The growth of three tropical pasture grasses on the mid-north coast of New South Wales

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Summary—The yields and seasonal growth curves of kikuyu grass, (*Pennisetum clandestinum*) setaria, (*Setaria anceps* cv. Kazungula) and broadleaf paspalum (*Paspalum wettsteinii*), were determined over a three year period at Taree (lat. 32°S) New South Wales with or without irrigation and under nil, 170 or 680 kg N ha^{-1} yr^{-1} (nil, low and high N).

Annual forage yields averaged 1300, 5100 and 13,000 kg DM ha^{-1} at nil, low and high N respectively. Kikuyu grass yields were significantly less than setaria or broadleaf, especially at low N. Both the apparent recovery of nitrogen and the efficiency of dry matter production by kikuyu grass were less than the other grasses.

Yields from the irrigated plots were similar to the dryland plots due largely to a generally favourable rainfall pattern. During short dry periods the extra yield from irrigation was less than from the application of nitrogen.

The patterns of seasonal growth were similar for each species at any one nitrogen rate and irrigation treatment. The growing season (>5 kg DM ha^{-1} day^{-1}) without nitrogen, was only four to six months, commencing in late spring. This was increased to eight months at low N (October to May) and nine months (September to May) with high N. The mean period of high growth rates (>60 kg DM ha^{-1} day^{-1}) over summer was nil at nil N, only six days at low N but increased to 154 days at high N. Winter growth was negligible.

Tropical grasses are the major component in many pastures along the subtropical east coast of Australia, either as naturalized species or sown as improved pasture. Colman (1971) reviewed the research on tropical pasture grasses on the far north coast of New South Wales and in coastal Queensland, and concluded that tropical grasses are capable of high forage yields when topdressed with nitrogen, but utilization of the forage produced is difficult because of the highly seasonal nature of production. However, many of the data on the seasonal growth of tropical pasture grasses collected, have been of a general nature and often obtained over periods of only one year. There are also only limited data on the main factors restricting tropical grass growth in the field and no quantitative data on the growth of tropical pasture grasses on the mid-north coast of New South Wales, an area that is frequently considered to be the southern limit for tropical pasture species (Griffith-Davies and Shaw 1964).

Tropical grasses, though, have been useful components in pastures on the mid north coast for many years. *Paspalum dilatatum*, carpet grass, (*Axonopus affinis*) and kikuyu grass (*Pennisetum clandestinum*) are all introductions that have become naturalized over large areas and a significant proportion of the milk and meat production of the New South Wales mid north coast, comes from pastures dominated by these species. A testing programme (Kemp 1974*a*) has shown that other species of tropical grasses are adapted to the area and could also be useful in pastures. However, the lack of quantitative data on the growth of tropical pasture grasses precludes a proper evaluation of their place in pastures for the mid north coast of New South Wales.

This paper reports the results of a three-year field experiment, designed to determine the yields and seasonal growth curves of three tropical pasture grasses on the mid-north coast of New South Wales and to assess the influence of nitrogen and irrigation on forage production.

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Experimental

Site and climate

The experiment was located on a river terrace 300 m from the Manning River at Taree (32°S) (Um 1.44—Northcote). Soil samples (0 to 7.5 cm), taken before the experiment began were analysed and showed a pH of 5.9, phosphorus content of 24 p.p.m. (Bray No. 1), total nitrogen of 0.18 per cent and exchangeable potassium 0.83 me per cent. Other samples showed that the N, P and K levels remained relatively constant to a depth of 1 m.

Temperatures at Taree range from a mean daily minimum in July of 6°C, to a mean daily maximum in January of 29°C. Foley (1945) records that Taree should expect an average of five frosts per year, but local experience indicates that nearly twice that number would be normal. Annual average rainfall is 1150 mm, the period of greatest reliability being from late January to July. Screen temperatures and rainfall were recorded at the field site. An American class A pan and a RIMCO silicone cell integrating pyranometer were situated 1.5 km from the experiment site. Figure 1 shows climatic data for the period of the experiment.

