

Elionurus purpureus E.J.Thomps. (*Panicoideae*: *Andropogoneae*: *Tripsacinae*), a new species for Queensland: circumscription and breeding system

E.J. Thompson

Summary

Thompson, E.J. (2017). *Elionurus purpureus* E.J.Thomps. (*Panicoideae*: *Andropogoneae*: *Tripsacinae*), a new species for Queensland: circumscription and breeding system. *Austrobaileya* **10(1)**: 139–162. A new species of *Elionurus* Willd. endemic to northeast Queensland is described and illustrated. It is distinguishable from *E. citreus* by the annual growth habit and spikelet morphology. The leaf anatomy of the two Australian species of *Elionurus* is illustrated and compared. The spikelet morphology of the two Australian species is contextualised within *Elionurus*, *Tripsacinae* and *Rottboelliinae*. A new distinguishing morphological character for *Elionurus* is presented, viz. the proximal beak on the sessile spikelets, which is shared by the African genus *Urelytrum* Hackel (*Tripsacinae*), and some Australian genera in other subtribes of *Andropogoneae*. The breeding system that involves cleistogamy is discussed for the two Australian species of *Elionurus*.

Key Words: Poaceae, *Andropogoneae*, *Rottboelliinae*, *Tripsacinae*, *Elionurus*, *Elionurus citreus*, *Elionurus purpureus*, Queensland flora, taxonomy, new species, cleistogamy, morphological characters, leaf anatomy, stem anatomy, cultivated plants

E.J. Thompson, Queensland Herbarium, Department of Science, Information Technology and Innovation, Brisbane Botanic Gardens, Mt Coot-tha Road, Toowong, Queensland 4066, Australia.
Email: John.Thompson@dsiti.qld.gov.au

Introduction

Elionurus Willd. is a genus of 15 species of tropical and subtropical caespitose grasses, 13 perennial and two annual. Nine (six endemic) species occur in Africa, five (two endemic) from southern North America, four (three endemic) from South America, one from India, and one species recorded for Australia and New Guinea (Clayton 1973; Clayton & Renvoize 1986; Watson & Dallwitz 1992). *Elionurus* has been placed in the tribe *Andropogoneae* subtribe *Rottboelliinae* on the basis of morphology (Watson & Dallwitz 1992) and a molecular phylogeny by Soreng *et al.* (2015), although Kellogg (2015) placed it in *Andropogoneae*, *incertae sedis* based on earlier molecular phylogenies. Soreng *et al.* (2017) in an updated phylogeny placed *Elionurus* in subtribe *Triplacinae*. Members of the tribe typically have racemose inflorescences composed of disarticulating segments made up of a pair of differentiated

spikelets (sessile and pedicellate) and a rachilla (Stapf 1934; Renvoize 1978; Watson & Dallwitz 1992). These spikelet pairs have phylogenetic significance and are considered by Zanotti *et al.* (2010) to be the evolutionary origin of the solitary spikelets in the sister tribe, *Paniceae*.

Tripsacinae is currently represented worldwide by a further six genera, none of which are native to Australia and includes the significant food plant maize (*Zea* L.) (Soreng *et al.* 2017). In the updated phylogeny of these grasses, Soreng *et al.* (2017) transferred five genera from *Rottboelliinae* to *Tripsacinae* that had previously comprised only *Tripsacum* L. and *Zea*, thus leaving *Rottboelliinae* with 16 genera. Species of *Tripsacinae* and *Rottboelliinae* have unbranched inflorescences and lack the conspicuous geniculate spiralled awn on the sessile spikelets present in most other subtribes of *Andropogoneae* (Clayton 1973; Clayton & Renvoize 1986; Watson & Dallwitz 1992; Kellogg 2015), although awnless spikelets also occur in subtribes *Chionachninae* and *Coicinae* (Soreng *et al.* 2017). Clayton (1973) used morphological

characters in a numerical analysis of species of *Andropogoneae* with awnless sessile spikelets covering 22 of the 23 genera from *Tripsacinae* (except *Zea*) and *Rottboelliinae* and presented similarity diagrams for the genera. Clayton (1973) considered *Rottboelliinae* to be a recent evolutionary branch disjunct from other members of the tribe.

The previous single Australian species, *Elionurus citreus* (R.Br.) Munro ex Benth., lemon-scented grass, occurs along the northern tropical and eastern subtropical coast of Australia and New Guinea (Simon & Alfonso 2011). This species is described and illustrated by Tothill & Hacker (1983) and Jacobs *et al.* (2008).

Lemon-scented foliage also occurs in other species of *Andropogoneae*, where fragrance of leaves has been used sometimes as a taxonomic character in keys to genera by Stapf (1934) and Simon (2002). Lemon-scented foliage is found in the Australian grass *Cymbopogon ambiguus* A.Camus (Australian lemon-scented grass), several species and cultivars of *Cymbopogon* Spreng. (lemon grass, citronella grass) from Asia, and *Elionurus muticus* (Spreng.) Kunth (lemon grass) from South America and Africa. The Asian and South African grasses are commercial sources of lemon-scented essential oils (e.g., citral, citronellol, geraniol) (Soenarko 1977; Watson & Dallwitz 1992; Sangwan *et al.* 2001; Nakaharar *et al.* 2003; Fuller *et al.* 2014; Kellogg 2015). Other essential oils (predominantly campherenone) have been reported in leaves and roots of *Elionurus elegans* Kunth, an annual from Africa (Mevy *et al.* 2002).

The breeding systems in grasses are highly diverse (Connor 1979) and in *Panicoideae* this is particularly so for the genera comprising *Tripsacinae* as represented by Soreng *et al.* (2017). *Tripsacum* L. and *Zea* provide unusual diversity in breeding systems for subtribes in *Andropogoneae*. *Tripsacum* has male and female flowers in separate portions of the same inflorescences, as is found in *Chionachne* R.Br. (subtribe *Chionachninae*) and *Zea* has

male and female inflorescences in different parts of the same plant (Watson & Dallwitz 1992). All of the species of *Tripsacinae* and *Rottboelliinae* have bisexual flowers and most are solely chasmogamous (CH), where anthers and stigmas emerge from florets with the ability to outcross and thereby provide gene flow (Watson & Dallwitz 1992; Simon & Alfonso 2011). The one known exception until now is the presence of cleistogamy (CL) (self-pollination within a closed flower), in *Rottboellia exaltata* L.f. reported by Heslop-Harrison (1959). Various types of CL have been reported for species in other subtribes of *Andropogoneae* (Connor 1979; Campbell *et al.* 1983; Watson & Dallwitz 1992; Culley & Klooster 2007).

This paper provides a taxonomic account of a new species of *Elionurus* with lemon-scented foliage from north Queensland. The breeding systems of the two Australian species of *Elionurus* are presented and categorised according to current CL classifications from the literature (**Table 1**). Morphological affinities of *Elionurus* to other genera of *Rottboelliinae* are also discussed.

Materials and methods

Field survey at the site of the type collection of *Elionurus purpureus* was conducted in three successive years, April 2015, April 2016 and May 2017.

A comparative study of gross morphology and anatomy was made for *E. purpureus* and *E. citreus*. Morphological data for *E. purpureus* were obtained from four accessions at BRI which includes the type (**Fig. 1**). Spikelets from terminal and axillary inflorescences were dissected to examine their characters. Six topotypes from Queensland Herbarium (BRI) collections of *E. citreus* were selected for sampling (**Appendix 1**). These specimens were collected in the vicinity of the type and are considered representative substitutes for the type, a collection by Robert Brown (*Bennett no. 6176*) made in 1802 from Northumberland Island, Queensland. Online images of the isotype (*Andropogon citreus* R.Br.) at E, K and W were examined.

