ANGLETON GRASS (*DICHANTHIUM ARISTATUM*) IN QUEENSLAND

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ABSTRACT

The taxonomy, nomenclature, breeding behaviour and agronomy of angleton grass (Dichanthium aristatum) *and its history of domestication and spread in Queensland are reviewed.*

The forms present and their distribution are described. Soil and climatic features favouring its invasion of and dominance in pasture are black cracking clays of open downs or savannah areas and a mean annual rainfall of between 700 mm and 1000 mm in tropical latitudes. Possible management features which can make it a useful plant are discussed.

INTRODUCTION

In the 65 years since angleton grass (*Dichanthium aristatum*) was first recorded in Queensland it has attracted spasmodic attention both as a potentially useful plant and as a possible weed. Because of its widespread naturalization, its capacity for invading certain native pasture associations and its adaptation to cracking clays, it is now receiving increasing attention by landholders and pasture scientists. This review collates available information to promote a better understanding of angleton grass and its role in Queensland.

NOMENCLATURE AND TAXONOMY

Dichanthium aristatum was first described by Willemet (1796) from Mauritius as *D. nodosum*, and its current synonymy based on Hubbard (1939) and De Wet and Harlan (1968) is: *D. nodosum* Willem. (1796) nomen illegit; *Andropogon aristatus* Poir. (1810); *A. mollicomus* Kunth (1830); *Diplasanthum lanosum* Desv. (1831); *Lepeocercis mollicoma* (Kunth) Nees (1835); *A. caricosus* L. subsp. *mollicomus* (Hack.) var. *mollicomus* Hack. (1889); *A. nodosus* (Willem.) Nash (1912); *D. caricosum* var. *mollicomus* (Hack.) Haines (1924); *D. aristatum* (Poir.) C. E. Hubbard (1939).

D. aristatum is one of three pan-tropical species which have long been confused. It is distinguished from all other species of *Dichanthium* by its pubescent peduncles but, like *D. caricosum* (Nadi bluegrass), has the lower glumes of the sessile spikelet more or less obovate, glabrous or shortly ciliate above the middle (De Wet and Harlan 1968), and closely overlapping (Hubbard and Vaughan 1940). Plants of typical *D. aristatum* are robust and sub-erect, with the peduncles to the racemes and the culms below the inflorescence strongly pubescent (De Wet and Harlan 1968). Some plants are decumbent with sparsely pilose peduncles and culm apices. These plants resemble artificially produced hybrids between *D. aristatum* and *D. caricosum*. Several authors (Hackel 1889, Haines 1924, Pandeya 1953) regard *D. aristatum* as a variety of *D. caricosum*. However, the two species are genetically isolated at the diploid level, and at the polyploid level only cross with difficulty (De Wet and Singh 1964). De Wet and Harlan (1968) therefore regarded them as separate species and included the aberrant specimens in *D. aristatum*.

The third species, *D. annulatum* (sheda grass), differs from the other two in having the lower glume of the sessile spikelet more or less oblong, with long bulbous-based cilia along the margins above the middle (De Wet and Harlan 1968), and the spikelets only slightly overlapping (Hubbard and Vaughan 1940). Vegetatively it is distinguished by the prominent, long (*c.* 5 mm) hairs on all nodes; those of *D. aristatum* and *D. caricosum* are either glabrous or covered with short (*c.* 1 mm) hairs (Celarier and Harlan 1955).

D. aristatum has been confused with *D. annulatum* in Texas (Hitchcock 1970) and Australia (White 1930). Conversely, the name angleton grass has been applied to *D. annulatum* in Hawaii (Whitney *et al.* 1939) and sometimes in Fiji (Parham 1946).

WORLD HISTORY

D. aristatum is indigenous from tropical India eastward to Indonesia but has been introduced into most tropical regions and has naturalized in Australia, Africa and the Americas (De Wet and Harlan 1968). In India it occurs in the Madras and Bombay states and in Madhya Pradesh (Bor 1960). In South Africa *D. aristatum* is not regarded as indigenous because of its curiously limited distribution from Pretoria to the Pienaars River area (Chippindall 1955).

In U.S.A. *Andropogon nodosus* (syn. *D. aristatum*) was grown at the Angleton Research Station in southern Texas in 1915, from seed obtained from Poona Agricultural College, India under the name *A. annulatus* (syn. *D. annulatum*). It was released in 1924 as 'Angleton bluestem' (Hanson 1972). The name 'angleton grass' subsequently became the standard common name for *D. aristatum* (Whyte *et al.* 1959) and was first suggested for use in Australia in 1953 (Anon. 1953).

In Fiji *D. aristatum* was collected at Suva in 1936 and may have arrived with *D. caricosum*, introduced about 1906 under the name 'Antigua hay grass' (Hynam and Hutson 1944, Parham 1946). Both grasses are known as 'Nawai' or 'Nadi' (pronounced Nandi) bluegrass (Parham 1955); *D. caricosum* has been extensively propagated and is much more prevalent (I. J. Partridge pers. comm.). *D. aristatum* was introduced to the Hawaiian Islands by C. P. Wilder from the West Indies in 1911 and became known as 'Wilder' grass (Whitney *et al.* 1939). It also occurs in the Philippines, a local selection 'Alabang X' being popular for grazing (Farinas 1970, de Guzman 1974). In Papua-New Guinea *D. aristatum* is naturalized near Port Moresby and Alabang X has been introduced (Henty 1969).

