

A REVIEW OF GUINEA GRASS (*PANICUM MAXIMUM*) FOR THE WET TROPICS OF AUSTRALIA

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ABSTRACT

Common guinea or Riversdale is the most important pasture grass for the humid tropical lowlands of Australia. Its general productivity, compatibility with legumes, freedom from important pests and diseases, relatively high feeding value and not too exacting agronomic and grazing requirements are major reasons for its popularity. Main weaknesses are intolerance of poor drainage and a very seasonal growth pattern. Hamil will grow on wetter soils than Riversdale, and Makueni exhibits superior cool season growth. Coloniao and Embu are relatively unproductive, and Coarse Guinea is considered a weed.

INTRODUCTION

The Guinea grasses (*Panicum maximum*) are well established throughout tropical countries of both hemispheres where they play important roles in beef and dairy production. Parsons (1972) has plotted their spread from the Guinea Coast of West Africa to Barbados during the Seventeenth Century and Brazil in the Eighteenth Century via slave ships.

On a global scale, Guinea grass is concentrated in Africa, Central and South America, Northern Australia, India, South-East Asia and the Pacific Islands (Motta 1953) between 20° S and 20° N and above 1300 mm rainfall isohyet. It ranges from sea level to approximately 2000 m (Motta 1953, Bogdan 1965) mostly in scattered tree grassland (Edwards and Bogdan 1951), open tall tree glades, coastal regions and bush vegetation (Motta 1953).

The species is extremely variable (Bogdan 1955, Ramaswamy and Raman 1971) and is poorly understood taxonomically and phylogenetically (Jouhar and Joshi 1966).

Australian experience suggests that a sensible agronomic and environmental grouping is to divide the commercially available *P. maximum* varieties into two: the "Guineas" and the "panics". The panics (Petrie, Sabi, and Gatton) are suitable for parts of the sub-tropics or elevated moist tropics, whilst the Guineas are most productive on high rainfall tropical lowlands. Grazing management and agronomic requirements of each group are also fairly distinct. Under this grouping, the only Guinea grasses of commercial significance in Australia are Riversdale (common Guinea), Hamil, Coloniao, Embu, Makueni and Coarse Guinea.

ORIGIN AND DISTRIBUTION OF AUSTRALIAN GUINEA GRASS VARIETIES

Riversdale or *Common Guinea* (*Panicum maximum* var *typica*) resembles ecological races introduced from east and central Africa whereas Hamil and Coloniao are similar to accessions from the West African coast (Grof and Harding 1970). It was introduced to Australia in the 1880's by W. Hill and was widely distributed from the Wollongbar Experimental Farm in the 1890's but never became popular in that area (Breakwell 1923). It had spread to the tropical coast by 1920 (Brooks 1921) and since that time Guinea has become the most widely used pasture grass in high rainfall tropical lowlands. It is, however, a somewhat variable type (Hopkinson, pers.comm.) and a

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morphologically uniform line of common Guinea (cv Riversdale) was selected by C.H. Middleton and released by the Queensland Herbage Plant Liaison Committee in 1975.

Hamil is a registered cultivar derived from seed supplied to Jack Hamil of Daintree, North Queensland in 1935 by C.T. White, Queensland Government Botanist. There are no records of the original source. It spread rapidly in the Daintree area and was noticed and named by D.O. Atherton, Director of Tropical Agriculture (Barnard 1967). It has since spread to other parts of the wet tropical coast.

Coloniao is thought to be the Guinea grass referred to by Parsons (1972) in his paper on the spread of African grasses, and this is supported by T.G. Graham (unpublished data) and Grof and Harding (1970). It is suspected that *Coloniao* was identified by Hans Sloane in 1684 in Barbados. It spread throughout the West Indies during the 1700's and was introduced into Brazil during that century by slave ships directly from the Guinea Coast of West Africa (Parsons 1972). The first Australian introduction (Q1202) was received from Molokai Is, Hawaii, where it had been introduced from Brazil (Grof and Harding 1970). It was grown at South Johnstone Research Station in the 1930's and has since found limited use on the wet tropical coast.

Embu (creeping Guinea) originated from a single plant found by R. Strange along a forest road near Embu, Kenya (Bogdan 1965). Seed was introduced from Kitale to Queensland independently by J. Redrup and B. Grof in January 1965. Embu is the only cultivar with a decumbent growth habit and is so unusual that Bogdan (1965) feels it may belong to a distinct taxon. Although it has been grown in south-east Queensland and on the wet tropical coast it has not been a successful species (Ostrowski pers. comm., Mellor, Hibberd and Grof 1973).

Makueni was first planted by J. Knight at Makueni in the Machakos district of Kenya, from locally collected seed. In 1962 it was brought to Kitale Experimental Station and multiplied as K6221. Makueni was collected from Kitale and brought to Australia independently by J. Redrup and B. Grof in 1965. It was released in Australia for commercial production in July 1974, and is recommended as an alternative to other "Guinea" grasses on the wet coastal lowlands and adjacent highlands of tropical far north Queensland (Middleton and McCosker 1975).

Coarse Guinea is an undesirable type whose origin was a result of contamination of imported seed or as an escapee from nursery stock. It has been on the wet tropical coast of north Queensland for at least 20 years. Flood waters, birds, road graders and commercial seed harvesters have assisted in spreading it to many areas of north Queensland (Teitzel and Harding 1972).

BOTANICAL DESCRIPTION

Bogdan (1955) classified 47 varieties of *Panicum maximum* into four broad groups:

- (a) *Tall vigorous type*: Robust plants with large leaves and rather thick stems. A fodder type of high productivity.
- (b) *Var trichoglume type*: Plants of medium vigour, with numerous fine stems. Leaves numerous, rather broad and short. Basal and stem leaves are both numerous. Mainly a grazing type.
- (c) *Medium sized type*: Narrow, predominantly basal leaves, usually stemmy although some good leafy forms.
- (d) *Annual type*.