Table 1. Morphological character differences between the Australian species of *Elionurus*

Character	<i>Elionurus purpureus</i>	<i>Elionurus citreus</i>
Growth habit	annual	perennial
Inflorescence type	multiple racemes at nodes at least on cultivated plants	single racemes at nodes on cultivated plant and topotypes
Culms Transverse section shape Anatomy sclerenchyma along convex edge	broadly concavo-convex mostly 3 or 4 cells wide	narrowly concavo-convex mostly 6–8 cells wide
Leaf blade and sheath Distribution Margin prickle hairs Abaxial surface length of stomata (μm) length of silica bodies (μm) Margins and mid-vein indumentum Mid-vein Anatomy of vascular bundles adaxial sclerenchyma	cauline absent 45–60 15–20 smooth obtusely keeled absent	mostly basal medium (60–70 μ) 41–51 8–15 usually scabrid acutely keeled present
Sessile spikelet (mid raceme*) Total length (beak, body and lobes) (mm), colour at maturity Lower glume lobe length (mm) body width \times length (mm), texture indumentum type, orientation hair length (mm) keeled margin of lower glume Upper lemma margin apex Callus length (mm) *apical spikelets are smaller and basal larger	8.1–9.2, purple 2.6–3.2 1.7–2 \times 3.5–4.2, chartaceous pubescent, appressed c. 0.2 not winged hyaline, pilose, hairs c. 0.3 mm long acute 1–2.3	10.6–13.1, pallid to pale pink, rarely purplish 5.5–7 1.5–1.7 \times 3.6–4.3, cartilaginous glabrous to pilose, ascending c. 2 narrowly winged hyaline, ciliate apically or glabrous attenuate 1.8–2.7
Pedicellate spikelet Lower glume width \times length (mm), colour at maturity, body, margins Upper glume	0.8–1.3 \times 5.2–5.7, purple; lanceolate, asymmetrical, 5-veined, 1-keeled, both margins with <i>oil streak</i> subequal to lower glume, 5-veined, back rounded	c. 0.9 \times 7.2–8.5, pallid to pale pink, rarely purplish, linear to narrow lanceolate, asymmetrically, 3-veined, 1-keeled, one margin with <i>oil streak</i> unequal to lower glume, 3-veined, back laterally compressed
Anther length (mm) Chasmogamous Cleistogamous	0.9–2 c. 0.8	1.3–2.7 0.7–1.8
Rachilla Width \times length (mm), shape Apex rim Sub-apical beard length of longest hairs (mm)	1.2–1.4 \times 4.3–4.4, distinctly clavate distinctly winged, unequally bilobed 2.8–2.9	0.9–1.3 \times 3.3–5, clavate usually narrowly winged and unequally bilobed, or not winged 3.6–4.9
Pedicel Width \times length (mm), shape	c. 0.8 \times 2.5–3.5	0.5–0.6 \times 2.9–4



Fig. 1. Holotype specimen of *Elionurus purpureus* (McDonald KRM16860 & Thompson, BRI).

Herbarium specimens and/or images of type specimens of all the other species of *Elionurus* and species in other genera of *Tripsacinae* and *Rottboelliinae* were examined in detail (**Appendices 1 & 2**).

Leaf and culm transverse sections were prepared using a modified freehand sectioning version of the method described by Frohlich (1984). Samples of herbarium material were rehydrated by initial immersion in hot water and left to soak for up to several days. Leaves from upper culms were used and sections taken from near the middle of each leaf. Leaf samples were placed on a glass slide covered with a glass slide cover that served as a cutting guide. Culm sections were cut without the use of the slide cover. Thin sections were cut using a razor blade while viewing under a binocular microscope at $\times 40$ magnification. Several sections were made for both *E. purpureus* and *E. citreus*. Three accessions of *E. citreus* were examined to capture variation and because some leaf blades retained distorted parenchyma following rehydration. Leaf blades and culms of near equivalent width were used for both species.

Leaf, spatheole and culm surface replicas were prepared using the method described by Hilu & Randall (1984).

Micromorphology was studied from images taken using a compound binocular microscope at $5\times$, $10\times$, $20\times$ and $40\times$ for transverse sections, and at $20\times$ and $40\times$ for surface replicas.

Plants of *E. citreus* and *E. purpureus* were cultivated for three main purposes: to study any impact of environment on growth habit, effect of environment on the breeding system, and provide a supply of viable caryopses for further studies. Caryopses were taken from the type of *E. purpureus* and BRI accession, McDonald KRM11354 for *E. citreus*. The caryopses were scarified by scraping off a small portion of pericarp just above the

scutellum. Germination was at ambient temperature on damp tissue paper in a covered transparent container in November 2016.

Plants were cultivated in pots in a well-drained potting medium in full sun in Brisbane, Australia (lat. $27^{\circ} 26' 37''$ S). Plants were watered daily, unless there had been sufficient rain, to maintain continuously moist potting medium. Watering rate was at about 7 mm per day, measured using a rain gauge, equating to about 1000 mm for the wet season (December – March). Plants were occasionally fertilised with a commercial pelletised chicken manure.

Rainfall data from Climate Data Online (BoM) for weather stations near the collection localities of BRI accessions of *E. purpureus* were examined to investigate the potential effect of soil moisture levels on plant growth and flowering. Frequency of rainy days of more than 5 mm and more than 10 mm are recorded in **Table 2** as a comparison with the watering regime of cultivated plants.

Spikelets from the cultivated plants were examined in detail at flowering and fruiting in April – June 2017. Spikelets from the upper and lower halves of racemes were harvested on a daily basis as they matured. The most distal spikelet of racemes disarticulated readily at maturity. Ripe spikelets were gathered by gently touching. The proportion of CH:CL was examined by randomly selecting 20 spikelets for two batches, each batch from the upper halves and lower halves of racemes.

Botanical terminology follows Beentje (2010) and Harris & Harris (1994) for general usage. An exception is the use of the term *convexo-concave* to differentiate the shape of the culm transverse section of *E. purpureus*. Anatomy descriptions and terminology follow Metcalfe (1960), Ellis (1976, 1979), Renvoize (1982) and Watson & Dallwitz (1992).

Taxonomy

Key to the Australian species of *Elionurus*

- 1 Perennial; spikelets pallid to pale pink; sessile spikelet with lobes longer than body; body of lower glume pubescent; upper glume glabrous on margin; NE NSW, E Qld, N NT, N WA **E. citreus**
1. Annual; spikelets purple at maturity; sessile spikelets with lobes shorter than body; body of lower glume pilose or glabrous; upper glume pilose on margin; N Qld **E. purpureus**

Elionurus purpureus E.J.Thomps., **sp. nov.** similar to *E. citreus* (R.Br.) Munro ex Benth. differing by the annual growth habit and purple spikelets 8.1–9.1 mm long with body of lower glume longer than the lobes and margin of upper glume pilose. **Typus:** Queensland. COOK DISTRICT: 0.8 km along Mt Spurgeon road from Mulligan Highway, Mt Carbine, 10 April 2015, *K.R.McDonald KRM16860 & E.J.Thompson* (holo: BRI).