AUSTRALIAN HISTORY

The first record of angleton grass in Australia is from a plant cultivated in the Sydney Botanic Gardens in 1912 (specimen in the Queensland Herbarium (QH)). The first Queensland record is from Alton Downs near Rockhampton in 1918 as *A. annulatus* (White 1930). Reputedly it appeared in a churchyard where the minister fed his sulky horse on chaff from South Africa during a drought. It spread through the district as 'churchyard' grass (Priddle 1972), and later 'Alton Downs blue grass' (White 1930). Material from the Department of Agriculture and Stock (DAS) (now Department of Primary Industries (DPI)) yard in Rockhampton was grown from 1929 to 1936 in nurseries at Archer, Gracemere and Pink Lily as 'giant blue grass' (Brooks 1929, 1930, Clydesdale 1933, 1936, QH). In 1933 rootlets and seed were planted in a nursery on Mr. A. McLeod's property at Yalboroo near Proserpine (Clydesdale 1933, pers. comm., Brooks 1934). More than 20 years later Mr. McLeod drew the attention of Mr. J. R. Jeppesen of 'Taranga', Bloomsbury to the old nursery, where giant blue grass (now called angleton grass) had spread over some 80 ha (N. E. Goodchild, pers. comm.). Mr. Jeppesen harvested seed and planted it with Townsville stylo (*Stylosanthes humilis*) in strips in a 50-ha paddock of black speargrass (*Heteropogon contortus*). This formed the basis of a successful commercial development (Onley and Sillar, 1965). Today angleton grass is dominant and stable over 2000 ha and co-dominant with native species over a further 2000 ha, but does not appear to be spreading further (E. R. Anderson, pers. comm.).

In the Rockhampton district spread has continued and most areas of black cracking clay on plains and gentle slopes between Rockhampton and Marlborough now carry some angleton grass; disturbed areas, such as old cultivations, roadsides and heavily grazed paddocks, are dominated by it (J. H. Wildin and B. Walker, pers. comm.).

In 1926 an occurrence was recorded from 'Strathmore' Collinsville (QH), where it became a common constituent of grassland/savannah communities (Perry 1953, Isbell 1954) on the Strathmore land system (Stewart and Perry 1953). Dominance in many areas has since been reported (Isbell and Murtha 1972a). Angleton grass is also common around coastal towns from Bowen to Townsville but is not a major constituent of pastures in this area (R. F. Isbell, pers. comm.). Unsubstantiated legend attributes the origin of at least some of the angleton grass in this region to the straw packing around insulators, from India, used to install the railway signalling system.

A specimen (QH) from Mt. Crosby (near Ipswich) in 1930 bears the comment 'the best natural grass in the area'. Today angleton grass is common on black soil areas in suburban Ipswich and along rural roads. A decumbent form is present in the southern outskirts of the city (Raceview). Another decumbent form, of unknown origin, occurs in isolation at Bargara, near Bundaberg (Table 2).

A ruderal (occurring in areas disturbed by man) population at Mareeba in far north Queensland may have naturalized there about 1917 (Knox 1967, R. W. Downes, pers. comm.).

D. aristatum recorded from Mungalla station, Ingham in 1953 (QH) was planted by Mr. R. L. Atkinson using seed from naturalized stands in the town, where it is said to have appeared on vacant allotments after circus elephants camped there. Atkinson also distributed roots to "Glendhu" and "Kinrara" holdings on the McBride Plateau (Isbell and Murtha 1972b) of the upper Burdekin River basin (P. Anning, pers. comm.) where it has naturalized over 1400 ha and is spreading onto several other properties (W. J. Bisset and R. Walker pers. observation). Locally known as "bluegrass" it is still being planted by the Atkinson family using seed harvested at Ingham. Although common in the town and on sugarcane headlands it is limited in pastures (P. Mortiss, pers. comm.).

D. caricosum was also recorded (QH) from Ingham ("Burnside") in 1952 with a comment "received as Nadi blue grass". This suggests Fiji as its origin and *D. aristatum* may well have been a co-immigrant. Presently *D. caricosum* is confined to 0.5 km of roadside adjacent to "Burnside" (observations by W. J. Bisset and R. Steel). There is also a small area, of unknown origin, on a property in the Tully hinterland (R. Steel, pers. comm.). A recorded occurrence (QH) from Yandina in south-east Queensland was found not to have spread from a small garden plot planted about 1952 (observations by W. J. Bisset and P. E. Luck).

Formal introductions of *D. aristatum* and *D. caricosum* fit into three groups. Material from the first group (of Indian origin) was grown by CSIR (now CSIRO) at Lawes (Queensland Agricultural College (QAC)) and Fitzroyvale (20 km east of Rockhampton) prior to 1946 (Table 1). Unspecified material of *D. aristatum* (Goodchild 1938) and *D. caricosum* was also grown by DAS at South Johnstone Research Station, the latter being considered unimpressive (Graham 1951). At Lawes *D. aristatum* CPI-5539 was regarded as outstanding (McTaggart 1942, Paltridge 1955) but was later discarded; unpalatability of mature growth and its aggressive nature caused concern (Paltridge 1955). The accessions of the second group (mainly *D. aristatum* from South Africa) were grown by DAS, DPI and CSIRO at various centres after 1957 (Table 1). The third group covers accessions introduced from 1961 to 1983.

Today angleton grass dominates all the uncultivated black soil flats at QAC (*c.* 150 ha). As well, material naturalized over *c.* 100 ha near Beaudesert owes its origin to planting material from QAC used in hobby plots in 1940–42 (S. Marriott, pers. comm.). Two forms occur at both locations (Table 2) and the date of the Beaudesert planting establishes their origin as Indian (Group 1 of Table 1). None of the material now present at Fitzroyvale matches that at QAC. The prior presence of naturalized angleton grass at Fitzroyvale (C. T. White, pers. comm.) would have provided more opportunities for genetic change (Knox 1967) than the isolated situation at Beaudesert; as well, the available niches suited to it could already have been filled.

