of sodium dihydrogen phosphate per acre) and nitrogen (2 cwt of ammonium nitrate per acre) on the growth of West Australian buffel grass seedlings. Reading from left to right: nil, phosphorus alone, nitrogen alone, nitrogen plus phosphorus.

The results, averaged over four varieties of buffel grass and one of Birdwood grass, are shown in Figure 2. Shoot growth was increased significantly ($P<0.01$) by applied phosphorus, and by nitrogen (equivalent to 2 cwt of ammonium nitrate per acre) in the presence of high rates of phosphorus (equivalent to 2 and 4 cwt of superphosphate per acre); there was no response to nitrogen at lower rates of phosphorus. Root growth responded significantly ($P<0.05$) only to nitrogen and phosphorus applied together.

Water use was determined in Experiment VIII by weighing the pots. Evapotranspiration was increased only slightly by additions of phosphorus and nitrogen, so that there was a rapid increase in efficiency of water use when fertilizer was added.

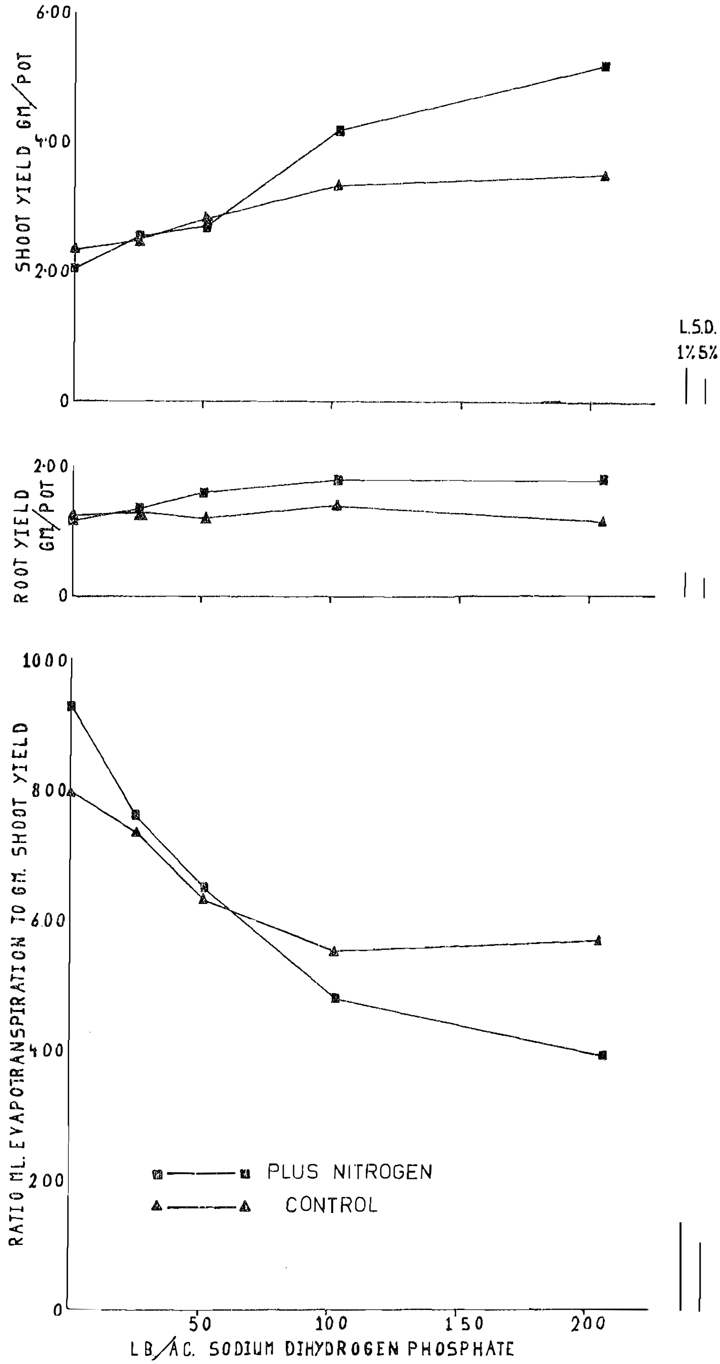

FIG. 2.—Effect of additions of phosphorus and nitrogen (2 cwt of ammonium nitrate per acre) on growth and efficiency of water use in *Cenchrus* spp. (Experiment VIII).

Top: Shoot yields
Centre: Root yields
Bottom: Efficiency of water use

Figure 2 shows how the ratio of water use to shoot dry matter yield fell with addition of phosphorus, and nitrogen in the presence of phosphorus.