Erect caespitose annual to 1.3 m high. Culms < 4 mm wide, shortly branched, nodes 3–9; internodes purplish, smooth, hairless, furrowed; nodes glabrous often purplish, half to two-thirds of total length exerted from sheath. Basal leaf sheaths purplish; culm sheaths with scattered white hairs mostly near apical margins; collar margins with hairs to 3.3 mm. Ligule a fringed membrane, *c.* 0.9 mm. Leaves cauline, blades up to 45 cm long and 0.8–2 mm wide, discolorous, cauline, keeled, pilose adaxially, hairs to 0.2 mm, margins smooth, inrolled on drying, lemon-scented when crushed. Inflorescences of single spatheolate one-sided racemes, 4 to 13 cm long. Peduncle absent. Up to 9 nodes with 1–3 one-noded branches each bearing a raceme; axillary racemes exerted, partly exerted or enclosed with spatheole; spatheoles *c.* 4.5 mm wide and up to 13 cm long, pilose; culms extending to 15 cm beyond spatheole. Spikelets paired (sessile and pedicellate), dimorphic, purple at maturity, closely overlapping in two opposing staggered rows along disarticulating jointed axis; diaspore composed of paired spikelets and rachilla. Callus elliptical, *c.* 0.4 × 1–2.3 mm. Sessile spikelet fertile, dorsi-ventrally compressed, 1.4–1.6 × 8.1–9.2 mm, gradational (larger from base to apex), proximal beak 2–2.2 mm

long. Glumes dissimilar; lower glume 6.1–7.5 mm long; body 1.7–2 × 3.5–4.2 mm, broadest in middle, 9-veined, symmetrical, chartaceous; back flattened, pubescent with appressed pale hairs *c.* 0.2 mm long or sometimes glabrous; margins keeled, keels not winged, with two rows of pectinate white bristles to 1.3 mm long at 45° to margin decreasing in length towards apex, sub-margins with broad dark purple glabrous *oil streak* continuous with lobes; apex 2-lobed, 2.6–3.2 mm long, obtuse, lobes fused in lower third to half; upper glume 4.2–4.5 mm long, symmetrical, lanceolate, membranous, 3-veined, carinate, midvein with short erect proximal hairs; margins winged, wing *c.* 0.3 mm wide, membranous, pilose; short appressed to ascending hairs on back, glabrous in upper 1/3, apex acute. Florets 2; lower floret neuter, lemma *c.* 3.5 mm long, lanceolate, hyaline, veins indistinct, margin pilose, apex acute. Lower palea absent. Upper floret hermaphrodite, upper lemma, 2.5–2.8 mm long, elliptic, hyaline, veins indistinct, margin pilose, apex obtuse. Upper palea absent. Lodicules 2, *c.* 0.5 mm long. Anthers chasmogamous 3, 0.9–2 mm long, cream when fresh, or cleistogamous 3 and *c.* 0.8 mm long. Caryopses *c.* 1 × 0.6 × 2.5–2.7 mm, dorsiventrally compressed, broadest in the middle, bowed longitudinally, buff to light brown; scutellum *c.* 1.4 mm long; hilum *c.* 0.5 mm long. Pedicellate spikelet neuter; glumes dissimilar, subequal, 5-veined, chartaceous, lanceolate, lobes orientation parallel to body; lower glume 0.8–1.3 × 5.2–5.7 mm, dorsally compressed, back glabrous, asymmetrical, broadest at the base, acute apex; 1-lobed, lobe orientation horizontal; margin 1-keeled, with a single row of pectinate white bristles *c.* 0.6 mm long decreasing in length apically, submargins with *oil streak*; upper glume, *c.*

0.8 × 4.5–5.3 mm, glabrous, symmetrical, laterally compressed; back convex, carinate in upper half, keel pilose with stiff parallel hairs *c.* 0.2 mm long; apex acute; 1-lobed, lobe orientation vertical; margins flat. Pedicel *c.* 0.8 × 2.5–3.5 mm, free from internode, clavate, hollow, plano-convex in cross-section, adaxial wall membranous and abaxial wall chartaceous; abaxial edge pubescent with white hairs, short and appressed along most of length and with a longer sub-apically tuft to 2.4 mm. Rachilla 1.2–1.4 × 4.3–4.4 mm, dissimilar to pedicel, free from internode, clavate, hollow, plano-convex in cross-section, adaxial wall membranous and abaxial wall chartaceous, abaxial edge pubescent with short white appressed hairs; apex *c.* 1.2 × 2.3 mm, oblique, adaxially flanged, unequally bilobed, subapical ring of white hairs to 2.8–2.9 mm long and longest on abaxial margin; disarticulation scar *c.* 0.7 mm × 1.5 mm, flat, elliptical. **Figs. 1, 2, 3 & 4.**

Additional specimens examined: Queensland. COOK DISTRICT: 9 km from Koolburra on the track S from Koolburra to the Kimba road, Jun 1981, *Clarkson 3699* (BRI); Conglomerate Creek, S of the Deighton Road, on Escort Creek Holding, SE of Laura: Lot/Plan 198/SP273726, Apr 2017, *Forster PIF45151 & McDonald* (BRI, MEL); 0.8 km along Mt Spurgeon road from Mulligan Highway, Mt Carbine, May 2017, *Thompson EJT1083* (BRI). CULTIVATED. Ashgrove, Apr 2017, *Thompson MOR804* (BRI).

Distribution and habitat: *Elionurus purpureus* occurs west of the Great Dividing Range in the range latitude 15°15' to 16°45'S and longitude 143°30' to 145°15'E (**Map 1**). It is found in woodland mostly dominated by eucalypts including *Corymbia clarksoniana* (D.J.Carr & S.G.M.Carr) K.D.Hill & L.A.S.Johnson, *Eucalyptus leptophleba* F.Muell. and *E. tetradonta* F.Muell. on sandy alluvial soil adjacent to intermittent creeks or lagoons.

Phenology: *Elionurus purpureus* flowers in March to June during the wet season and early dry season.

Notes: The identification key to *Elionurus* species of the world provided by Renvoize (1978) was used to verify that *E. purpureus* is not an introduced species as specimens fail to key out satisfactorily. Using the

key character *annual*, specimens key to *E. hensii* K.Schum from the African continent, although examination of the online image of the isosytype provided confirmation of the dissimilarity with *E. hensii*. If the growth habit is assumed to be perennial then specimens key to *E. citreus* but do not have the *lower glume with lobes longer than the body*. **Table 3** lists the character differences between *E. purpureus* and *E. citreus* and **Fig. 4** provides images of the respective spikelet pairs for comparison.

Diaspore dispersal in the Australian species of *Elionurus* occurs via two modes. Most of the diaspores readily disarticulate from the racemes at maturity and can disperse by various vectors in similar ways to other grasses. Secondly, the basal spikelet pair that is CH or CL of each raceme is resistant to disarticulation. This delayed release of the spikelet may have some advantage with dispersal allowing the spikelet to fall further from the mother plant after the culms collapse.

Appendix 2 lists spikelet differences for all the species of *Elionurus*. This comparison shows that the Australian species exhibit morphological similarities between themselves but are distinct from the other species. Only the Australian species have the pedicellate spikelets composed of just the two glumes and they always neuter. The non-Australian species have developed pedicellate spikelets with two lemmas and anthers. This variation in development of the pedicellate spikelet within a genus is uncommon in *Andropogoneae* but has parallels in *Arthraxon* Beauv. (van Welzen 1981). Furthermore, the Australian species have a distinctive character of the sessile spikelets that they share with most of the other species. The lower glumes have conspicuous submargins that Clayton & Renvoize (1986) referred as a *brown oil streak* and Watson & Dallwitz (1992) called *glandular*. Three species, *Elionurus elegans* Kunth, *E. hirtifolius* Hack. and *E. royleanus* A.Rich. from Africa to NW India, lack this *oil streak*. These species differ by having tufts of hairs along the margins of the lower glume of the sessile spikelets instead of the row of parallel hairs present in the other species

Table 2. Categories of cleistogamy (CL) in Poaceae as presented by eight authors with those that apply to the Australian species of *Eilonurus* shown in **BOLD**