Coloniao, *Hamil* and *Coarse Guinea* appear to fit into group (a) while common and *Makueni* appear to be from group (c) of Bogdan's classification.

Jauhar and Joshi (1966) working with 20 accessions in India have defined 5 types based on morphological characters. All accessions introduced from Australia were of

TABLE 1
Botanical differences between six Guinea grasses (from Middleton & McCosker 1975)

Attribute	Common	Makueni	Hami	Coloniao	'Coarse'	Embu
Growth form	Medium height (1.8-2.0 m) erect canopy, fine stems.	Medium height (1.8-2.4 m) leaves less erect than others. Moderately coarse stems.	Giant robust type, thick stems. Canopy 3.0-3.5 m.	Giant robust type, thick fleshy stems. Canopy 2.5-3.0 m.	Giant robust thick woody stems. Canopy 2.5-3.0 m.	Semi-erect, rambling habit, roots freely from nodes, produces aerial roots from lower nodes. Canopy 1.0-1.5 m.
Leaves - colour	Green	Light Green	Dark Green	Distinctive Blue-green	Dark Green	Light Green/green
- length	70-80 cm	80-90 cm	70-80 cm	80-90 cm	80-90 cm	20-30 cm
- width	15-18 mm	18-22 mm	24-26 mm	25-30 mm	25-30 mm	12-16 mm
- blade hairs	sparsely hairy upper surface - few on lower surfaces.	densely soft hairs both surfaces, hairs whitish. Much more hairy than all others.	sparsely hairy on upper surface	nil	sparse to moderately dense stiff short hairs giving rough feel to the leaf.	Occasional short hairs on leaf surfaces.
- sheath hairs	moderately hairy on outside surface, density increasing towards node	densely hairy, increasing in length towards node. Hairs on both surfaces of sheath.	sparsely hairy, increasing in density on sheaths towards base of plant.	glabrous except for few short hairs on sheath margin toward sheath/blade junction	moderately dense long stiff brittle hairs on outside surface increasing in density towards the blade/leaf junction. Sheath painful to handle.	Sparse short hairs on lower outside of sheath near the node junction.
Exposed stem hairs	nil	moderately dense particularly on lower side of nodes.	nil	nil	nil	Occasional hairs on lower internodes.
Panicle - size (seed head)	15-40 cm long	15-40 cm long	20-60 cm long	20-50 cm long	20-60 cm long	15-20 cm long
- colour	15-30 cm wide green	12-30 cm wide green with purplish tinge	15-40 cm wide dark green	15-30 cm wide dark green	15-40 cm wide distinctive dark brown	12-15 cm wide green
Spikelet - outer (seed) glume hairs	nil	densely hairy	nil	nil	nil	nil

Type 2 which agrees with Middleton and McCosker's (1975) morphological description of Common Guinea. Hamil and Coarse appear to fit into Type 4 but Makueni, Coloniao and Embu do not fit any of their groupings.

While all the accessions included in the study of Jauhar and Joshi (1966) showed the character rugosis of the upper lemma, which is regarded as the typical or key character of *P. maximum*, they represented a highly heterogeneous group in respect of many other characters of diagnostic value. The authors therefore placed greater emphasis on floral characters such as shape, texture, serration, and nervation of each constituent part of the spikelet.

For the practical convenience of distinguishing the main Guinea grass types of Queensland the morphological differences listed by Middleton and McCosker (1975) are reproduced in Table 1.

ENVIRONMENTAL ADAPTATION

Climate

The distribution of Guinea grass is largely governed by a requirement for high temperatures and a rainfall greater than 1300 mm. Guinea grass is very frost sensitive: top growth is burnt and plants may even die (Motta 1953). Growth rates of Riversdale, Hamil and Coloniao are very temperature sensitive and winter production of all three is poor. Even in the frost-free wet lowland tropics of north Queensland peak summer growth rates of common guinea ($>150 \text{ kg ha}^{-1}\text{day}^{-1}$) are at least five times higher than mid winter growth rates ($<30 \text{ kg ha}^{-1}\text{day}^{-1}$) (Middleton, Mellor and McCosker 1975). Makueni is an improvement in that it combines relatively good winter production and fair summer production (Grof and Harding 1970). Its better winter production has also extended its environmental range to include tropical highlands (Quinlan, Edgley and Shaw 1975; Middleton and McCosker 1975).

Riversdale, Hamil and Coloniao are therefore best suited to the wetter coastal areas of tropical North Queensland (Humphreys 1974; Teitzel, Abbott and Mellor 1974b) although they perform satisfactorily in tropical areas with a lower and more erratic distribution of rainfall where dry winter and spring periods are commonly experienced (T.G. Graham unpublished data, Motta 1953).

All varieties are used in the sub-tropical coastal areas of Queensland but they have never been popular chiefly because they are less tolerant of low temperatures than other grasses such as the setarias (*Setaria anceps*) and the 'panics' (Middleton pers. comm.).

More detailed experimental data is scanty with most controlled environment studies mainly highlighting the large differences between tropical grasses and legumes. However 't Mannelje and Pritchard (1974) placed Hamil in a less cold tolerant group than Petrie panic (*P. maximum* var *trichoglume*) which is in accordance with the commercial agronomic grouping used in this paper.