Other angleton grass material present today at QAC (Table 2) could have originated from either the first or second group of introductions (Table 1). There has

TABLE 1

Inventory, with comments, of known accessions of Dichanthium aristatum *and* D. caricosum *grown in Queensland*

CPI* No.	Date of Introduction	Source	Determinations and Comments
Group 1—introduced before 1940 and grown by CSIR at Lawes (QAC) prior to 1946			
3753	1933	India (Poona)	Received as *Andropogon annulatus*, later determined as *D. aristatum* (Queensland Herbarium (QH)), (specimen checked by Simon and Bisset in 1981).
5527	1933	India (Nagpur)	Received as *A. caricosus* (syn. *D. caricosum*). Determined as *D. aristatum* by QH in 1939. Specimen in QH and original seed sample from Canberra showed a mixture of the two (examined by Simon and Bisset in 1981). Also grown at Fitzroyvale.
5539	1933	India (Indore)	Received as *Chloris* sp. Determined by QH in 1939 as *D. aristatum*. Also grown at Fitzroyvale. Yellow stems in QH specimens resemble those of the "Lawes Green" ecotype (Table 2) present today at Lawes.
7746	1939	India (Poona)	Received as *D. caricosum*. No QH specimens available but original seed sample (obtained from Canberra) was a mixture of *D. aristatum* and *D. caricosum* (examined by Simon and Bisset in 1981).
Group 2—introduced between 1951 and 1958 and grown by DPI and CSIRO			
14366	1951	Sth Africa (Pretoria)	*D. aristatum*. Grown at QAC and Townsville by CSIRO, Mackay (Sillar 1978) and Gayndah by DPI. Used by Knox (1967) in studies on aposporous apomixis.
16773	1952	Sth Africa (Worcester Veldt Reserve)	*D. aristatum*. Grown at Brisbane by CSIRO and Inverell by N.S.W. Soil Conservation Service where it was finally discarded (Cameron 1959).
22516 } 22517 }	1957	Sth Africa (Pretoria) via R. Celarier	*D. aristatum*. Grown at GRS†, Darling Downs, Gayndah, Sth Johnstone and Mackay (Sillar 1978) by DPI. Favourably regarded at GRS (R. W. Downes, pers. comm.), but discarded in 1961 because of weed potential in Darling Downs plots (J. K. Leslie pers. comm.). Discarded at South Johnstone because of inability to beat weeds (Station Records).
22525	1957	India via R. Celarier	*D. carisosum*. Grown at GRS by DPI. Palatable and recovered well after grazing (R. W. Downes, pers. comm.).
23732	1958	Philippines	*D. aristatum* var. *heteropogonoides* "Alabang X". Grown at GRS by DPI. Showed poor frost tolerance, low leaf/stem ratio and almost nil stock acceptance (J. K. Leslie, pers. comm.); failed to establish elsewhere.
24324	1958	Sth Africa via R. Celarier	*D. aristatum*. Grown at Mackay (Sillar 1978) by DPI.
Group 3—introduced since 1960 and grown by DPI and CSIRO			
28637	1961	Philippines	"Alabang X". Currently being grown by DPI at Toowoomba.
33051	1963	Papua-New Guinea	"Alabang X". A few plants were grown by CSIRO at Brisbane in 1964.
50820	1970	Philippines	"Alabang X". Grown by CSIRO at Townsville and probably Brisbane, and currently by DPI at Toowoomba.
84136	1978	India (Nander)	Introduced as *Bothriochloa* sp. subsequently determined as *D. aristatum* by W. J. Scattini. Currently being grown by DPI at Toowoomba.
84147	1978	India (Rahuri)	Introduced as *D. annulatum*, subsequently determined as *D. aristatum* by W. J. Scattini. Currently being grown by DPI at Toowoomba.

*Commonwealth Plant Introduction.
†DPI Research Station at Lawes.
Accessions introduced into Australia for which no record of having been grown in Queensland has been sighted are: (CPI) 2302, 29425, 33044 and 36574.

been no significant naturalization of any of the formally introduced material at any other centre of testing.

Angleton grass is now widely but sporadically naturalized in coastal and subcoastal Queensland from Brisbane to Mareeba (see Figure 1), in pastures, along roadsides and in other disturbed areas, and a range of plant types can be recognized (Table 2). The closely related Nadi bluegrass (*D. caricosum*) has not naturalized.

Angleton grass was tested at several centres in New South Wales but was discarded (Cameron 1959) and failed to persist (Watt 1976). It was also grown at Kimberley (Western Australia) and Katherine (Northern Territory) research stations but no significant naturalization has been recorded in either state (G. Perry, pers. comm. for W.A., B. Thomson, pers. comm. for N.T.).

BREEDING SYSTEM

D. aristatum is mostly a tetraploid (2n = 40), but there are also diploid and hexaploid forms (Bogdan 1977). Australian material is a facultative apomict (Knox 1967), the degree of apomixis increasing with reduction in day-length during inflorescence development. Naturalized populations showed varying degrees of apomixis, some having a relatively constant high level (90% to 95%) while others showed marked seasonal variation; a population from Mareeba had 50% apomixis in December, increasing to 90% in April (Knox 1967).

MORPHOLOGICAL VARIATION

Angleton grass varies considerably in morphology according to growing conditions. In wet places it grows to a height of 110 cm and produces inflorescences of up to five racemes; under unfavourable conditions it is only 15 cm high with inflorescences of only one raceme (Chippindall 1955, Hubbard and Vaughan 1940, Pandeya 1953). In Queensland we have observed wide variation in growth due to microhabitat, but more striking is the seasonal difference between the lush summer growth and the diminutive clumpy growth in winter-spring following mowing or close grazing in autumn.