Experimental design

Two, very similar, experiments were set down on adjacent sites. One experiment received only natural rainfall but the other also received irrigation.

Dryland experiment—The experiment was based on six replications of the factorial arrangement of three grasses and two nitrogen levels in 2.44 m × 4.78 m plots.

Grasses

Pennisetum clandestinum	—	kikuyu grass
Setaria anceps c.v. Kazungula	—	setaria
Paspalum wettsteinii	—	broadleaf

Kikuyu grass was selected as a control species as it is widely established on the mid north coast. Setaria and broadleaf are two of the more successful recent introductions to the area (Kemp 1974*a*).

Nitrogen—17 kg N ha^{-1} (low N) and 68 kg N ha^{-1} (high N)—was applied after each harvest as ammonium nitrate. Ten applications were made each year. The low nitrogen rate was calculated to be about equivalent to the amount that a legume would contribute to the soil and the high rate as an adequate commercial application. In addition to the basic design, control treatments (nil N) consisting of four plots of each grass were included within the experimental block, and finally, to increase precision of the experiment, the number of kikuyu grass plots for each treatment was doubled.

Irrigation experiment—The above experiment was repeated on an adjacent site, the major difference being that it received supplementary irrigation. Plots were irrigated as far as practical whenever the estimated soil moisture deficit approached 35 mm (47 per cent of available water). The amount of irrigation water applied per week is shown on figure 1.

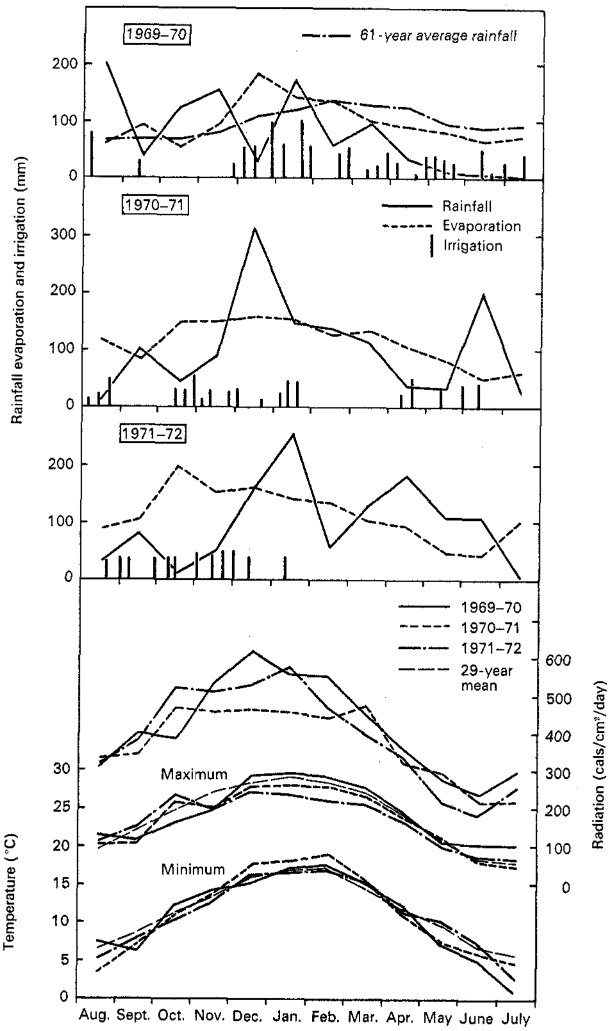

Figure 1—Monthly rainfall and evaporation, and weekly irrigation, with global radiation and air temperatures at Taree from August 1969 to July 1972.

Establishment and fertilizer

All species were sown onto a prepared seed bed. Kikuyu grass cuttings, obtained from near the experiment site, were planted at a spacing of 40 to 50 cm. Seed of setaria and broadleaf were sown at 10 and 20 kg ha^{-1}, respectively, to obtain dense swards. Plots were sown on November 14 and 15, 1968, and were irrigated during the establishment period. From February to July 1969 the plots were mown once a month.