Soils

Guinea grasses are adapted to a wide range of soils (Motta 1953) but production in infertile situations is poor and response to fertilizer is marked. Riversdale and Coloniao will not tolerate waterlogged conditions while Hamil which prefers well drained sites will grow on slightly wetter areas. Little is known of the performance of Embu and Makueni under poor drainage (Teitzel, Abbott and Mellor 1974b).

AGRONOMIC CHARACTERS

Establishment

Because it seemed to set little viable seed (Motta 1953) and harvesting techniques were poor, Guinea grass was planted vegetatively in Queensland up to 1945 (Winders 1945). It was so difficult to obtain good quality seed that the minimum prescribed germination was only 3% (Humphreys 1974) whereas the minimum is now 20% in

Queensland. This improvement in seed quality was due to improved harvesting and handling techniques. As a result, recommended planting rates now range from 2 to 7 kg ha⁻¹ depending on the quality and age of the seed and purpose of the pasture (Humphreys 1974; Teitzel, Abbott and Mellor 1974b). On the other hand, in Uganda Olsen and Tiharuhondi (1972) significantly decreased total D.M. yield at nil and high (5.6 kg ha⁻¹) *Desmodium intortum* seeding rates by increasing seeding rates of *P. maximum* (type not stated) from 0.56 kg ha⁻¹ to 2.24 kg ha⁻¹. There was no difference in total D.M. yield between high and low seeding rates of *P. maximum* at low (1.12 kg ha⁻¹) and medium (3.36 kg ha⁻¹) legume seeding rates.

Planting methods have ranged from broadcasting seed into the ash of scrub burns (Humphreys 1974 in Queensland; Motooka *et al* 1967 in Hawaii) to the full preparation of a fine, firm, seed bed (Teitzel, Abbott and Mellor 1974a) with the latter preferred in Queensland. Because seed is small, care must be taken not to plant deeply. The common method is to remove the shoes from a combine and drop the seed directly on the surface of a crumb structured seed bed. A Cambridge roller follows to break up the clods and compress soil around and over the seed. Planting times vary but spring and early summer are favoured as it is dry enough to burn timber and work soil and follow-up rains are reasonably assured. Guinea grass, however, has been successfully planted at any time of the year on the wet coast where Cambridge rollers have been used (Teitzel, Abbott and Mellor 1974a).

Legumes have been successfully sod-seeded into Guinea grass dominant pastures in north Queensland (Teitzel, Abbott and Mellor 1974a).

General fertilizer requirements

Motta (1953) suggested that Guinea grass would most likely benefit from phosphorus fertilizer. This has been shown by Teitzel (1969) who measured large dry matter yield responses to phosphorus and potassium fertilizer, and showed a greater response from Guinea grass than from the associated legume (*Stylosanthes guyanensis*) on a granitic soil. He showed a 261% increase in dry matter yield from an application of 72 kg ha⁻¹ P on Guinea grass compared to a 2% increase from the legume and a 62% increase for the grass compared to a 28% increase for the legume from 121 kg ha⁻¹ K. For the establishment of Guinea/legume pastures in the Queensland wet tropics, Teitzel and Bruce (1972) recommend P and Mo on basaltic soils; P, K, Cu, Zn, and S on granitic soils; P, K, Mo and S on metamorphic soils and P, K, Cu, Zn and B on soils derived from beach sand.

For older pasture, the initial response to additional phosphorus was from the legume but this was later followed by a grass response (Bruce 1972) leading to a balanced mixture or even grass dominance. A similar pattern has been reported from Puerto Rico (Caro-Costas and Vicente-Chandler 1963, Vicente-Chandler *et al* 1964); in other words, a classical pattern of nitrogen build up by legumes followed by a grass response.

Nitrogen fertilizer responses

As an alternative to legume nitrogen, nitrogenous fertilizers have been used on Guinea grass for many years. Results vary and are not conclusive. Although extrapolation is difficult, it appears that Guinea grass responds markedly to nitrogen fertilization in most situations (Vicente-Chandler, Silva and Figarella 1959; Grof and Harding 1970; Mott, Quinn and Bisschoff 1970; Quinn *et al* 1970), and that winter application provides for more efficient nitrogen utilization than summer application (Quinn *et al* 1970). However, other grasses such as signal grass (*Brachiaria decumbens*), pangola grass (*Digitaria decumbens*) and para grass (*Brachiaria mutica*) have produced more dry matter for a given nitrogen fertilizer input (Grof and Harding 1970).

Plant productivity

Annual dry matter yields of 10 Guinea grass varieties in a cutting experiment conducted over two years at South Johnstone ranged from 15,700 (Embu) to 28,000 (Hamil) kg ha⁻¹, with an input of 224 kg of nitrogen and 5 cuts a year (Grof and Harding 1970). This production varied with season and variety. The taller forms, Hamil and Coloniao, produced most of their dry matter yields during the summer wet period, Hamil (24,500 kg ha⁻¹) being more productive than Coloniao (20,700 kg ha⁻¹). The shorter forms, in particular Makueni and to a lesser extent Riversdale and Embu, were superior in the cool season.

In Puerto Rico, Vicente-Chandler, Silva and Figarella (1959) measured much higher Guinea grass yields. When cut at 90 day intervals with an input of 1,792 kg ha⁻¹N, mean yields of 54,000 kg dry matter per annum were produced compared to 43,900 kg ha⁻¹ for para grass (*Brachiaria mutica*) and 77,900 kg ha⁻¹ (1,344 kg ha⁻¹N) for Napier grass (*Pennisetum purpureum*). In Australia, Middleton and McCosker (1975) under higher rainfall but lower nitrogen input (300 kg ha⁻¹N) obtained 62,400, 62,500, 62,500, 52,400 and 24,600 kg ha⁻¹ D.M. yield from common and Makueni guinea, *Setaria splendida*, *Brachiaria decumbens* and pangola (*Digitaria decumbens*) respectively when cut at 12 week intervals and 10 cm above ground.