W. J. Scattini (unpublished) has found real differences in morphology and stature between populations collected from different localities and grown in observation plots at Toowoomba. The different ecotypes have been provisionally named according to type locality and the main ones are listed in Table 2. In a replicated nursery at Mackay, Sillar (1978) measured lower DM yield from three populations naturalized in a 660–990 mm annual rainfall environment compared to the local Bloomsbury ecotype from a *c.* 1350 mm rainfall area; four African lines (Table 2) were heavier tillering and more robust as seedlings than the Bloomsbury line.

ENVIRONMENTAL ADAPTATION

Soil

Angleton grass is most commonly found (and usually becomes completely dominant) on black cracking clay of principal profile form Ug5.1 (Northcote 1971) derived from basalt or other basic rock which originally carried open downs grassland or savannah. Examples are found at Collinsville, the McBride Plateau, Rockhampton-Marlborough, Nebo, Beaudesert, Ipswich and Lawes. Related brigalow soils (Ug5.2) are also colonized around Rockhampton. On the McBride Plateau angleton grass has also invaded red soil (euchrozem, Gn3.12 and 3.22) woodland areas carrying a kangaroo grass (*Themeda australis*)/speargrass association (communities 5g and 7d of Isbell and Murtha 1972a); however, it is less dominant than on the interspersed black soil (Ug5.12, 5.13) areas carrying a canegrass (*Ophiuros exaltatus*/bluegrass (*Dichanthium* spp.) association (community 7j).

Colonizing ability on Ug5.1 clays was noted by Paltridge (Plant Introduction Records (PIR)) Cunningham Laboratory (1944), Cameron (1959), J. K. Leslie (pers.

TABLE 2

Main ecotypes of angleton grass naturalized in Queensland as at 1983

Name*	Distinctive Features** (including flowering commencement†)	Origin	Distribution
1. *Erect and tall (to > 1 m), poor nodal rooting*			
Lawes Green	Green foliage, and yellow stems cf. glaucous foliage and mauve stems in all others; all nodes pilose; I	CSIR plots (pre-1946); possibly CPI-5539 (Table 1)	Lawes & Beaudesert, pastures and roadside
Fitzroyvale Tall	Culm apex sparsely pilose, topmost node pilose, L	Either CSIR plots (1936–46) (Table 1) or previously naturalized material	Rockhampton district, pastures and roadside
2. *Semi decumbent to c. 750 mm, poor nodal rooting*			
Bloomsbury	Topmost node pilose, E	Naturalized around Rockhampton since 1918; known as "Alton Downs" and "giant" blue grass	The commonest type in central and south-east Qld, pastures and roadside
Lawes Blue	All nodes glabrous, peduncles and culm apex sparsely pilose, E	CSIR plots (pre-1946) (Table 1)	Lawes and Beaudesert, pastures and roadside
Lawes 3	Topmost node pilose, E	Either CSIR (pre-1946) or DPI plots (1958–61) (Table 1)	Lawes, pastures
3. *Decumbent to c. 500 mm, good nodal rooting*			
Mareeba	Topmost node pilose, I	Unknown	Mareeba town area
Glendhu	Topmost node pilose, I	Ingham town area, previous history not substantiated	McBride Plateau, pastures and roadside
Bargara	All nodes pilose, strongly glaucous, I	Unknown	Bargara, roadside and sugarcane headlands
Raceview	All nodes pilose, culm apex sparsely pilose, strongly glaucous, I	Unknown	Pastures and roadside in southern outskirts of Ipswich (the Bloomsbury type is also present around Ipswich)
Strathmore (includes material variously identified as Carinya, Myuna or Bowen (Sillar 1978))	Topmost node pilose, shorter stature than all other types, E	Unknown, naturalized by 1926	Collinsville, Nebo, Bowen, Townsville area, pastures and roadside

*Based on type locality.
**From observations by W. J. Scattini on DPI nursery plots at Toowoomba, 1981–83, and Sillar (1978).
†E = early (late March), L = late (late April), I = intermediate; an arbitrary classification based on observations at Toowoomba in 1981 and 1982 (Scattini, pers. comm). The difference between the earliest and latest was *c.* 37 days.

comm.), Younger and Gilmore (1978) and Mackenzie *et al.* (1982). When sown on such soils angleton grass established at least as well as creeping bluegrass (*Bothriochloa insculpta* cv. Hatch and makarikari grass (*Panicum coloratum* var. *makarikariense*) (Younger and Gilmore 1978), but purple pigeon grass (*Setaria porphyrantha* cv. Inverell) was better (Watt 1976, W. J. Scattini, pers. comm.).

The Bloomsbury stands are on moderate textured soils (brown gradational (Gn) and solodic duplex (Dy3)). Much of the area was sown to angleton grass and Townsville stylo with some soil disturbance (stickraking, strip planting or cropping) (Anderson *et al.* 1983). The grass will not persist on light textured sandy soil (E. J. Jeppesen, pers. comm.). Long-established ruderal stands are present on basalt-derived alluvium (Um6, Um4) at Ingham, kraznozem (Gn3.11) and prairie soil (Uf6) at Bargara, and euchrozem (Gn3.12) at Mareeba.

On a soil of pH 5.5 near Mackay, dry matter yield of sown angleton grass was increased from 4 t ha^{-1} to 6 t ha^{-1} by an application of lime at 1.1 t ha^{-1} (D. I. Sillar, unpublished). This suggests that the neutral to alkaline pH levels associated with black soils are important. The black soils and euchrozems of the McBride Plateau and the black soil at Collinsville are well supplied with nutrients (Isbell and Murtha 1970). The solodic soils at Bloomsbury are very low in phosphate (available P $<$ 4.4 ppm). A nil response by angleton grass to applied superphosphate was recorded; in contrast associated Townsville stylo responded strongly (D. I. Sillar, unpublished). Some black soils colonized around Rockhampton are also very low in phosphate (J. H. Wildin, pers. comm.)