At sowing, all plots received 75 kg P, 80 kg K and 50 kg N ha^{-1} and a further three dressings of 40 kg N ha^{-1} from February to May 1969. In July 1969, prior to commencement of harvesting, all plots received 43 kg P and 60 kg K ha^{-1}. Subsequent dressings of 75 kg P and 200 kg K ha^{-1} were made in July each year. P was applied as superphosphate and K as potassium chloride.

Harvesting

The six replicates were allocated to three series, each of two replications, and each harvested in a different sequence to produce overlapping growth periods. This method enabled three times the estimates of pasture growth rates over a year to be made, than would have been possible if all replicates had been harvested at the same time. From the data a mean pasture growth curve over time was constructed by the method of Anslow and Green (1967). The nil N plots were only allocated to two series.

An area of 0.91 m × 2.95 m was cut from the centre of each plot with an autoscythe. Kikuyu grass and broadleaf swards were cut at a height of 7 to 8 cm and setaria at 11 to 12 cm, the cut herbage being weighed green and a sub-sample taken for dry matter determination (80°C for 16 hours) and nitrogen analysis (Kjeldahl). Replicates were bulked for nitrogen analysis. Herbage remaining on the plots was cut and removed.

Harvest intervals were chosen to coincide with the frequency that fertilized kikuyu grass pastures are grazed on the mid-north coast. Plots were cut every three to four weeks during summer, with the cutting interval gradually increasing up to 11 weeks in winter. Ten harvests were taken annually. Harvesting commenced on August 1, 1969 and ceased on August 2, 1972.

Analysis

Initially the data were grouped into harvest periods and analysed to provide error estimates over time. For example, the experiment commenced on August 1, 1968; the first harvest of series 1 plots, (two replications), was on August 8, of series 2 September 10 and of series 3 October 1. Data from these harvests were grouped to form harvest period 1. The second harvest of series 1 was October 16, of series 2 October 29 and of series 3 November 13. These harvests were grouped to form harvest period 2. The data were analysed as growth rate (kg DM ha^{-1} day^{-1}). This method produced error estimates relevant to the seasonal growth curves.

The total dry matter yields from each plot over each year were also analysed. Data from the dryland and irrigated experiments were analysed separately. The nil N treatments were not included in any analyses as they were irregularly replicated.

Results

Annual dry matter yields

Annual dry matter yields of kikuyu grass were less than setaria or broadleaf, though the degree of difference depended on nitrogen rate and year (table 1). At low N, yields from kikuyu in 1969–70 were only 25 per cent of the other species, though this increased to 50 per cent in later years. Kikuyu grass yields with high N in 1969–70 were 50 per cent of the yields from the other grasses, then this rose to 90 per cent in the next two years. Differences between setaria and broadleaf were of a low order and inconsistent.

Dry matter yields without nitrogen were very low. Kikuyu grass yields at low N were 25 per cent of that at high N, whereas setaria and broadleaf were 45 per cent. The interaction between species and nitrogen was significant ($P < 0.05$).

Irrigation increased yields in 1969–70, but in 1970–71 and 1971–72, annual yields with irrigation were less than from the dryland experiment. The lower yields with irrigation were mainly at high N.

Seasonal growth curves

Sward growth rates differed significantly between grasses and were considerably influenced by nitrogen rate, and to a small extent by irrigation (figure 2).

Kikuyu grass growth rates were often significantly less ($P > 0.05$) than setaria or broadleaf at low N, though at high N differences between species were mostly non-significant, particularly in the second and third year. Differences between setaria and broadleaf were few and largely non-significant.

TABLE 1

Total annual dry matter yields for kikuyu grass, setaria and broadleaf at three nitrogen levels, with or without irrigation over three years.