Higher yields of Guinea grass in response to less frequent cutting intervals are widely recorded throughout the world [Oyenuga (1960) in Nigeria; Vicente-Chandler, Silva and Figarella (1959) in Puerto-Rico; Infante (1970) in Cuba; van Voorthuizen (1972) in Tanzania; and Watkins and Lewy (1951) in San Salvador]. Middleton and McCosker (1975) have confirmed a similar response in the wet tropics of Australia where an increase in the sampling interval from 3 weeks to 12 weeks increased annual dry matter yields from 22,700 kg ha⁻¹ to 62,400 kg ha⁻¹ for common and 23,300 kg ha⁻¹ to 62,500 kg ha⁻¹ for Makueni Guinea.

The effect of cutting height on yield is less clear. It is commonly claimed e.g. Grof and Harding (1970) that low cutting (6 cm) reduces yield. However, there is experimental evidence showing that Guinea grass can tolerate severe defoliation. Caro-Costas and Vicente-Chandler (1961) found that cutting at 8 cm had no adverse effect on yield in Puerto Rico. Richards (1965) reported a similar result from Jamaica. In cutting frequency x height experiments both van Voorthuizen (1972) and Middleton and McCosker (unpublished) obtained highest Guinea grass yields when cut at the longest interval (12 weeks) and the lowest heights (5 and 10 cm respectively). However, van Voorthuizen suggested that constant mowing seemed to reduce the Guinea grass population.

Seed Production

Guinea grass is a facultative apomict with about 1% sexual reproduction (Bogdan 1965), so to all intents and purposes the plant breeds true. However Smith (1972) successfully isolated completely sexual plants and hopes to make use of all the genetic variability within *P. maximum* species to develop more productive apomictic varieties.

At South Johnstone (17° 36'S) common Guinea normally flowers during November-December and the seed is ready for harvest in late December or early January. Hamil and Coloniao flower in February-March and the main crop of seed is ready for harvest in April (Harding — personal communication). In Colombia, Coloniao requires 32 days from flowering to seed setting (Alarcon, Lotero and Escobar 1969). Uneven ripening of seed and shattering as it matures makes harvesting difficult (Anon 1965).

In Kenya the yield of harvested seed can be as low as 5% of the potential because of prolonged flowering within a given head, low seed set, low numbers of fertile tillers, low seed retention, disease and bird damage (Boonman 1971). The tall growth habit can also present harvesting problems. It is best to keep the plants well eaten down during the summer and then remove stock early enough to enable the plants to reach

maturity quickly. The modern header harvesters using high mountings have been found quite efficient and yields of 100 to 200 kg ha⁻¹ of seed are reasonably common in North Queensland.

Prior to the advent of header harvesters, most Guinea grass seed in Queensland was hand harvested by severing the entire seed heads which were then stacked in the fresh state and 'sweated' for about three days. A belief that this sweated seed was of a superior quality led to an investigation which has highlighted two obvious consistent effects and a third inconsistent effect. The consistent effects were a loosening of the seed on the head, and superior longevity. The inconsistent effect was of early dormancy breaking (Hopkinson pers. comm.).

Common Guinea grass seed is contained in smooth hairless hulls and there are 1,800,000 to 2,200,000 seeds kg⁻¹ (Anon 1965; Humphreys 1974). Quality improves with age and Alarcon, Lotero and Escobar (1969) found in Colombia that the highest germination occurs 160-190 days after harvesting. The best storage conditions are 10° C at low relative humidity (Alarcon, Lotero and Escobar 1969). Light and temperature markedly influence germination, which increased from 12.5% with no light to 25 and 40% with 12 and 16 hours light respectively, and from 25% at a constant temperature of 30 to 32° C to 50% when the temperature was dropped to 22° C at night (Binard 1958). Febles and Padilla (1971) claim that germination of Guinea grass will improve if seed is subjected to fixed temperatures of between 6 and 50° C or alternate temperatures in the same range, and that the effect of temperature is not cumulative and the time of exposure is therefore not critical. They also state that a higher temperature than that of the soil, induced by some thermal pre-treatment (up to 50° C) is indispensable in order to break dormancy in Guinea grass.

The Queensland Department of Primary Industries Standards Branch specifies a minimum germination of 20% with a minimum purity of 70% under the Agricultural Standards Acts 1952 to 1963.

Pests and diseases

In Australia Guinea grass is free of pests and diseases of economic importance, but in the Belgian Congo young stands have been attacked by various insects of the order Orthoptera and pasture establishment has been improved by applying BHC baits (Kesler 1961). Gramalote, a strain of *P. maximum* grown extensively in central and southern America, shows universal infection of mature plants by leaf spot (*Cercospora fusimaculosus*) (Warmke 1951).

Fodder conservation

Successful silage (Motta 1953 in Jamaica) and hay (Motta 1953 in Jamaica; Owen 1964 in Tanganyika) have been made from Guinea grass. In north Queensland high humidity usually leads to rapid deterioration of hay but Teitzel, Abbott and Mellor (1974c) report that good quality silage can be made from Guinea-centro pastures although this method of conservation is not popular and possibly uneconomic.

Nutritive value

Many studies of the nutritive value of Guinea grass have been reviewed by Motta (1953) and Mahendranathan (1971). Other studies have been reported by Reyes (1972) in Cuba, Van Voorthuizen (1971) and Miller and Blair Rains (1963) in Tanzania, Olsen (1972) and Reid *et al* (1973) in Uganda, Silva and Gomide (1967) in Brazil, Minson (1971), Minson and Laredo (1972) and Laredo and Minson (1973) in Australia.