A preference for black soils has been expressed in South Africa (Anon. 1956) and in Texas where a fair tolerance to salt has also been claimed (Hanson 1972). However, a formal experiment found angleton grass less tolerant of artificial salinization with calcium and magnesium chlorides than rhodes grass (*Chloris gayana*), green couch (*Cynodon dactylon*), blue panic (*Panicum antidotale*) and buffel grass (*Cenchrus ciliaris*) (Gausman *et al.* 1954).

Angleton grass is more tolerant of seasonal waterlogging than creeping bluegrass but less tolerant than water couch (*Paspalum distichum*) and para grass (*Brachiaria mutica*) F. H. Kleinschmidt, pers. comm.). A recent glasshouse experiment at QAC (J. W. Sands, unpublished) showed angleton grass to have a flooding tolerance at least as good as *Panicum coloratum* (Anderson 1972). Both species showed an accumulation of roots towards the soil surface following waterlogging. On the other hand flooded seed of angleton grass failed to establish.

Climate

The main growth of angleton grass occurs from January to April, with only slow growth during the rest of the year (Paltridge 1955, Miles 1949, pers. comm., E. J. Jeppesen, pers. comm., Mackenzie *et al.* 1982). The more reliable and more summer-dominant rainfall of northern Queensland would fit this growth pattern better than that of southern Queensland with its considerable winter rainfall (Coaldrake 1964). This, as well as lower temperatures, could explain the mediocre yields on the Darling Downs (Mackenzie *et al.* 1982) and poor performance in northern New South Wales (Cameron 1959, Watt 1976). The major areas of angleton grass in Queensland lie between the 700 and 1400 mm isohyets in tropical latitudes. All experience frost to varying degrees. Although frost has little effect on overall dry matter production it damages standover material. The McBride Plateau areas have an altitude of 600–850 m and an average annual rainfall of 650–800 mm.

Persistence on the solodic soils at Bloomsbury could reflect the higher rainfall (*c.* 1350 mm) compared to the $<$ 1000 mm of the sub-coastal black soil areas. This is suggested by the complete loss of the stand at Bloomsbury in 1965 when only 72 mm of rain was recorded from July to November inclusive. (Excellent seedling regeneration occurred in the following wet season). On the cracking clay at Emerald the same ecotype survived in 1972 when only 46 mm of rain fell from March 9 to November 6 (Younger and Gilmore 1978). Low spring rainfall (i.e. average of *c.* 100 mm July to