Year and Species	Dryland Nil N	Dryland Low N	Dryland High N	L.S.D.† $P < 0.05$	Irrigated Nil N	Irrigated Low N	Irrigated High N	L.S.D. $P < 0.05$
		kg DM ha^{-1}				kg DM ha^{-1}		
1969–70								
Kikuyu grass	110	1010	6580		590	2570	9370	
Setaria	1360	6280	13960	1000	3760	6770	17130	1390
Broadleaf	1990	7140	14880		3010	8110	18470	
1970–71								
Kikuyu grass	1040	3380	13450		460	2960	11430	
Setaria	1280	6610	15140	1450	1410	5870	12790	1620
Broadleaf	1340	7240	18330		1410	5420	11940	
1971–72								
Kikuyu grass	380	3110	11940		520	2380	9990	
Setaria	1050	5080	12290	1480	1010	6110	11730	1560
Broadleaf	1310	6650	13870		2830	5600	10850	

† L.S.D's apply to comparisons between species at low and at high N and between low and high N for each species within each year.

The time of commencement of growth (>5 kg DM ha^{-1} day^{-1}) for each species depended largely on nitrogen. At low N, growth commenced from September to November, and at high N during September. Growth ceased (<5 kg DM ha^{-1} day^{-1}) during April or May at low N and from May to June at high N. Figure 3 shows the length of the growing season for each species, at each nitrogen level. Kikuyu grass had a shorter growing season than the other grasses at nil and low N, but not at high N.

The period of rapid production by the grasses was assessed as the period when growth rates exceeded 60 kg DM ha^{-1} day^{-1} and this was primarily dependent on nitrogen (figure 3).

Irrigation reduced the fluctuations in summer growth in 1969–70, prolonged autumn growth in 1970, and also increased growth rates during the dry spring of 1971. In 1970 the high N irrigated swards suffered from heavy frosting in late winter when an unprecedented 35 days with frosts occurred. Setaria and broadleaf were severely affected and growth did not commence until late spring. The heavy frosting had only a small effect on kikuyu grass growth (figure 2). The dryland plots did not appear to be affected. In 1971–72, the irrigation water increased in salt content and this may have affected plant growth in that year. The main dry period encountered was in winter 1970 and then low temperatures restricted growth.

Nitrogen

Per cent nitrogen in kikuyu grass was greater than in the other grasses (table 2), and greater at nil N compared with low N. This was attributed to the harvesting system used. All plots were cut at the same height and this resulted in mainly leaf being harvested from the nil N plots, whereas leaf plus some stem was cut from the low N plots. Per cent nitrogen varied during the year; for example in 1970–71, high N kikuyu grass contained 3.71 per cent N in early spring and this declined to 2.24 per cent in mid summer. Similarly setaria declined from 3.71 per cent to 2.04 per cent and broadleaf from 2.79 per cent to 2.23 per cent in that year. There was also a gradual increase in nitrogen content with time. In 1969–70 the mean per cent nitrogen of all treatments was 1.77 per cent, in 1970–71 was 1.95 per cent and in 1971–72 was