TABLE 11

DRY MATTER YIELDS OF SHOOTS AND ROOTS OF BUFFEL GRASS AND BIRDWOOD GRASS SEEDLINGS (EXPERIMENT VIII)

Variety of Grass	Shoots	Roots	Ratio Shoots : Roots
	g	g	
Buffel grass			
Gayndah	2.8	2.0	1.4
West Australian	2.6	0.9	3.2
Cloncurry	3.1	1.1	2.9
Biloela	3.5	1.8	2.0
Birdwood grass	3.5	1.1	3.2
Least significant difference $P<0.05$	0.3	0.2	0.4
Least significant difference $P<0.01$	0.4	0.3	0.5

Table 11 shows the dry matter yields of shoots and roots for the separate varieties of grass. The varietal differences in shoot dry matter were statistically significant ($P<0.05$) but relatively small in absolute amount. In contrast, there were large differences in root weight, the late-maturing Gayndah and Biloela buffel grasses outyielding the others. These trends were reflected by marked variation in the ratio of shoots to roots. In general, the nitrogen and phosphorus treatments had little effect on varietal behaviour, although applied phosphorus did increase the shoot : root ratio less with Gayndah and Biloela buffel grass than with West Australian buffel grass and Birdwood grass.

Other measurements showed that the form of growth varied greatly between varieties, but because of compensating effects, such as the association of small tiller size and large tiller number, most of these characters were not closely related to dry matter yield.

Survival of wilted seedlings:

The object of Experiment IX was to determine the effects of nitrogen and phosphorus dressings on the drought survival of seedlings of buffel grass and Birdwood grass. The plants were grown in pots containing 6.5 kg of Yalleroi soil, to which a basal fertilizer dressing was applied (see Experiment VIII). All the pots were watered to field capacity at sowing, then the soil was allowed to dry out until the plants wilted. The mean time from emergence to wilting was 38.4 days, with little difference between varieties and fertilizer treatments. The pots were rewatered 46 days after emergence and kept watered until the final harvest 7 days later.

The results in Table 12 indicate that none of the Birdwood grass seedlings and only a very few Cloncurry buffel grass seedlings survived the eight days of wilting. The remaining varieties of buffel grass were more hardy. Taking the figures for these three varieties (Biloela, Gayndah, and West Australian), the application of phosphorus fertilizer at a rate equivalent to 4 cwt of superphosphate per acre increased the mean survival from 24 to 42 per cent; nitrogen fertilizer (2 cwt of ammonium nitrate per acre) had no significant effect on drought survival.

TABLE 12

EFFECT OF PHOSPHORUS FERTILIZER ON THE PERCENTAGE OF SEEDLINGS SURVIVING A PERIOD OF WILTING (EXPERIMENT IX)

Variety of Grass	Without Phosphorus	With Phosphorus
	% plants surviving	
Buffel grass		
Biloela	26	56
Gayndah	34	46
West Australian	14	24
Cloncurry	4	0
Birdwood grass	0	0

Discussion

The results of Experiment I showed quite clearly that application of fertilizers to the native spinifex pasture did not cause any important changes in chemical composition of the feed during winter. This finding agrees with the results from previous work in Queensland, though recent research has shown that very heavy fertilizer dressings are required to maintain a high nitrogen percentage in grasses that are allowed to grow to maturity (Henzell, unpublished data). The 1 cwt of ammonium sulphate per acre used in Experiment I was certainly too small a dressing to have much effect on crude protein content during winter. Although there was no obvious increase in yield in Experiment I, the native pasture plants definitely respond to fertilizer. In Experiment VI they gave about the same total yield, when fertilized with 5 cwt of NPK mixture per acre, as sown pasture dominated by West Australian buffel grass. Nevertheless, the decision to experiment on the replacement of native pasture by exotic plants appears to be correct, since there is considerable scope for selection of new plants with a higher nutritive value. Amongst the grasses, species of *Cenchrus* are the obvious choice. The question of introducing legumes and other non-gramineous plants into the desert has not been investigated so far, but this needs to be done.

The yield of unfertilized pastures at Yalleroi was quite low. Spinifex pasture produced only about 340 lb, and buffel grass pasture only about 330 lb of dry matter per acre per annum in Experiments V and VI. Other spinifex pastures in Australia have given similar low yields (Winkworth, 1958; Suijdendorp, 1960). By contrast, West Australian buffel grass at Yalleroi produced 5,420 lb of dry matter per acre during a single wet summer when fertilized with phosphorus and nitrogen.