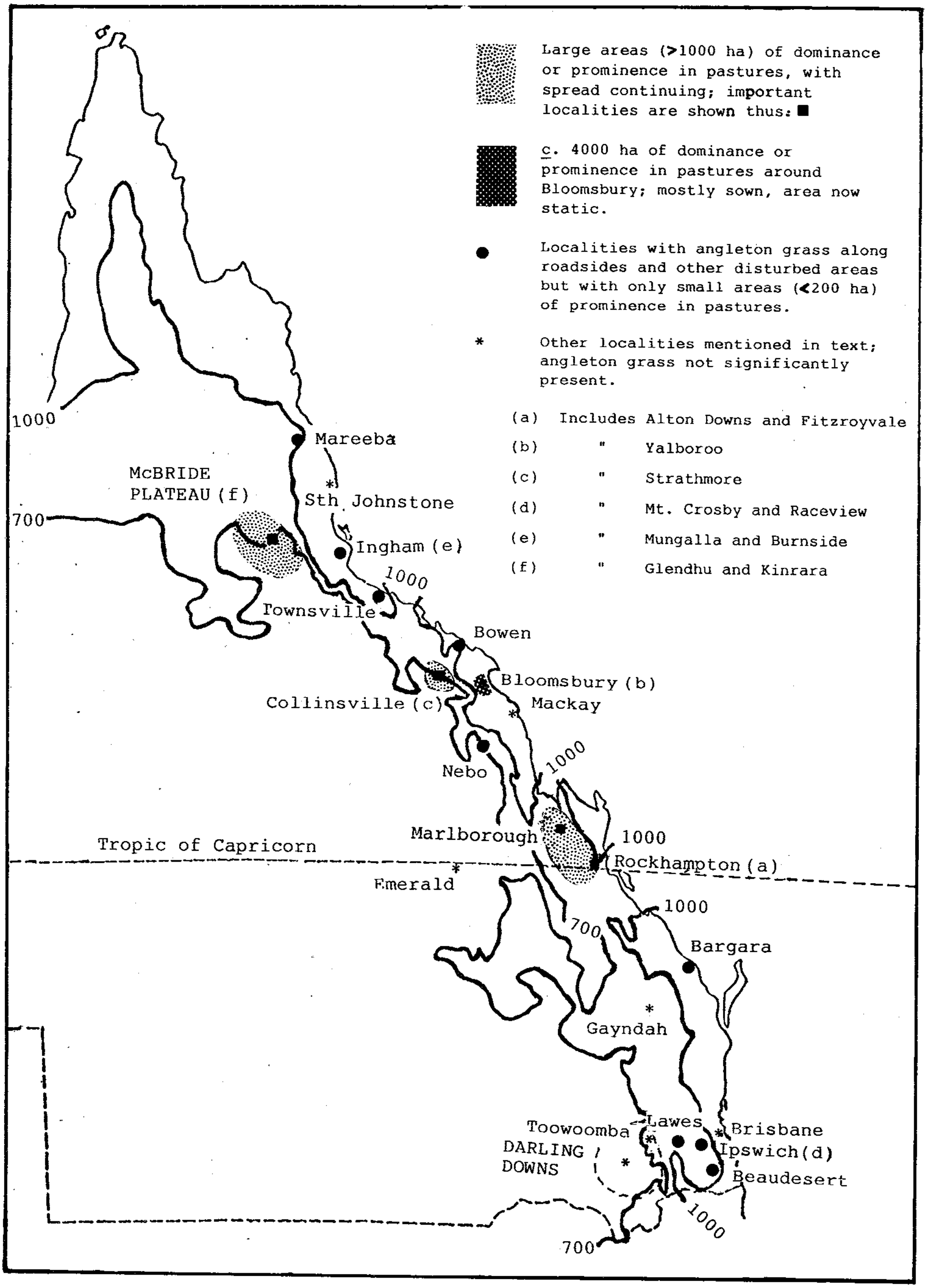

FIGURE 1

Important existing areas of angleton grass in Queensland together with the 700 mm and 1000 mm isohyets.

November inclusive) is no barrier to the survival on the cracking clays and euchrozems of the McBride Plateau.

Angleton grass has a higher rainfall requirement than creeping bluegrass (Younger and Gilmore 1978). In mixed pastures of both species near Rockhampton, it is more apparent in wet than in dry years (Bisset and Graham 1978). In Texas, Hansen (1972) stipulates a minimum annual rainfall of 750 mm and claims some drought tolerance.

Tolerance of waterlogging enables angleton grass to take advantage of the better moisture status of roadside table drains.

AGRONOMY

Establishment

In native speargrass pasture angleton grass establishes well from surface broadcasting following a single cultivation or burning (Onley and Sillar 1965). Recommended seeding rates are 2–4 kg ha^{-1} (based on actual area sown) and the preferred sowing time is November to January inclusive. Waiting until after the first effective rainfall facilitates seedbed cultivation. At Bloomsbury no covering harrows were used, reliance being placed on rain and trampling by grazing cattle to cover the seed (E. J. Jeppesen, pers. comm.). Following sowing, the pasture was stocked heavily to control growth of native grasses, thus allowing the slowly growing angleton grass seedlings (Younger and Gilmore 1978) to establish firmly. Destocking in April allowed it to seed for thickening of the stand. Angleton grass sown in strips 20 metres apart had joined up to form a dominant sward after 7 years (Onley and Sillar 1965). On clay hillsides speargrass was completely replaced within 10 years by burning the original sward and broadcasting angleton grass seed; heavy grazing was maintained (D. I. Sillar, unpublished). Another method used at Bloomsbury was to broadcast seed of angleton grass (freshly-harvested) and Townsville stylo over a crop of grazing sorghum in May–June. The seed was trampled in by cattle and germinated in summer (Onley and Sillar 1965). On a cracking clay, Scattini (1980) obtained a good establishment of angleton grass undersown to either Japanese millet (*Echinochloa utilis*) or Panorama panic (*Setaria italica*) under conditions of moisture stress which caused both companion crops to fail.

Dry matter (DM) production

On the Darling Downs, mean annual DM production of angleton grass over a 5-year period was 4.23 t ha^{-1}, ranging from 2.33 t ha^{-1} without nitrogen fertilizer to 7.30 t ha^{-1} with 170 kg N ha^{-1}. Yields of makarikari grass and rhodes grass were significantly greater (McKenzie *et al.* 1982). At Emerald, DM yield (mean of nil N and 100 kg N ha^{-1}) in a year of 585 mm of rainfall was 3.2 t ha^{-1}, with Nunbank buffel grass, makarikari grass and sabi grass (*Urochloa mosambicensis*) significantly better; in a year of exceptional rainfall (1073 mm) DM yield of angleton grass was equal to that of buffel grass and makarikari grass at 11.2 t ha^{-1} and significantly greater than that of sabi grass (Younger and Gilmore 1978).

In 8-weekly summer cutting over 4 years on the Darling Downs (Mackenzie *et al.* 1982), more than half the total DM was produced from mid December to mid February. By contrast rhodes grass and makarikari grass also made considerable growth from mid October to mid December, and creeping bluegrass gave the highest yields from mid February to mid April.

Nitrogen concentration, utilization, grazing management

With various rates of nitrogen fertilizer applied in mid October over 5 years (Mackenzie *et al.* 1982) the mean herbage nitrogen concentration of angleton grass in mid December (beginning of fast growth) was 0.94% without applied nitrogen and 1.38% with 120 kg N ha^{-1}. Subsequent N concentrations were respectively 0.86% and 1.24% in mid February (end of fast growth), 0.68% and 1.00% in mid-April, and 0.88%

and 1.33% for the overwintered material in mid-October. In plots at Lawes, Downes (1959) measured a herbage N concentration of 2.0% from "vigorous plants perhaps a little past the optimum" compared to 1.6% in Queensland bluegrass; fibre content of the two species was 28.2% and 35.1.% respectively.

At Lawes Paltridge (1955) found the mature growth of the Indian accessions unacceptable to sheep. On the other hand Downes (1959) found two African accessions readily eaten by stock in the flowering stage; subsequently T. Dickson (pers. comm.) complained of a tapering off in growth and a long seeding period during which the grass was unattractive to stock.

At Emerald, makarikari grass and buffel grass were more closely grazed by cattle than angleton grass and creeping bluegrass (Younger and Gilmore 1978). In plots on the McBride Plateau the Bloomsbury ecotype became coarse and unacceptable to cattle although the standing material was consumed by September; on the other hand, naturalized stands of the Glendhu ecotype are highly regarded by local graziers (Anning 1982). Whether this indicates a real difference between ecotypes cannot be stated. At Bloomsbury, heavy grazing of angleton grass/Townsville stylo pastures during summer was aimed at having the grass no taller than 45 cm by the time of the first frost (early June). This practice resulted in total utilization of the pasture, which fattened cattle at a stocking rate of a beast per hectare in summer-autumn and carried a beast to two hectares until the following wet season (E. J. Jeppesen, pers. comm.). In a grazing trial over two successive years Brahman cross steers showed a mean liveweight gain of 140 kg hd^{-1} (272 kg ha^{-1}) from January to June (164 days) on an angleton grass/Townsville stylo pasture fertilized with superphosphate (Sillar and Rudder 1967).