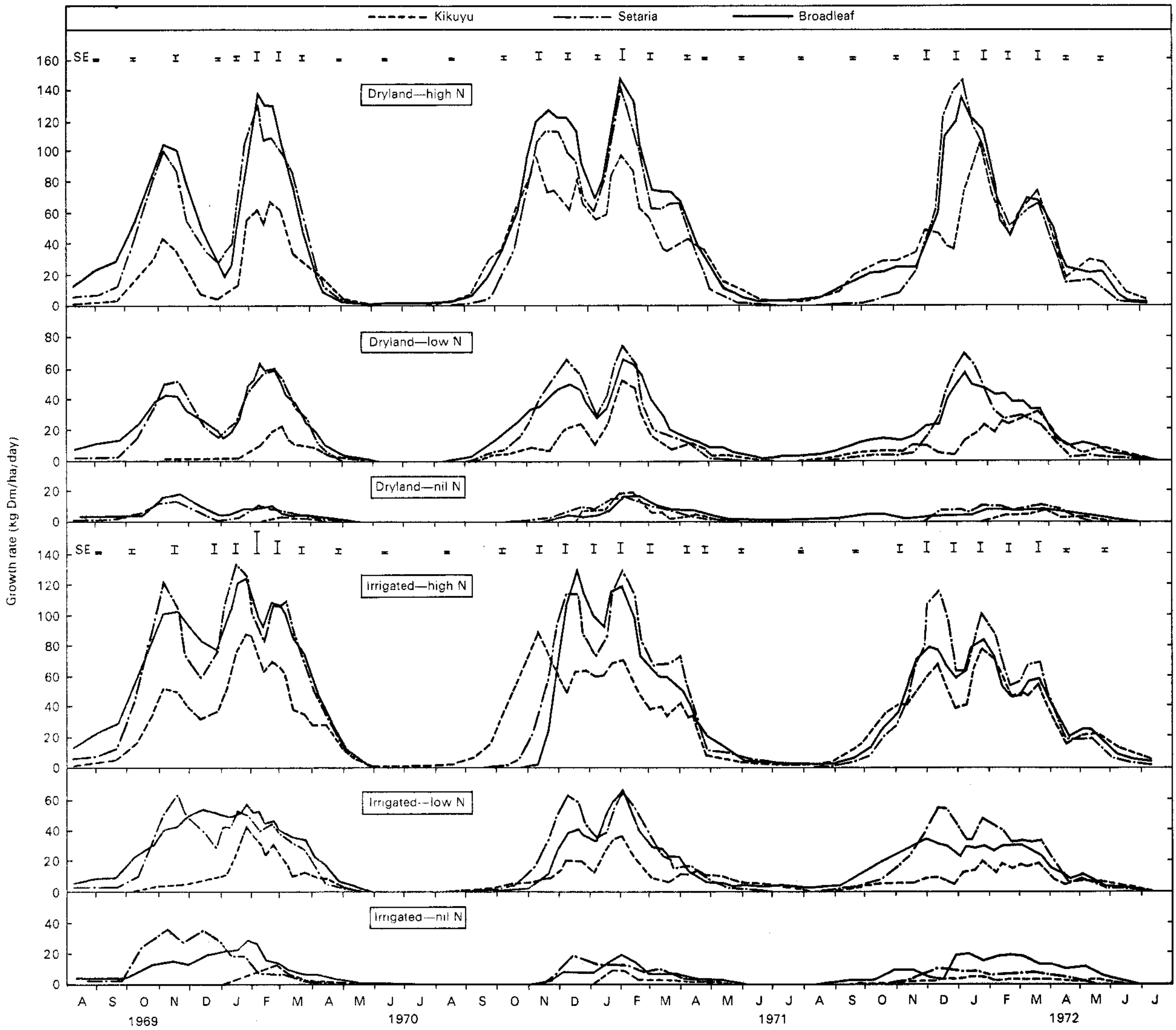

Figure 2—Seasonal growth curves for kikuyu grass, setaria and broadleaf paspalum at three nitrogen levels with or without irrigation from August 1969 to July 1972. Standard errors apply to comparisons between species at high and at low N within each moisture treatment.

2.12 per cent. This increase was observed for all treatments except dryland, nil N, kikuyu grass.

The mean apparent recovery of applied nitrogen by kikuyu grass, over all harvests, increased from 25 per cent at low N to 37 per cent at high N, compared with 45 per cent and 44 per cent by setaria and 50 per cent and 48 per cent by broadleaf.

The efficiency of nitrogen utilization by kikuyu grass was 13 kg DM kg N^{-1} applied, at low N and 15 kg DM kg N^{-1} at high N. In contrast setaria and broadleaf declined from 29 to 20, and 30 to 20 kg DM kg N^{-1}, respectively, as the nitrogen level increased from low to high.

TABLE 2

Mean per cent nitrogen in forage samples for kikuyu grass, setaria and broadleaf at three nitrogen levels from all harvests.