Author	Taxonomic context of CL classification	Number of CL types recognised	Monomorphic anthers		Dimorphic anthers			
			CH = CL on the same plants	CL only	Polymorphism – CH and CL on separate plants	Amphigamy – CH and CL in two types of inflorescences in different parts of the same plant	Another dimorphism or morphology not specified	Structural peculiarities
Darwin (1877)	Angiosperms	2	No structural peculiarities	no category (Darwin doubted this possibility)	no category	no category	Structural peculiarities <i>true cleistogamy</i>	
Haeckel (1906)	Poaceae	4	Facultative CL (Group 1)	CL only (Group 3)	Dimorphic (Group 2)	Amphigamous (Group IV)	no category	no category
Uphof 1938)	Angiosperms	2	Ecological CL	Constitutional CL	no category	no category	Constitutional CL	
Connor (1979)	Poaceae	3	CL and CH	CL only	no category	Clandestine axillary (<i>cleistogenes</i>)	no category	no category
Lord (1981)	Angiosperms	4	Preadthesis, pseudocleistogamy	Complete	no category	no category	True	
Campbell <i>et al.</i> (1983)	Poaceae	4	Type Ia. sheath fertilization (upper-most sheaths) Type IVb. spikelet fertilization (lodicule failure)	no category	no category	Type II. cleistogenes, Type III. rhizanthogenes	Type Ib. sheath fertilization (lowermost sheaths of culms) Type IVa. spikelet fertilization (spikelet bract modifications)	
Watson & Dallwitz (1992)	Poaceae	2	Exposed-cleistogamous	no category	no category	Hidden cleistogenes – very modified, highly modified	no category	no category
Culley & Klooster (2007)	Angiosperms	3	Induced	Complete	no category	no category	Dimorphic	

(see **Fig. 4**). However, the three species have similarities to the Australian species by the lower glume of the pedicellate spikelets being asymmetrical with the apex lobed or awned (**Appendix 2**).

Harvesting of ripe spikelets from the cultivated plants of *E. purpureus* to collect caryopses revealed a further character uncommonly represented on herbarium specimens. Spikelets on each raceme ripen and disarticulate successively until the basal one that is resistant to detachment from the culm but ultimately falls. The specimens of the species of *Elionurus* observed for this study frequently had over-mature racemes preventing observation of this phenomenon, although it was present on one specimen of *E. citreus* at BRI. The herbarium specimens usually had complete racemes and sometimes partially disarticulated ones. Permanent retention of the basal spikelet is uncommon in Australian *Andropogoneae* but has been reported by Veldkamp *et al.* (1986) and observed on herbarium specimens by the author for *Thaumastochloa* C.E.Hubb., also *Rottboelliinae*.

Very few of the caryopses obtained from BRI specimen accessions were viable. Several caryopses from the holotype of *E. purpureus* germinated and two plants survived to maturity. One caryopsis of *E. citreus* from McDonald KRM11354 (BRI) germinated and the plant survived to maturity.

Observations from the cultivated progeny of *E. purpureus* revealed striking differences from the type that initially appeared to be the only collection. This promoted a review of the 148 accessions of *E. citreus* at BRI. One of the accessions, Clarkson 3699, matched the cultivated plants. At the point of nearing completion of this manuscript another specimen, Forster PIF45151 & McDonald, was incorporated at BRI. This accession is comprised of plants that are identical to the type in growth habit and inflorescence composition.

The difference in the growth habit of the type from its cultivated progeny was considerable. The plants comprising the type

have single slender culms to 30 cm high while all cultivated plants had multiple culms, one main robust culm to 1.3 m high and up to 4 subordinate ones to 50 cm high. Cultivated plants had much larger leaves, to 6 mm wide \times 42 cm long, compared to the type with leaves 1–2 mm wide \times 18 cm long. All of the cultivated plants closely resembled BRI accession Clarkson 3699 (**Fig. 2**).

There were also differences in the inflorescences of cultivated plants. The cultivated plants of *E. purpureus* had racemes to 13 cm long in fasciculate inflorescences comprised of up to three racemes on branches arising at as many as nine culm nodes. The holotype and accession Forster PIF45151 & McDonald have single racemes to 8 cm long on short branches at up to three nodes. The cultivated plant of *E. citreus* had single racemes at the nodes as was observed for the topotypes listed in **Appendix 1**.

The study of the wet season rainfall data presented in **Table 2** resulted in equivocal conclusions. The sample size is too small for any clear trends but there is some evidence to support a hypothesis that December rain of *c.* 100 mm may be responsible for plants developing the taller growth habit. This seems plausible since no intermediate sized plants were observed despite the presence of soil moisture gradients at least for some of the collection sites (pers. comm. P.I. Forster). The possibility of dimorphic growth habit requires further investigation, particularly from further field survey.

Breeding system

In order to categorise the CL found in *Elionurus*, the classification schemes of CL presented by eight authors were investigated. These schemes are of two broad types in terms of taxonomy, for flowering plants in general and more specifically for grasses. The classifications by Campbell *et al.* (1983) and Hackel (1906) provide more specific categories relevant to Poaceae. In summary, the schemes assess CL by the presence of various morphological modifications of the CH morph or whether CL is induced by environmental conditions. The categories



Fig. 2. Paratype of *Elionurus purpureus* (Clarkson 3699, BRI).