These indicate that crude protein declines with age and has ranged from 19% in two week regrowth with a high nitrogen input to 9% or less at maturity. After three months regrowth the crude protein may be as low as 5%. Conversely crude fibre content increased with age. On fertile soils Guinea grass had adequate phosphorus levels for stock maintenance requirements but on poor soils phosphorus reached a sub maintenance level. Other nutrients will also vary according to age of regrowth and soil type.

TABLE 2
In vitro dry matter digestibility coefficients (%) for selected grasses harvested at different stages of maturity,
 and relationship between dry matter digestibility and number of days growth in Uganda. (From Reid et al. 1973)

Species	Weeks of Growth																Standard error $S_{y \cdot x}$
	1	2	3	4	5	6	7	8	9	10	11	12	14	16			
	in vitro dry matter digestibility (%)																
<i>Brachiaria decumbens</i>	78.2	72.8	73.0	71.9	71.0+	66.7	66.9	61.6	63.7	58.9	54.8	48.9	Y = 84.75-0.29X	1.68			
<i>Digitaria decumbens</i>	77.0	78.1	75.8+	75.0	70.4	66.0	59.5	62.4	59.8	56.3	55.2	56.3	Y = 83.21-0.25X	3.61			
<i>Hyparrhenia rufa</i>	60.1	59.6	62.8+	63.2	64.1	56.2	61.1	57.9	57.5	59.2	48.7	42.0	39.5	Y = 69.52-0.21X	4.17		
<i>Panicum maximum</i> cv. 'Creeping Embu'	82.2	77.2	74.8	69.8+	70.6	61.2	59.6	55.8	54.6	53.8	48.6	38.4	Y = 91.33-0.45X	2.06			
<i>Panicum maximum</i> cv. 'Makueni'	76.4	75.2	60.5+	52.4	46.1	52.5	49.6	53.8	47.1	49.8	41.6	42.0	Y = 71.23-0.27X	5.87			
<i>Setaria splendida</i>	71.8	67.8	68.2	63.5	62.6	60.0	60.9	60.6	61.7	54.4+	56.7	52.6	37.4	Y = 75.08-0.24X	3.68		

* Y = % *in vitro* dry matter digestibility, X = number of days of growth after clipping plots on February 2, 1970

+ Stage of early heading in grasses.

Table 2 illustrates the relationship between stage of maturity and dry matter digestibility (DMD) of tropical grasses in Uganda. It also illustrates a difference between the DMD of cv Makueni and cv Embu as the latter has a higher DMD but a faster rate of decline than the former. Reid *et al* (1973) place *Panicum maximum* in a group of "improved" grasses e.g. *Brachiaria*, *Chloris* and *Setaria* sp which has a higher DMD than the "unimproved" group e.g. *Cymbopogon*, *Hyparrhenia* and *Themeda* sp. Unlike many other species, *Panicum maximum* DMD was found to decrease in a curvilinear manner with time (Reid *et al* 1973).

Laredo and Minson (1973) found mean voluntary intake of leaf was 46% higher than that of stem (57.7 v 39.6 g/kg^{0.75}), despite a slightly lower DMD of the leaf fraction (52.6 v 55.8%). The higher intake of the leaf fraction was associated ($r=0.74$, $P<0.01$) with a shorter retention time of dry matter in the reticulo-rumen. With % leaf ranging from 39% to 68% voluntary intake with range from 52 to 81 g/kg^{0.75} (Minson and Laredo 1972).

For plant evaluation studies within the range of *P. maximum* species, Minson and Laredo (1972) suggest leafiness as a parameter for estimating voluntary intake but indicate that this character loses its value when evaluating across species.

PASTURE MANAGEMENT AND ANIMAL PRODUCTION

Pasture management

Careful post germination management is essential for Guinea-legume pastures (Teitzel, Abbott and Mellor 1974 b). Grazing too early or too late can ruin the pasture or at least greatly reduce its productive life. The timing and intensity of the early grazing varies with such factors as climate, soil type, stage of growth and the associated legume. For instance, stylo is not particularly palatable in the early stages and is sensitive to shading. Consequently a Guinea-stylo pasture may be lightly grazed relatively early in the establishment phase without injury to the legume. On the other hand, centro and puero are much more palatable and greater care must be taken to prevent damage from selective grazing. Light, rapid, intermittent grazings are the general rule during this period (Teitzel, Abbott and Mellor 1974b).

Once established, the difficulty is in striking a balance between preventing the Guinea from becoming rank, coarse and unpalatable during summer and not overgrazing during winter (Teitzel, Abbott and Mellor 1974c). Normal practice is to set stocking rates according to the pasture's ability to carry animals through the winter and spring. These rates are, however, hopelessly inadequate for controlling the bulk of feed produced during summer. The effect may be removed by slashing or roller chopping and the above authors emphasise the importance of not slashing too low. They also consider slashing a wasteful process and to overcome the imbalance caused by poor winter production, a system whereby approximately 25% of the farm is planted to nitrogen fertilized *Brachiaria decumbens* or *Digitaria decumbens* was proposed. These pastures are seen as buffer areas which remove pressure from the more vulnerable but more economical Guinea-legume pastures during times of stress. The latter may then be more fully utilized during summer.