Species	Nitrogen		
	Nil	Low	High
		%	
Kikuyu grass	2.16	1.88	2.48
Setaria	1.44	1.64	2.22
Broadleaf	1.64	1.76	2.31

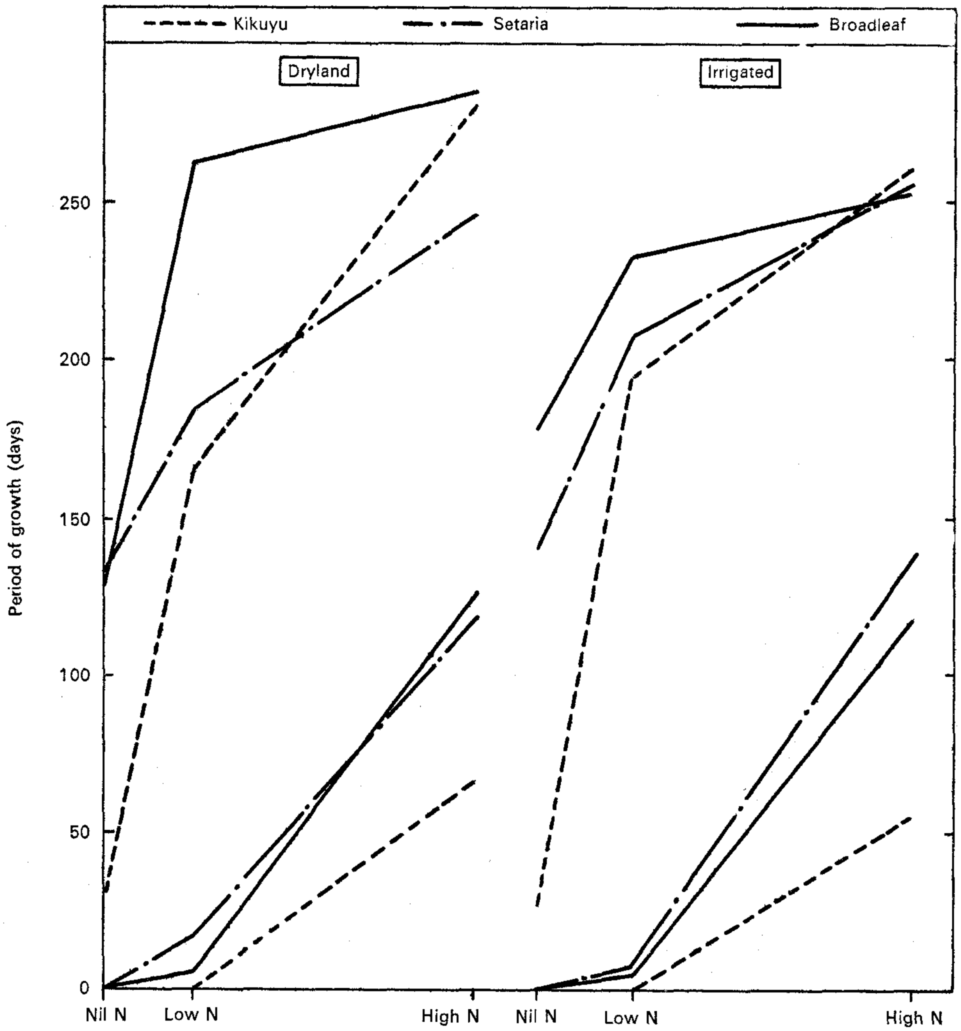

Figure 3—Length of periods of growth for each grass in relation to nitrogen level and moisture treatments—mean of 3 years. Upper three curves show length of period that sward growth rates exceeded 5 kg DM ha^{-1} day^{-1}. Lower three curves show length of period that sward growth rates exceeded 60 kg DM ha^{-1} day^{-1}.

Discussion

The dry matter yields obtained were lower than have been recorded elsewhere on the subtropical east coast of Australia (Colman 1971). The lower yields were probably due, in part, to the cutting frequency used. Reduced yields of tropical grasses from frequent harvests have been recorded by Schofield (1944), Vincente-Chandler *et al.* (1964) and Bryan and Sharpe (1965).