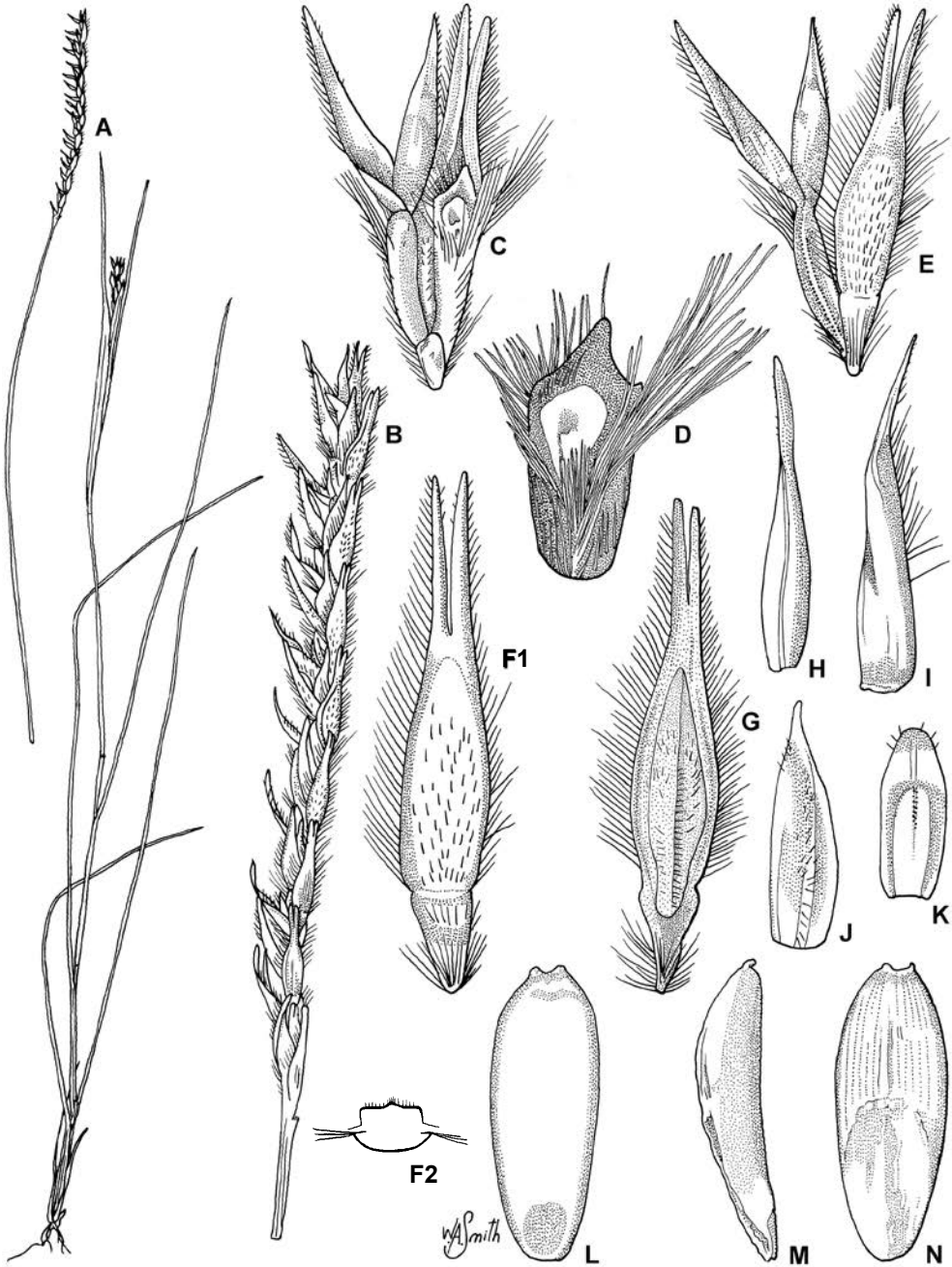


Fig. 3. *Elionurus purpureus*. A. growth habit $\times 0.5$; B. terminal raceme $\times 2$; C. adaxial view of diaspore $\times 6$; D. apex of rachilla showing flange $\times 12$; E. abaxial view of diaspore $\times 6$; F1. lower glume of sessile spikelet $\times 8$; F2. TS of lower and upper glumes at mid-point $\times 6$; G. back of lower glume showing upper glume *in situ* $\times 8$; H. upper glume of pedicellate spikelet $\times 8$; I. lower glume of pedicellate spikelet $\times 8$; J. lower lemma of sessile spikelet $\times 8$; K. upper lemma of sessile spikelet $\times 8$; L. back view of caryopsis $\times 16$; M. side view of caryopsis $\times 16$; N front view of caryopsis $\times 16$. All from McDonald KRM16860 & Thompson (BRI). Del. W. Smith.



Fig. 4. Top: *Elionurus purpureus*. front and back of diaspore from McDonald KRM16860 & Thompson (BRI). Bottom: *E. citreus*. front and back of diaspore from Halford QM342 & Bean (BRI).

from these schemes that apply to the Australian species of *Elionurus* are shown in **Table 1**. Overall these categories help define the expression of CL in the Australian species of *Elionurus* but none of the individual schemes provides a comprehensive classification alone. *E. purpureus* has a mixed breeding system consisting of CH and CL morphs with dimorphic anthers. Racemes can be mixed CH and CL and solely CL on the same plants as observed on cultivated plants. Racemes with CL spikelets can occur from the lowest to the upper most nodes. Also, plants can be solely CL as for the type specimen.

Racemes can occur on elongated branches with spikelets fully exposed or racemes can be partially retained within spatheoles or leaf sheaths. This provides two dispersal mechanisms or at least differential release of spikelets. Exposed CL and CH spikelets can disperse in the usual way as for most grasses

whereas the retained CL spikelets are likely to remain close to the mother plant after collapse of the culms.

Random selections of spikelets gathered from a single cultivated plant revealed spikelets from:

- the upper half of racemes – 40–50% CL, 40–50% CH and 10% empty.
- the lower half of racemes – 30–70% CL, 20–60% CH and 10% empty.

From this small sample it appears that the ratio of CL:CH is more variable in the lower half of racemes. Further sampling is required to determine if the CL:CH ratio varies with position of the raceme on plants and maturation of plants. Racemes develop sequentially on plants such that the fasciculate inflorescences have as many age groups of racemes as there are racemes. Age groups of racemes on cultivated plants differed by

Table 3. Monthly rainfall data (mm) from two Queensland weather stations near the three collection locations of *Elionurus purpureus* for the wet season covering the date of the collection. N - number of days with rain exceeding 5 and (10) mm

Rainfall station	Accession	Plant growth habit	Wet Season Year	D	J	F	M	Total	
Mt Carbine Township	<i>McDonald & Thompson KRM16860</i> (April 2015)	small plants with a single slender culm	Mean (mm)	120	206	225	178	730	
			2014–15	mm	30	132	122	121	405
			N	1 (1)	7 (5)	7 (6)	6 (3)	21 (15)	
	(April 2016)	no plants observed	2015–16	mm	262	97	68	144	571
			N	9 (7)	4 (3)	3 (2)	3 (2)	19 (14)	
	<i>Thompson EJT1083</i> (May 2017)	small plants with a single slender culm	2016–17	mm	40	383	293	131	847
N			2 (1)	14 (11)	9 (5)	7 (4)	32 (21)		
Laura PO	<i>Clarkson 3699</i> (June 1981)	tall plants with multiple robust culms	Mean (mm)	149	234	247	177	807	
			1980–81	mm	100	442	520	103	1165
			N	6 (4)	19 (14)	18 (15)	4 (2) [0]	47 (35)	
	<i>Forster PIF45151 & McDonald</i> (April 2017)	small plants with a single slender culm	2016–17	mm	27	440	238	217	922
			N	2 (1)	13 (9)	16 (8)	9 (7)	40 (25)	

about two weeks in their maturity. From this study, the evidence suggests that the presence of CL is not environmentally induced but the ratio of CL:CH may increase with increasing moisture stress.

E. citreus also has a mixed breeding system similar to *E. purpureus*. Furthermore, one specimen of *E. citreus* that lacked CH had dimorphic spikelets with CL anthers, *c.* 0.6 and 1.2 mm long, respectively compared to the CH, 1.3 to 2.7 mm from other specimens examined. The latter occurrence may be explained in terms of spikelets that potentially would be CH but because of lodicule failure induced by environmental conditions did not open. Spikelets with monomorphic CL anthers were not observed for *E. purpureus*.

The occurrence of CL in the non-Australian species of *Elionurus* requires further research.

Anatomy

Anatomical differences between the two Australian species of *Elionurus* are presented in **Table 3**. Descriptions of anatomy of leaf blade TS and surface, and culm TS for *E. purpureus* are as follows:

Adaxial leaf blade epidermis: Costal/intercostal zonation evident. Long-cells markedly different in shape costally and intercostally, the costals much narrower, sinuous. Intercostal short cell sinuous, uncommon. Papillae absent. Bicellular microhairs present, uncommon, panicoid-type, *c.* 3 µm wide at septum, 60–67 µm long; apical cell length/total length ratio 0.6–0.7. Stomata with parallel-sided subsidiary cells, one row, *c.* 8/mm, 45–60 µm long. Intercostal silica bodies dumb-bell shaped, 15–20 µm long. **Figs. 5A & B.**

Transverse section of leaf blade: C4: XyMS +. Mesophyll with indistinctly radiate chlorenchyma with columns of clear cells between vascular bundles. Bulliform cells continuous with constant size, not in discrete adaxial groups over vascular bundles. Midrib conspicuous, keeled, rounded; adaxial clear cells above bundle sheath; bundle sheaths with single arcs of sheath cells with chloroplasts

bordered by a single row of indistinctly radiate chlorenchyma. Three orders of vascular bundles; primaries and secondaries with a single layer of bundle sheath cells with even outline, interrupted adaxially by air cells only, sclerenchyma absent, and abaxially by girder of sclerenchyma; tertiaries bundle sheath a ring without girder of sclerenchyma. Blade tip with sclerenchyma 1 or 2 cells thick. **Figs. 6A & B.**

Transverse section of culm: asymmetrical, bread-loaf shaped. Chlorenchyma lacking. Pith present. Sclerenchyma a continuous peripheral band mostly 2 or 3 cells wide, larger cells on concave surface. Vascular bundles of three types: small marginal, medium-sized sub-marginal and large extramarginal, the latter separated from the sclerenchyma by one layer of large clear cells. **Figs. 7A & B.**

Etymology: The specific epithet *purpureus* is in reference to the distinctive dark purple spikelets that make the plants of this species very conspicuous in the field.

Conservation status: *Elionurus purpureus* is known from three locations and is considered to have a **Vulnerable** conservation status based on criterion B2a (IUCN 2001).