Low oxalate content (Mathams and Sutherland 1952) makes angleton grass safe for horses.

Haymaking from ungrazed stands in northern and central Queensland poses problems due to the main growth being confined to the wet season. Cutting at early flowering runs the risk of bogging machinery, particularly on heavy-textured soils, and poor drying conditions. At Bloomsbury, with the somewhat lighter soils, hay has been made from grazed stands in which flowering was delayed until April. The practice was discontinued in favour of seed production and no quantitative data are available (E. J. Jeppesen, pers. comm.). In Texas, haymaking is a standard use with yields ranging from 4.5 to 13.5 t ha^{-1} and an average of 9.0 t ha^{-1} (Archer and Bunch 1953).

Seed production

Angleton grass is a short-day plant (Knox 1967). Flowering usually commences between late February and late April and, with interruption by frost and dry spring conditions, can continue until November–December. Differences of up to 37 days between commencing dates have been observed for different ecotypes grown at the same site (Table 2). In Colombia the interval between flowering and seed maturation was 26 days (Alarcon *et al.* 1969).

At Bloomsbury seed is harvested in May–June from pastures destocked in April. Yields range from 17 to 34 kg ha^{-1} (DPI records). At Emerald, seed yield in small plots was increased from 195 kg ha^{-1} with no nitrogen, to 395 kg ha^{-1} by applying 100 kg N ha^{-1} three months prior to a June harvest. In the Philippines, Mendoza *et al.* 1975 (cited by Javier, Siota and Mendoza 1975) increased seed yield from 102 kg ha^{-1} with no nitrogen to 290 kg ha^{-1} by applying 400 kg N ha^{-1} in four equal applications.

At Bloomsbury seed is header-harvested, scalped and cleaned with a sealed aspirator and a centrifugal screen (E. J. Jeppesen, pers. comm.). In Texas stripping is preferred to header harvesting in which most of the seed is recovered from the tailings; whichever method is used, scalping or light hammer-milling before cleaning with a fan will prepare the seed for sale (Ahring *et al.* 1978).

Spikelets of angleton grass are paired, with each pair consisting of an awned sessile spikelet (mostly fertile) and an awnless pedicellate spikelet (sterile) (De Wet and Harlan 1968). The seed unit consists of the sessile spikelet (with or without a caryopsis, some with awns still attached), the joint of the raceme and the sterile spikelet if attached. A kilogram of pure seed contains *c.* 1 000 000 seed units (DPI Standards Branch). Purity (determined by the Irish method) ranges from *c.* 60% to *c.* 95% with a mean value of *c.* 80%. Wolff (1951) indicated a low seed fill in the sessile spikelets and, using the presence of a caryopsis as the basis for determining purity, obtained average values of only 43%. Pure live seed counts for Bloomsbury seed range from *c.* 20% to *c.* 50% (DPI Standards Branch).

In Colombia, germination of seed was nil at harvest time, increasing to a maximum at 7 months (Alarcon *et al.* 1969).

Associated legumes

The cracking clay soils on which angleton grass grows best present a difficult environment for tropical pasture legumes and this is accentuated by the density of the grass sward. The successful commercial combination of Townsville stylo and angleton grass over a decade at Bloomsbury was made possible by the sub-optimal (for angleton grass) soil type; as well, the heavy summer grazing regime suited both species. With the disappearance of the Townsville stylo resulting from anthracnose (*Colletotrichum gloeosporioides*) disease in the mid 1970s the pasture is now grass-only (Anderson *et al.* 1983).

GENERAL DISCUSSION

The ability of angleton grass to invade speargrass pastures is surprising in view of the observation by one of us (D.I.S.) that the invading patches are selectively grazed. In north Queensland, however, speargrass is not resistant to heavy grazing, particularly in association with Townsville stylo (Ritson *et al.* 1971). The diminutive, prostrate and more stoloniferous habit resulting from heavy grazing, together with the later commencement of growth, would give angleton grass competitive advantages over the tufted speargrass. Regular burning is a feature of speargrass pastures (Tothill 1971). The selectively grazed patches of invading angleton grass often escape fire because of insufficient dry matter remaining in spring. Recovery of angleton grass from severe fire was tested in plots at Emerald, where growth accumulated over two years was burnt in November; more than 40% ground cover was measured in the following April (Younger and Gilmore 1978).

It is generally agreed that invasion of speargrass pastures by angleton grass is a desirable change (e.g. Onley and Sillar 1965). Such invasion is confined to the areas of higher rainfall and heavier-textured soils which form only a small proportion of the total area occupied by speargrass communities in tropical Queensland (Isbell 1969).

Invasion of pastures containing bluegrasses (*Dichanthium* spp.), forest bluegrass (*Bothriochloa bladhii*) and desert bluegrass (*B. ewartiana*) tends to be unfavourably regarded (Sillar 1978). This is due to the apparent similarity in quality of angleton grass to these native species and its shorter growing season. What is overlooked is that invasion is the result of heavy grazing (E. R. Anderson pers. comm.); without angleton grass it is conceivable that less desirable species would invade. Some Rockhampton district graziers have found that by utilizing angleton grass adequately during the growing season it can be a valuable pasture resource on country unsuited to other sown pastures and without the need for a fertilizer input. It lends itself to use for bullock fattening or stocking with breeders being mated. The black soils areas invaded at QAC are non-arable because of extremely heavy texture and poor drainage. These features also restrict wet season grazing; however, the great mass of growth is progressively reduced to ground level by cattle and horses during the winter-spring period (W. J. Scattini, pers. comm.).