The low forage yields could also have been due to the nitrogen rates used. Colman (1971) recorded yields of 30,000 kg DM ha^{-1} yr^{-1} from kikuyu grass with 1120 kg N ha^{-1} yr^{-1}. The high N rate in the present experiment only supplied 680 kg N ha^{-1} yr^{-1}, and was applied throughout the year, including winter when grass growth was minimal.

The seasonal pattern of growth of the three grasses was qualitatively similar to that reported for tropical grasses on the far north coast of New South Wales by Colman (1964, 1966) and in south-east Queensland by Henzell (1963), Shaw *et al.* (1965), Bryan and Sharpe (1965), Hacker (1972) and Strickland (1973). The main difference between the results cited above and those of this experiment, is the earlier cessation of grass growth due to the lower temperatures in May and June on the mid-north coast of New South Wales. This difference is one of degree rather than of kind, implying that the environment of the mid north coast of New South Wales is similar to that of the far north coast and of south east Queensland, for tropical grass growth.

Winter growth was effectively nil. In general, results from lower latitudes have also shown little winter growth by tropical grasses, the main exceptions being *Paspalum yaguaronense* (Shaw *et al.* 1965), some *Eragrostis* sp. (Strickland 1973) and some *Digitaria* sp. (Strickland 1974) that have a small, but significant winter component. The prospect of improving winter production by using frost tolerant cultivars appears doubtful as the results of Shaw *et al.* (1965) and Hacker (1972) indicate that there is little correlation between winter production and frost tolerance. The consequence of these results for the mid-north coast is that tropical grasses will not be a satisfactory source of forage during winter.

All species showed a potential for a long period of high growth rates over summer at high N, but not at low N, indicating that high rates of nitrogen will be required if these grasses are to be used for intensive animal production. The use of nitrogen on these grasses in spring resulted in large increases in forage production and indicates a major use for these species in overcoming feed shortages, during a period when the feed supply is often low.

The large response to nitrogen and the small effects of irrigation support the conclusion of Henzell and Stirk (1963) for south east Queensland, that nitrogen and not water was the main factor restricting tropical grass growth in spring. However, both this experiment and that of Henzell and Stirk (1963) were on deep soils with large water holding capacities. This hypothesis still requires testing on the shallow soils that occur over large areas of the Australian east coast.

The lower efficiency of use of nitrogen by kikuyu grass is supported by the literature. Mears (1970) reviewed research on kikuyu grass and concluded that the mean efficiency was 13 to 27 kg DM kg N^{-1} applied. This compares with 30 to 40 kg DM kg N^{-1} for setaria (Hacker and Jones 1969). The lower efficiency of nitrogen use by kikuyu grass, under low N, has important practical consequences. Kikuyu grass is now being established from seed over large areas, on soils with low nitrogen levels, without the use of nitrogen fertilizers. This experiment suggests that it is not the best grass to use in such situations. Setaria and broadleaf would be the better species to use, especially where grass/legume pastures are desired. Kikuyu grass is best restricted to sites where it will be used intensively with applied nitrogen fertilizer.

The results of this study are of value for assessing the place of tropical grasses in mid north-coast pastures. The species studied recorded long growing seasons and an ability for high forage yields when fertilized with nitrogen. The latter is especially valuable in spring when the feed supply is normally low. In addition it is known (Kemp 1974*a*) that these species will survive indefinitely in permanent pastures. Their major deficiency is poor winter growth. One reliable means of improving winter feed supply can be to over-sow pastures with annual forage crops, of oats or annual ryegrass (Kemp 1974*b*).

In the past, temperate grasses, e.g. perennial rye-grass, have been commonly used as the base species in permanent pasture sowings, but such species rarely survive for more than two years and apart from the necessity for continual resowing of such pastures it is also necessary to sow summer forage crops for the period when temperate grass growth is poor. Also, it is often found that temperate grass pastures are frequently invaded and dominated by volunteer tropical grasses such as kikuyu grass and carpet grass.

Considering the alternatives it seems to be more logical to base any permanent pastures on the New South Wales mid north coast on tropical grasses rather than temperate grasses as previously.

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