Elionurus characters and affinities

This study revealed some morphological characters that help distinguish *Elionurus* from other genera of *Andropogoneae* with awnless lemmas. These characters are additional to those presented in studies by Clayton (1973), Renvoize (1978), and Watson & Dallwitz (1992). All species of *Elionurus* have the sessile spikelets with a distinctive beak below the lower glume (see **Figs. 3E & F**). The Australian species of *Elionurus* have inflated chartaceous rachillas and pedicels differing from the other species that have cartilaginous, slender to slightly inflated rachillas. *E. purpureus* and usually *E. citreus* differ from the other species by the rachillas having a distal asymmetrical bilobed flange (see **Fig. 3D**). In a study of morphological characters of *Rottboelliinae*, Clayton (1973) referred to this flange as an *internode tip with membranous rim* but he did not indicate which species had this character.

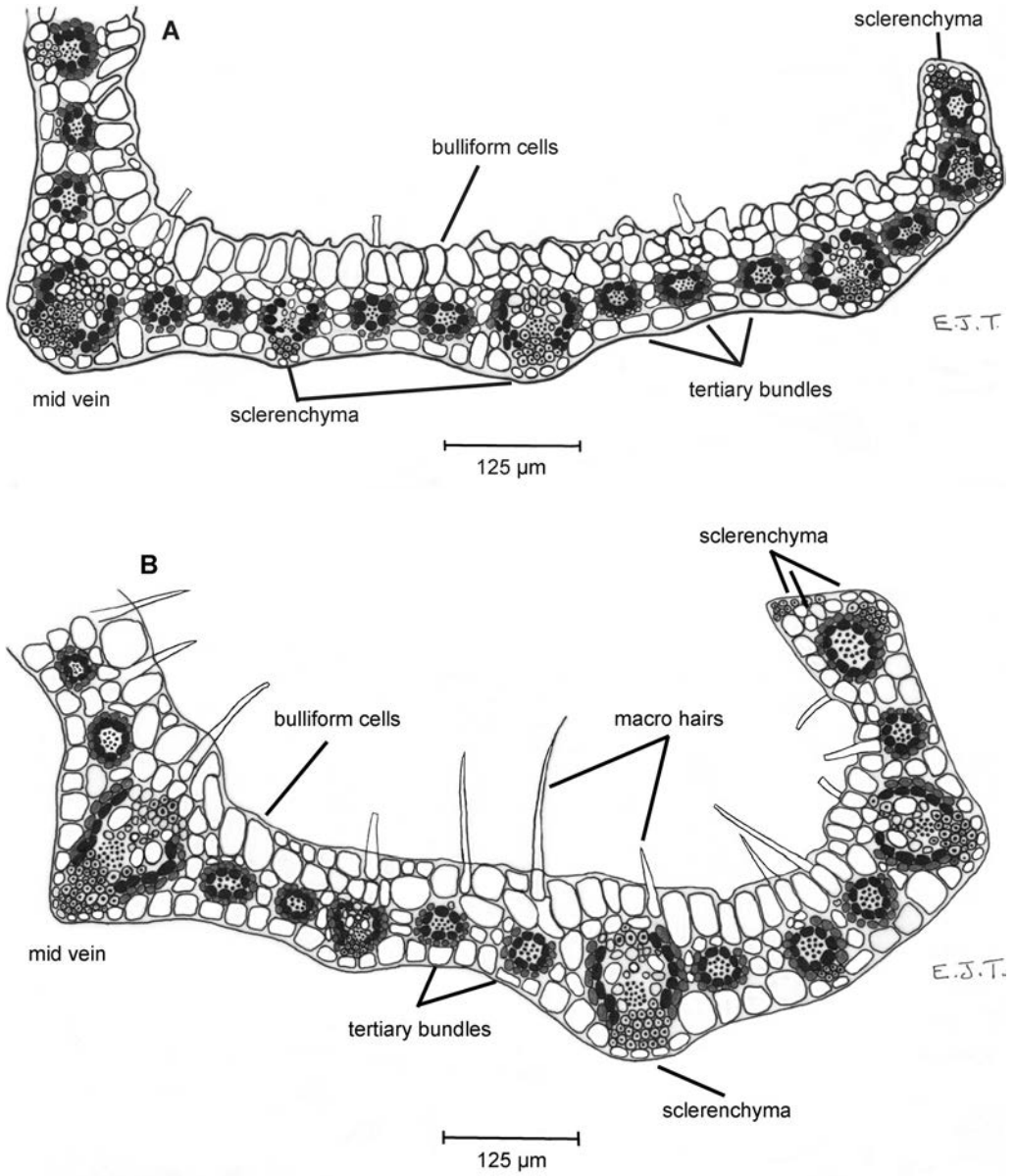


Fig. 5. A. *Elionurus purpureus*. transverse section of half of leaf blade. B. *E. citreus*. transverse section of half of leaf blade; A from McDonald KRM16860 & Thompson (BRI); B from Halford QM342 & Bean (BRI). Del. E.J.Thompson.

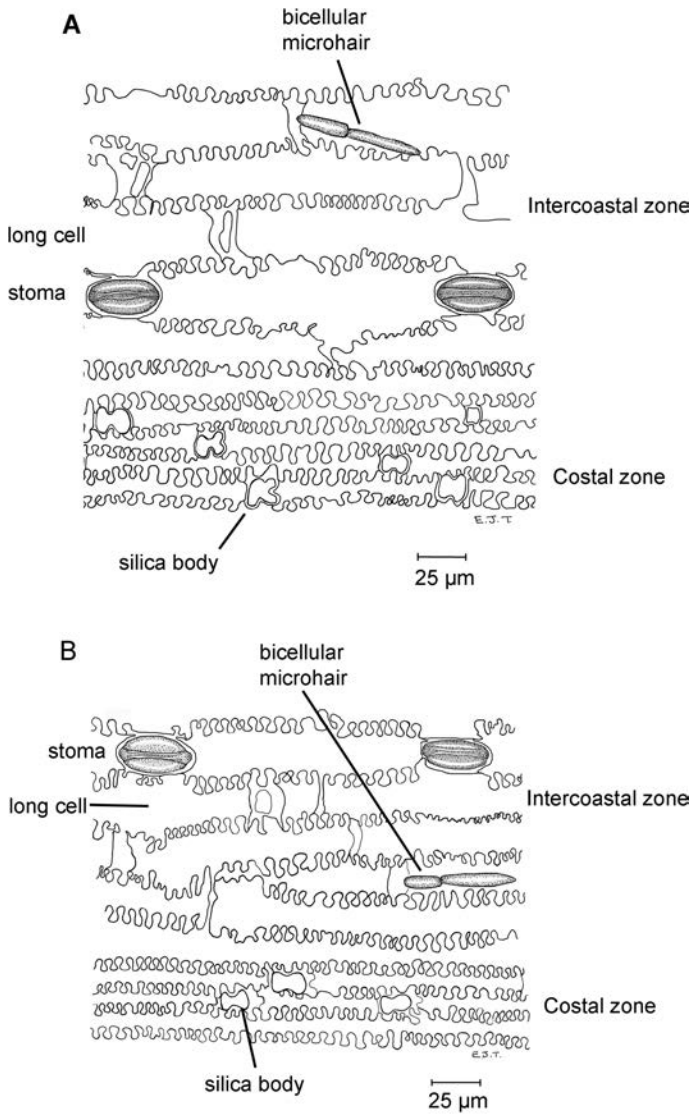


Fig. 6. A. *Elionurus purpureus*. abaxial leaf blade epidermis. B. *E. citreus*. abaxial leaf blade epidermis. A from McDonald KRM16860 & Thompson (BRI); B from Everist s.n. (BRI [AQ286391]). Del. E.J.Thompson.