Priddle (1972) complained that angleton grass "choked out valuable swamp couches on the Fitzroy River flood plain". What he meant by "swamp couches" is not known. However, a disturbing feature noticed by one of us (W.J.B.) on the McBride

Plateau was the apparent invasion by angleton grass of green couch pastures occurring in shallow depressions. Although limited in extent, the couch grass pastures produce a high yield of good quality forage and have a high stocking rate (Perry and Lazarides 1964), and should constitute a valuable dry-season resource.

Angleton grass does not invade vigorous sown pastures (rain-grown or irrigated) nor is it a problem weed of crops either at QAC or the adjacent DPI Research Station (F. H. Kleinschmidt, pers. comm., J. Rawson, pers. comm.). In spite of sowings in pasture plots and as a contaminant of creeping bluegrass seed used in waterway plantings on the Darling Downs in the 1970s, early fears of its becoming a weed of crops in that area (see Table 1) have not materialized. Priddle's (1972) similar fears at Alton Downs have largely dissipated with improved farming practice and modern cultivation machinery. The later start of growth (Mackenzie *et al.* 1982) makes angleton grass less troublesome than other grass weeds such as rhodes grass and green panic (*Panicum maximum* var. *trichoglume*). Local farmers claim that an angleton grass pasture requires one or two more cultivations to eliminate than does green panic, and that crop growth is poor for a year afterwards. Angleton grass has not been recorded as a significant weed of sugar cane in Queensland. Its presence in creeping bluegrass pastures is a serious drawback if the latter are used for seed production (Bisset and Graham 1978). Resistance to mowing makes it very tenacious in lawns and playing fields.

Angleton grass is popular for waterways and contour banks on the grassland clay (Ug5.1) at Alton Downs. It is easily established by spreading surface soil from the adjacent naturalized swards during the construction process (R. M. Stephens and C. C. Gillies, pers. comm.).

CONCLUSIONS

With the exception of the *c.* 4000 ha of mostly sown angleton grass around Bloomsbury, the existing stands throughout Queensland are the result of natural spread. Sources are long naturalized stands of unconfirmed origin (Rockhampton, Collinsville, Ipswich) relatively small scale commercial plantings (McBride Plateau), small test plots (Lawes, Beaudesert) or fortuitous seed distribution. Currently no sizeable stands are known which can be traced to the several tonnes of seed believed to have been sold over the last 15 years.

Angleton grass will continue to spread on cracking clays carrying open downs/savannah grassland in the 700–1000 mm rainfall belt of tropical Queensland. Spread is particularly noticeable on the McBride Plateau where it is also occurring in kangaroo grass/speargrass pastures on a euchrozem. The eventual colonization of much of the 5000 square kilometres of this landform seem possible.

In the whole property context more efficient utilization of pastures dominated by angleton grass will require the adoption of management practices which recognize its tolerance of heavy grazing and its short growing season.

There is a dearth of quantitative information on angleton grass in Queensland, particularly in regard to the relative merits of the different forms present.

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EFFECT OF TEMPERATURE AND DAYLENGTH ON DRY MATTER YIELD AND FLOWERING OF TWO ACCESSIONS OF *CASSIA ROTUNDIFOLIA*

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ABSTRACT

The effects of temperament (20/15, 25/20, 25/25, 30/25, 30/30, and 35/30°C) were similar in both accessions of Cassia rotundifolia. *There was little growth at 20/15°C in either accession. Only at the intermediate temperatures (25/25, 30/25, 30/30) did the late variety (Q10057) have a higher yield than the early variety (CPI 34721). At 35/30°C both accessions had similar weights. Dry matter yields were higher in both strains in the 8 week harvests compared with the four week harvest. In the experiment with 4 daylengths (10, 12, 14 and 16 hours photoperiod) the time to flowering in the 10 hour daylength was the same for both accessions (34 days). However under 12 hour photoperiod the late variety flowered in 80 days compared with early variety in 53 days. The late flowering accession (Q10057) had the largest number of flowers in the 10 hour day, but the smallest in the 12 hour. There was no flowering over 4 months at the 14 and 16 hour daylength. Both accessions had the same weight of seed per plant, but because of the smaller seed weight in the late variety (Q10057) it would have borne the highest number of seeds. Plants were grown in the same number of sun hours (8 hours/day) with incandescent light providing the rest. Plant dry weight increased with each daylength increase until at 16 hours plants were 4–5 times heavier than the 10 hours. Weights were higher in the 8 weeks harvest compared with the 4 week harvest.*

INTRODUCTION

Cassia rotundifolia, a prostrate to semi-erect perennial herbaceous legume from South America, has been introduced into Australia over the past 30 years. It has shown promise in agronomic experiments on the coast and inland in Queensland and northern New South Wales. One cultivar called Wynn is being prepared for release (Strickland 1983).

There are four maturity groups, with the earliest flowering a few weeks after emerging and the latest about 5 months after planting. The cultivar Wynn (CPI 34721) is in the early group, and has a better persistence and spread than other accessions. It also gave 20% more liveweight gain per day in rats than the other accessions or lucerne.

C. rotundifolia may become important as a legume in lower rainfall environments and it is thus useful to understand its response to effects of temperature and of daylength in its growth and flowering. These studies may assist in future plant improvement. It has also been suggested that the late flowering cultivars may give higher yields when left uncut until flowering, but that, when defoliated regularly, as