The literature is not clear on the effect of different grazing systems. Anon (1965) states that Guinea grass pastures should not be subjected to heavy continuous grazing and Grof and Harding (1970) at South Johnstone, report 16% higher liveweight gains over two years by rotationally grazing Guinea grass compared with a continuous system. However, Humphreys (1974) reports that Guinea pastures have withstood heavy continuous grazing for long periods and feels that any advantages to be gained from rotational grazing may not always justify the added expenditure involved. In Uganda, Tiharuhondi, Olsen and Musangi (1973) produced high liveweight gains using a rotational grazing system with a regrowth period not exceeding 3 weeks, while in the Lajas Valley in Brazil, Rivera-Brenes *et al* (1958) reported satisfactory results

from rotational grazing intervals ranging from six and a half to ten days. Tiharuhondi, Olsen and Musangi (1973) recommend rapid, rotational grazing as a grazing management system as it appears to offer the best utilization of grasses at their optimum stage of growth, especially in the presence of adequate N and soil moisture.

Animal productivity

Guinea grasses are capable of giving very high animal production. In the most productive year of an experiment using Guinea grass-legumes, run over a three year period in the wet tropics of Queensland, Mellor, Hibberd and Grof (1973) recorded total annual liveweight gains of 904 kg ha⁻¹ from Riversdale, 758 kg ha⁻¹ from Hamil and 736 kg ha⁻¹ from Coloniao. Embu failed to carry the imposed stocking rates of 4.94 beasts ha⁻¹ during the wet season and 2.47 beasts ha⁻¹ for the remainder of the year. Per animal production in the area is also high and on good pastures averages about 0.7 kg animal⁻¹ day⁻¹ for the year (Teitzel, Abbott and Mellor 1974c). Milk production from eight year old pastures of pangola, Guinea and Napier (elephant) grasses fertilized with 600 kg ha⁻¹ N, P and K (14:13:10) at 3 month intervals, in a 1,650 mm rainfall area of Puerto Rico, was 2,330, 3,240 and 2,520 kg milk cow⁻¹ respectively (Caro-Costas and Vicente-Chandler 1969).

On Guinea/nitrogen fertilized pastures production varies widely depending on the level of nitrogen used. Quinn, Mott and Bisschoff (1961) recorded annual liveweight gains in Brazil of 300, 500 and 700 kg ha⁻¹ from the 0, 100 and 300 kg ha⁻¹ N treatments respectively. Under irrigation, productivity can be pushed even higher and in Jamaica, Richards (1965) measured annual liveweight gains ranging from 800 to 1,250 kg ha⁻¹ from irrigated Guinea grass fertilized with 160 kg N ha⁻¹ yr⁻¹.

In Uganda, Tiharuhondi, Olsen and Musangi (1973) with a mixed *P. maximum*, *Setaria sphacelata* and *Chloris gayana* pasture produced liveweight gains ranging from 279 kg ha⁻¹ (irrigated, nil N) to 1,360 kg ha⁻¹ (irrigated, 672 kg ha⁻¹ N) under a rotational system. Where nitrogen was applied at 224, 448 and 672 kg ha⁻¹ production from the irrigated pasture was higher than the non-irrigated pasture by 331, 352 and 370 kg ha⁻¹ l.w.g. per annum respectively. Stobbs (1969) also working in Uganda measured 791 kg ha⁻¹ l.w.g. per annum from *Panicum maximum* var likoni — *Stylosanthes guyanensis* pastures in small plots.

Conclusions

Motta (1953) in his review of Guinea grass suggested four areas where further information was needed: (1) the potential value of existing strains and ecotypes under different environmental conditions both from the fodder and seed production aspects; (2) methods of incorporating suitable companion legumes in the pastures; (3) an assessment of the true value of this grass as a soil improver and fertility builder under ley conditions; (4) the best methods of management and utilization of this grass, alone and with pasture legumes over the whole year and from season to season.

With the possible exception of (3), which is not an important aspect in Australia, these knowledge gaps have largely been filled with the result that the potential of Guinea grass recognized by Motta (1953) has been realized in terms of beef and milk production in the tropical countries of the world. The major problem area of Guinea grass now appears to be one of taxonomy. There is a need for a practical key to be designed and the Guinea grasses of the world shown accordingly so that the workers in different countries will know to which *Panicum maximum* future literature refers.