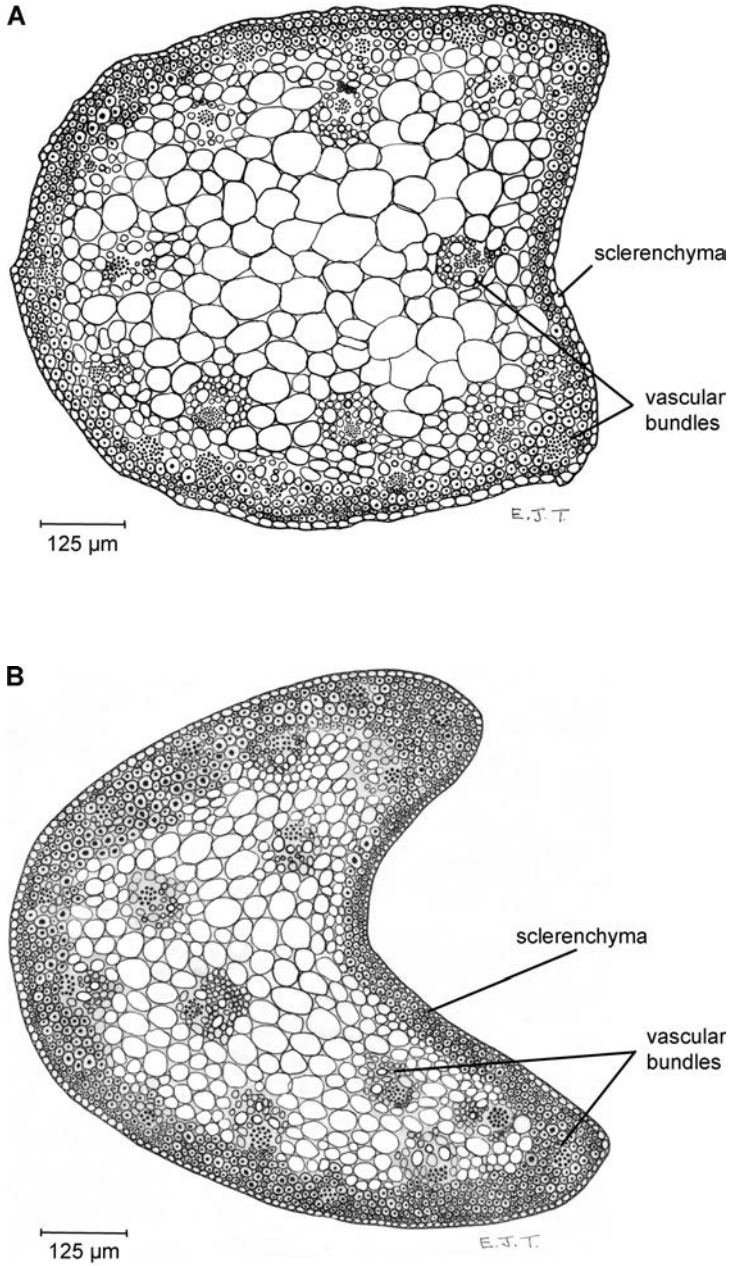


Fig. 7. A. *Elionurus purpureus*. transverse section of culm. B. *E. citreus*. transverse section of culm. A from McDonald KRM16860 & Thompson (BRI); B from Everist s.n. (BRI [AQ286391]). Del. E.J.Thompson.

Three other genera within *Tripsacinae* and *Rottboelliinae*, viz. *Eremochloa* Buse, *Loxodera* Launert and *Urelytrum* Hackel, have morphological affinities to *Elionurus* (Clayton 1973) although Kellogg (2015) placed *Urelytrum* in subtribe *Tripsacinae*. *Eremochloa* occurs in Australia and Asia, while *Loxodera* and *Urelytrum* are from Africa (Watson & Dallwitz 1992). The lower glume of the sessile spikelet and the pedicel of the pedicellate spikelet of *Elionurus*, *Eremochloa* and *Loxodera* are chartaceous to slightly hardened, while for most other species of *Rottboelliinae* these structures are crustaceous. Additionally *Elionurus*, *Eremochloa* and *Loxodera* have free pedicels, whereas commonly in *Tripsacinae* and *Rottboelliinae* species have the pedicels fused to the rachillas.

A notable variation in the genera of *Tripsacinae* and *Rottboelliinae* is the margins of the lower glume of the sessile spikelets that have a row of trichomes which can be viewed as a continuum of different types, viz. bristles, prickles, setae, spicules, tubercles or glabrous. *Eremochloa* has a row of tough bristles or setae (Buitenhuis & Veldkamp 2001), *Jardinia* Benth. & Hook.f. has pectinate spicules, *Elionurus* has tufts of hairs or stiff hairs, *Urelytrum* has a row of bristles and *Loxodera* has a scabrid margin (**Appendix 3**).

Observations from herbarium specimens for this study revealed that *Urelytrum* has close morphological affinity to *Elionurus*. *Urelytrum* is the only other genus of *Tripsacinae* and *Rottboelliinae* to have species with a proximal beak on the lower glume and a distal asymmetrical flange on the rachillas. However, *Urelytrum* differs from *Elionurus* by the sessile spikelets being embedded into crustaceous rachillas. Other genera in subtribes of *Andropogoneae* including *Chrysopogon* Trin. (*incertae sedis*), *Sarga* Ewart (subtribe *Sorghinae*) and *Schizachyrium* Nees (subtribe *Andropogoninae*) (Soreng *et al.* 2015) also have a proximal beak although these genera have the upper lemmas of the sessile spikelets with geniculate spiralled awns. Also, *Urelytrum* has similarities to many of the non-Australian species

of *Elionurus* by the pedicellate spikelets being male and lacking lobes. Conversely, *Urelytrum* has affinities with the Australian species of *Elionurus* by the dissimilarities of the paired spikelets and characters of the pedicellate spikelets including the lower glume being asymmetrical with one of the margins being keeled, and upper glume laterally compressed.

The type of inflorescence exhibited by the cultivated plants of *E. purpureus* has similarities to that found in some other Australian *Rottboelliinae*. Watson & Dallwitz (1992) described the inflorescences of *Elionurus* as “spatheolate; a complex of ‘partial inflorescences’ and intervening foliar organs”. It is described here as: single spatheolate racemes on up to three nodeless or one-noded elongated branches emanating from several culm nodes. Veldkamp *et al.* (1986) referred to this type of inflorescence as fasciculate and Sharp & Simon (2002) referred to it as a synflorescence. The racemes develop sequentially and herbarium specimens display this by usually having the branches of unequal length bearing youngest racemes on the shortest branches. Such inflorescences occur in *Ophiuros* Gaertn.f. and some species of *Mnesithea* Kunth.

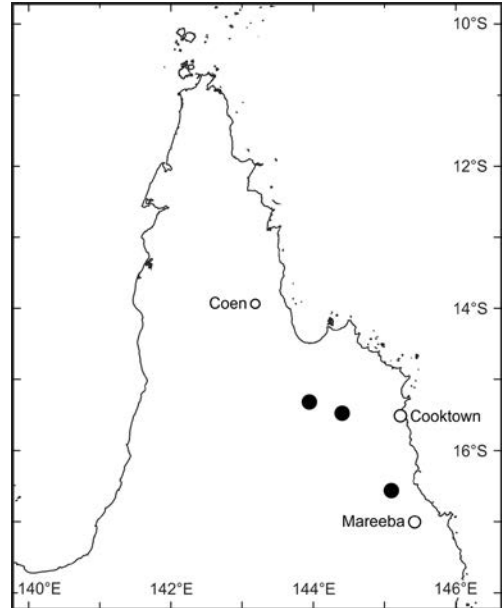
Acknowledgements

A special thanks to Keith McDonald for his invitation to conduct fieldwork in north Queensland that resulted in the serendipitous discovery of this new grass species. Thank you to Will Smith for the botanical illustrations and the map. I am very grateful to Dr Jennifer Firn and Dr Melody Fabillo for feedback on an early draft of the manuscript. I am especially thankful to Dr Neil Snow for his very helpful editorial on a previous version of this paper. I am particularly appreciative for the invaluable editorial feedback on a final version of the manuscript provided by Dr Gordon Guymer.