Nitrogen and phosphorus appear to be the only important nutrient deficiencies limiting establishment of buffel grass at Yalleroi. Nitrogen deficiency is almost universal on grass pastures in northern Australia, but this sandy soil at Yalleroi is unusually deficient in phosphorus. The evidence we obtained from soil analysis and pot and field trials all indicates acute phosphorus deficiency. The potassium status of this soil appears to be marginal. There was a significant response to potassium in pots but buffel grass did not respond in the field. Probably there will be no problem with grass pastures provided the plant material is grazed *in situ* and never cut for removal.

Phosphorus deficiency will almost certainly have to be corrected by fertilizer dressings if pasture legumes are to be used in the desert country. Potassium may be limiting for growth of legumes, and zinc may also have to be added. White clover showed a response to lime when grown in pots, but it is not clear whether this was a true response to $CaCO_3$ or whether it was due to release of molybdenum. Molybdenum was tested (and gave no response) in Experiment IV, but all the trace element treatments in that experiment were superimposed upon a basal dressing of 10 cwt of $CaCO_3$ per acre. It will be necessary to elucidate this lime response when further work is done with legumes at Yalleroi.

Our results suggest that it is necessary to sow on a cultivated seed bed to obtain good establishment of buffel grass. Probably, the chief effect of cultivation in Experiment VI was to provide more mineral nutrients for the buffel grass seedlings, firstly, because of increased mineralization of soil organic nitrogen and phosphorus, and secondly, because competition for nutrients by the native plants was eliminated. It is necessary to stress that Experiment VI was carried out during a wet period. In dry years, the main effect of cultivation may be to reduce competition for soil moisture. In Experiment VI the buffel grass seed was sown onto dry soil, but there is the alternative of sowing after rain. For example, successful emergence of Gayndah buffel grass was obtained on moist ploughed ground at Katherine, provided the planting rain was sufficient to keep the top 6 in of soil above the wilting point for five or six days (Norman, 1960).

The dormancy of freshly harvested buffel grass seed presents a problem if the seed is required for planting immediately after harvest, but this probably does not happen very frequently. The results presented in this paper confirmed that dry storage will increase germination, though West Australian buffel grass never attained a high percentage germination even after eight months. The efficacy of sulphuric acid treatment for improving the germination of freshly harvested buffel grass seed was also confirmed. However, the results of Experiment VII demonstrated the danger in a semi-arid environment of sowing seed that germinates rapidly on a small fall of rain. Norman (1960) has recorded a similar result at Katherine. It appears that treated seed should be reserved for areas with a reliable rainfall.

Studies of the early growth of seedlings under glasshouse conditions (Experiments VIII and IX) fully confirmed the importance of nitrogen and phosphorus for the establishment of *Cenchrus* spp. on the desert soil. Phosphorus was definitely more important than nitrogen for growth of seedlings. Phosphorus was also important in increasing drought survival in young plants. The importance of phosphorus in seedling growth is a well-documented fact, but, as the results of Experiment V showed, there is often a much smaller response when the grass is fully established.

One interesting finding with wilted seedlings was that the grasses normally used in arid regions, Cloncurry and West Australian buffel and Birdwood grass, did not survive nearly as well as the Biloela and Gayndah varieties which are used in wetter areas. It can be concluded that the seedlings of varieties such as Cloncurry and West Australian buffel grass become established more by escaping drought than by their resistance to wilting.

The low inherent fertility of the soil, the lack of suitable pasture legumes, and the high costs of clearing limit the use of sown pastures in the Central Queensland desert. It has been demonstrated that West Australian buffel grass cannot be successfully established on the soils of the cabbage gum–bloodwood community without ploughing and the application of nitrogen and phosphorus fertilizers. However, it may be possible to establish buffel grass without fertilizer on the desert soils that carry box and iron-bark communities; our preliminary results were inconclusive on that point. There is little immediate possibility of using nitrogen fertilizer profitably in this region. If fertilizer is to be used, it more likely will be to supply phosphorus and trace elements for the growth of an effectively nodulated pasture legume which is independent of the limited soil nitrogen supply. Townsville lucerne (*Stylosanthes humilis*) has naturally colonized some homestead sites on the wetter margin of the desert country, and warrants further study.

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Acknowledgements

The authors wish to record their thanks for the help they received from many sources during these investigations; particular mention should be made of: Mr. and Mrs. R. L. Davidson, Manfred, Longreach; Mr. and Mrs. A. Nielsen, Ryandale, Yalleroi; Dr. J. M. Harvey and members of the Agricultural Chemical Laboratory, Department of Primary Industries, Brisbane; Mr. S. L. Everist and Dr. S. T. Blake; The British Tractor and Implement Co. Pty. Ltd.; The Australian Estates Co. Ltd.; Mr. H. M. Finucan and Mr. K. P. Haydock; and the authors' colleagues within the Department of Agriculture, University of Queensland.