REFERENCES

- ALARCON, M.E., LOTERO, C.J., ESCOBAR, R. (1969) — Production of seed from Angleton grass, Jaragua grass and Guinea grass. *Agricultura tropical* **25**: 206-14.
- ANON. (1965) — Pasture legumes and grasses. (Bank of New South Wales: Sydney).
- BARNARD, C. (1967) — Australian Herbage Plant Register (CSIRO Division of Plant Industry, Canberra).
- BINARD, L. (1958) — Results from some trials on the germination of *Panicum maximum*. *Agricultura, Louvain*, **6**: 305-10.
- BOGDAN, A.V. (1955) — Herbage plants at the Grasslands Research Station, Kitale, Kenya. *East African Agricultural and Forestry Journal* **20**: 151-65.
- BOGDAN, A.V. (1965) — Cultivated varieties of tropical and sub-tropical herbage plants in Kenya. *East African Agricultural and Forestry Journal* **30**: 330-8.
- BOONMAN, J.G. (1971) — Experimental studies and seed production of tropical grasses in Kenya. 1. General introduction and analysis of problems. *Netherlands Journal of Agricultural Science*. **19**: 23-36.
- BREAKWELL, E.J. (1923) — "The Grasses and Fodder Plants of New South Wales" (Government Printer, Sydney).
- BROOKS, G.B. (1921) The dissemination of introduced pasture grasses in Central Queensland. *Queensland Agricultural Journal* **16**: 242.
- BRUCE, R.C. (1972) — The effect of topdressed superphosphate on the yield and botanical composition of a *Stylosanthes guyanensis* pasture. *Tropical Grasslands* **6**: 135.
- CARO-COSTAS, R., and VICENTE-CHANDLER, J. (1961) — Effects of two cutting heights on yields of five tropical grasses *Journal of Agriculture of the University of Puerto Rico* **45**: 46-9.
- CARO-COSTAS, R., and VICENTE-CHANDLER, J. (1963) — Effect of liming and fertilization on productivity and species balance of a tropical kudzu-molasses grass pasture under grazing management. *Journal of Agriculture of the University of Puerto Rico* **47**: 231-42.
- CARO-COSTAS, R., and VICENTE-CHANDLER, J. (1969) — Milk production with all grass rations from steep, intensively managed tropical pastures. *Journal of Agriculture of the University of Puerto Rico* **53**: 251-8.
- EDWARDS, D.C. and BOGDAN, A.V. (1951) Important Grassland Plants of Kenya. Isaac Pitman and Sons.
- FEBLES, G. and PADILLA, C. (1971) Effect of temperature on Germination of guinea grass seed (*Panicum maximum* Jacq.) *Revista Cubana de Ciencia Agricola*. **5**: 77.
- GROF, B., and HARDING, W.A.T. (1970) — Dry matter yields and animal production of guinea grass (*Panicum maximum*) on the humid tropical coast of North Queensland. *Tropical Grasslands* **4**: 85-95.
- HUMPHREYS, L.R. (1974) — A guide to better pastures for the tropics and sub-tropics. Revised 3rd Edition (Wright Stephenson and Co. Pty. Ltd, Melbourne).
- JAUHAR, P.P. and JOSHI, A.B. (1966) — Cytotaxonomic Investigations in the *Panicum maximum* Jacq. Complex 1. Morphological Studies. *Bull Bot. Sur. India* **8**: 287-295.
- KESLER, W. (1961) — The possibilities of establishing, by sowing, pastures of perennial grasses in the Yangambi region (Congo). *Bulletin of Information I.N.E.A.C.*, **10**: 295-308.
- LAREDO, M.A. and MINSON, D.J. (1973) The voluntary intake, digestibility and retention time by sheep of leaf and stem fractions of 5 grasses. *Australian Journal of Agricultural Research*. **24**: 875-888.

- MAHENDRANATHAN, T. (1971) Potential of tapioca (*Manihot utilissima* Pohl) as a livestock feed — A review — *Malaysian Agricultural Journal* **48**: 77-89.
- MANNETJE, L. and PRITCHARD, A.J. (1974) — The effect of daylength and temperature on introduced legumes and grasses for the tropics and sub-tropics of Coastal Australia I. Dry matter production, tillering and leaf area. *Australian Journal of Experimental Agriculture and Animal Husbandry* **14**: 173-181.
- MELLOR, W., HIBBERD, M.J., and GROF, B. (1973) — Beef Cattle liveweight gains from mixed pastures of some guinea grasses and legumes on the wet tropical coast of Queensland. *Queensland Journal of Agriculture and Animal Sciences*. **30**: 259-266.
- MIDDLETON, C.H. and McCOSKER, T.H. (1975) — Makueni — A new guinea grass for North Queensland. *Queensland Journal of Agriculture and Animal Sciences*. **101**: 351-355.
- MIDDLETON, C.H., MELLOR, W., and McCOSKER, T.H. (1975) — Agronomic Limitations to Pasture and Animal Performance in the Wet Tropics. Australian Conference on Tropical Pastures., Vol. 1, 1(C)-25.
- MILLER, T.B. and RAINS, A.B. (1963) — The nutritive value and agronomic aspects of some fodders in northern Nigeria. 1. Fresh herbage. *Journal of the British Grasslands Society* **18**: 158.
- MINSON, D.J. (1971) — The digestibility and voluntary intake of six varieties of *Panicum*. *Australian Journal of Experimental Agriculture and Animal Husbandry* **11**: 18-25.
- MINSON, D.J. and LAREDO, M.A. (1972) — Influence of leafiness on voluntary intake of tropical grasses by sheep. *Journal of the Australian Institute of Agricultural Science*. **38**: 303-5.
- MOTT, G.O., QUINN, L.R., and BISSCHOFF, W.V.A. (1970) — The retention of nitrogen in a soil-plant-animal system in guinea grass (*Panicum maximum*) pastures in Brazil. Proceedings of XIth International Grassland Congress, Surfers Paradise, 414-6.
- MOTTA, M.S. (1953) — *Panicum maximum*. *Empire Journal of Experimental Agriculture* **21**: 33-41.
- MOTOOKA, P.S. PLUCKNETT, D.L., SAIKI, D.F. and YOUNGE, O.R., (1967) — Pasture establishment in tropical bushlands by aerial herbicide and seeding treatment on Kauai. Technical Progress Report 165, Hawaii Agricultural Experiment Station, p. 18.
- OLSEN, F.J. (1972) — Effect of large applications of nitrogen fertilizer on the productivity and protein content of four tropical grasses in Uganda. *Tropical Agriculture* **49**: 251-260.
- OLSEN, F.J. and TIHARUHONDI, E.R., (1972) — The productivity and Botanical Composition of Some Selected grass/legume mixtures at different seeding rates. *East African Agricultural and Forestry Journal* **38**: 16-22.
- OWEN, M.A. (1964) — A note on the effect of a late application of nitrogenous fertilizer on hay quality. *East African Agricultural and Forestry Journal* **29**: 322-5.
- OYENUGA, V.A. (1960) — Effect of stage of growth and frequency of cutting on the yield and chemical composition of some Nigerian fodder grasses — *Panicum maximum* Jacq. *Journal of Agricultural Science Cambridge* **55**: 339-50.
- PARSONS, J.J. (1972) — Spread of African Grasses to the American Tropics. *Journal of Range Management* **25**: 12-17.
- PEREZ INFANTE, F. (1970) — Effect of cutting interval and N fertilizer on the productivity of eight grasses. *Revista Cubana de Ciencia Agricola* **4**: 137-148.

- QUINLAN, T.J., EDGLEY, W.H.R., and SHAW, K.A. (1975) — Dairy Pastures for Atherton Tableland. *Queensland Agricultural Journal* **101**: 28-36.
- QUINN, L.R., MOTT, G.O., BISSCHOFF, W.V.A., and DE FREITAS, L.M.M. colonial guinea grass pastures and beef production with Zebu steers. IBEC Research Institute, Bulletin 24.
- QUINN, L.R. MOTT, G.O., BISSCHOFF, W.V.A., and DE FREITAS, L.M.M. (1970) — Production of beef from winter vs summer nitrogen-fertilized colonial guinea grass (*Panicum maximum*) pastures in Brazil. Proceedings of the XIth International Grassland Congress, Surfers Paradise, 832-835.
- RAMASWAMY, K.R. and RAMAN, V.S. (1971) Investigations on Intra-specific Chromosomal and Morphological variations in *Panicum maximum*. *The Madras Agricultural Journal* **58**: 865-870.
- REID, R.L., POST, AMY. J., OLSEN, F.J. and MUGERWA, J.S. (1973) Studies on the nutritional quality of grasses and legumes in Uganda. 1. Application of in-vitro digestibility techniques to species and stage of growth effects. *Tropical Agriculture* **50**: 1-15.
- REYES, Y. (1972) Determination of the nutritive value of some grasses commonly used in Cuba. *Revista Cubana de Ciencia Agricola* **6**: 203-210.
- RICHARDS, J.A. (1965) — Effects of fertilizers and management on three promising tropical grasses in Jamaica. *Experimental Agriculture* **1**: 281-8.
- RIVERA-BRÉNES, L., COLON TORRES, E., GELPI, F., and TORRES MAS, J., (1958) Influence of nitrogenous fertilizer on Guinea grass yield and carrying capacity in Lajas Valley. *Journal of Agriculture of the University of Puerto Rico* **42**: 239-47.
- SILVA, J.F.C.DA, and GOMIDE, J.A. (1967) — Effect of maturity stage on intake and apparent digestibility of dry matter of three tropical grasses. *Revista Ceres* **13**: 255-75.
- SMITH, R.L. (1972) — Sexual reproduction in *Panicum maximum* Jacq. *Crop Science* **12**: 624-627.
- STOBBS, T.H. (1969) The use of liveweight-gain trials for pasture evaluation in the tropics 5. Type of stock. *Journal of the British Grasslands Society* **24**: 345-348.
- TEITZEL, J.K., ABBOTT R.A., and MELLOR, W. (1974c) — Beef cattle pastures in the wet tropics — 4. *Queensland Agricultural Journal*. **100** : 204-210. **3**: 43-48.
- TEITZEL, J.K. and BRUCE, R.C. (1972) — Pasture fertilizers for the wet tropics. *Queensland Agricultural Journal* **98**: 13-22.
- TEITZEL, J.K., and HARDING, W.A.T. (1972) — Coarse guinea grass is a weed. *Queensland Agricultural Journal* **98**: 295.
- TEITZEL, J.K., ABBOTT, R.A., and MELLOR, W. (1974a) — Beef cattle pastures in the wet tropics — 2. *Queensland Agricultural Journal* **100**: 149-155.
- TEITZEL, J.K., ABBOTT, R.A., and MELLOR, W. (1974b) — Beef cattle pastures in the wet tropics — 3. *Queensland Agricultural Journal*. **100**: 185-189.
- TEITZEL, J.K., ABBOTT, R.A., and MELLOR, W. (1974c) — Beef cattle pastures in the wet tropics — 4. *Queensland Agricultural Journal*. **100**: 204-210.
- TIHARUHONDI, E.R., OLSEN, F.J. and MUSANGI, R.S. (1973) — Application of Nitrogen and irrigation to pasture to enhance cattle production during the dry seasons in Uganda. *East African Agricultural and Forestry Journal* **38**: 383-393.
- VICENTE-CHANDLER, J., SILVA, S., and FIGARELLA, J. (1959) — The effect of nitrogen fertilization and frequency of cutting on the yield and composition of three tropical grasses. *Agronomy Journal* **51**: 202-206.
- VICENTE-CHANDLER, J., CARO-COSTAS, R., PEARSON, R.W., ABRUNA, F., FIGARELLA, J., and SILVA, S. (1964) — The intensive management of tropical forages in Puerto Rico. University of Puerto Rico, Agricultural Experiment Station Bulletin No. 187.

- VOORTHUIZEN, E.G. VAN (1971) A quality evaluation of four widely distributed native grasses in Tanzania. *East African Agricultural and Forestry Journal* **36**: 384-91.
- VOORTHUIZEN, E.G. VAN (1972) The effects of cutting frequency and cutting height on four naturally occurring pasture grasses in Tanzania. *East African Agricultural and Forestry Journal* **37**: 258-264.
- WARMKE, H.E. (1951) — Cytoplasmic investigations of some varieties of *Panicum maximum* and of *P. purpurascens* in Puerto Rico. *Agronomy Journal* **43**: 143-149.
- WATKINS, J.M. and LEWY-VAN SEVEREN, M (1951) Effect of Frequency and Height of cutting on Yield, Stand, and Protein content of some forages in El Salvador. *Agronomy Journal* **43**: 291-6.
- WINDERS, C.W. (1945) Establishing grasses in coastal districts. *Queensland Agricultural Journal* **61**: 69.

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