References

- BEENTJE, H. (2010). *The Kew Plant Glossary: an illustrated dictionary of plant terms*. Kew Publishing: Royal Botanic Gardens, Kew.
- BUITENHUIS, A.G. & VELDKAMP, J.F. (2001). Revision of *Eremochloa*. *Blumea* 46: 399–420.
- CAMPBELL, C.S., QUINN, J.A., CHEPLICK, G.P. & BELL, T.J. (1983). Cleistogamy in grasses. *Annual Review of Ecology and Systematics* 14: 411–441.
- CLAYTON, W.D. (1973). The awnless genera of Andropogoneae studies in the Gramineae: XXXIII. *Kew Bulletin* 28: 49–57.
- CLAYTON, W.D. & RENOVOIZE, S.A. (1986). *Genera Graminum Grasses of the World*. Her Majesty's Stationery Office: London.
- CONNOR, H.E. (1979). Breeding systems in the grasses: a survey. *New Zealand Journal of Botany* 17: 547–574.
- CULLEY, T.M. & KLOOSTER, M.R. (2007). The cleistogamous breeding system: a review of its frequency, evolution, and ecology in angiosperms. *The Botanical Review* 73: 1–30.
- FROHLICH, M.W. (1984). Freehand sectioning with parafilm. *Stain Technology* 59: 61–62.
- FULLER, T.N., BERTRAND, C., SIMON, A., DE BARROS, I.B.I. & NETO, J.F.B. (2014). *Elionurus muticus* as an alternative source of citral from Pampa biome, Brazil. *Journal of Oleo Science* 63: 1109–1116.
- HARRIS, J.G. & HARRIS, M.W. (1994). *Plant Identification Terminology: an illustrated glossary*. Spring Lake Publishing: Spring Lake, Utah.
- HESLOP-HARRISON, J. (1959). Photoperiod and fertility in *Rottboellia exaltata* L.f. *Annals of Botany* 23: 345–349.
- HILU, K.W. & RANDALL, J.L. (1984). Convenient method for studying grass leaf epidermis. *Taxon* 33: 413–415.
- IUCN (2001). *IUCN Red List Categories and Criteria*. IUCN Species Survival Commission: Gland/Cambridge.
- JACOBS, S.W.L., WHALLEY, R.D.B. & WHEELER, D.J.B. (2008). *Grasses of New South Wales*. University of New England: Armidale.
- KELLOGG, E.A. (2015). *The Families and Genera of Vascular Plants. Flowering Plants: Monocots: Poaceae*. Springer International Publishing: Cham.
- METCALFE, C.R. (1960). *Anatomy of the Monocotyledons 1. Gramineae*. Oxford University Press: London.
- MEVY, J.P., BESSIERE, J.M., DHERBOMEZ, M. & VIANO, J. (2002). Composition and some biological activities of the essential oils from an African grass: *Elionurus elegans* Kunth. *Journal of Agricultural and Food Chemistry* 50: 4240–4243.
- NAKAHARAR, K., ALZOREKY, N.S., YOSHIHASHI, T. & NGUYEN, H.T.T. (2003). Chemical composition and antifungal activity of essential oil from *Cymbopogon nardus* (citonella grass). *Japan Agricultural Research Quarterly* 37: 249–252.
- RENOVOIZE, S.A. (1978). Studies in *Elionurus* (Gramineae). *Kew Bulletin* 32: 665–672.
- (1982). A survey of leaf-blade anatomy in grasses. I. Andropogoneae. *Kew Bulletin* 37: 315–321.
- SANGWAN, N., YADAV, U. & SANGWAN, R. (2001). Molecular analysis of genetic diversity in elite Indian cultivars of essential oil trade types of aromatic grasses (*Cymbopogon* species). *Plant Cell Reports* 20: 437–444.
- SHARP, D. & SIMON, B.K. (2002). AusGrass: Grasses of Australia (Version 1.0, June 2002). Australian Biological Resources Study: Canberra.
- SIMON, B.K. (2002). Key to genera of Australian grasses. In K. Mallett & A.E. Orchard (eds.), *Flora of Australia. Poaceae 1: Introduction and Atlas*. 43: 263–277. ABRS/CSIRO Australia: Melbourne.
- SIMON, B.K. & ALFONSO, Y. (2011). *Ausgrass2*. <http://ausgrass2.myspecies.info/>, accessed 21 September 2016.
- SOENARKO, S. (1977). The genus *Cymbopogon*. *Reinwardtia* 9: 225–375.
- SORENG, R.J., PETERSON, P.M., ROMASCHENKO, K., DAVIDSE, G., ZULOAGA, F.O., JUDZIEWICZ, E.J., FILGUEIRAS, T.S., DAVIS, J.I. & MORRONE, O. (2015). A worldwide phylogenetic classification of the Poaceae (Gramineae). *Journal of Systematics and Evolution* 53: 117–137.
- SORENG, R.J., PETERSON, P.M., ROMASCHENKO, K., DAVIDSE, G., TEISHER, J.K., CLARK, L.G., BARBERA, P., GILLESPIE, L.J. & ZULOAGA, F.O. (2017). A worldwide phylogenetic classification of the Poaceae (Gramineae) II: and update and a comparison of the two 2015 classifications. *Journal of Systematics and Evolution* 55: 259–290.

- STAPF, O. (1934). *Flora of Tropical Africa*. L. Reeve & Co Ltd: London.
- TOTHILL, J.C. & HACKER, J.B. (1983). *The Grasses of Southern Queensland*. University of Queensland Press: St Lucia.
- VAN WELZEN, P.C. (1981). A taxonomic revision of the genus *Arthraxon* Beauv. (Gramineae). *Blumea* 27: 255–300.
- VELDKAMP, J.F., DE KONING, R. & SOSEF, M.S.M. (1986). Generic delimitation of *Rottboellia* and related genera (Gramineae). *Blumea* 31: 281–307.
- WATSON, L. & DALLWITZ, M.J. (1992). *The Grass Genera of the World*. Cambridge University Press: Cambridge.
- ZANOTTI, C.A., POZNER, R. & MORRONE, O. (2010). Understanding spikelet orientation in Paniceae (Poaceae). *American Journal of Botany* 97: 717–729.



Map 1. Distribution of *Elionurus purpureus*

Appendix 1. List of topotypes for *Elionurus citreus*

PORT CURTIS DISTRICT: Middle Percy Island, *s.dat.*, *Tryon s.n.* (BRI [AQ286398]); Bruce Highway, opp. Mt Colosseum, Jun 1962, *Tothill H323* (BRI); Just S of Round Hill Head on Island side of Peninsula, Mar 1970, *Everist s.n.* (BRI [AQ286391]); Rocky Shelf Bay, South Percy Island; 50 km NE of Arthur Point, Shoalwater Bay, Oct 1989, *Batianoff 11438* (BRI); Smiths Bluff, South Percy Island, Oct 1989, *Batianoff 11333* (BRI); Shoalwater Bay training Area, Razorback sector, 350m S from East West Road, Apr 2011, *Halford QM342 & Bean* (BRI).

Appendix 2. Spikeler differences between the species of *Elionurus*

Species	Paired spikeler likeness*	Sessile spikelers			Foret	LG symmetry	Pedicellate spikelers		
		LG margin hairs	LG sub-margins	LG apex			LG sub-margins	LG margins	LG apex
<i>E. barbichinus</i> Hack.	similar	pectinate	<i>oil streak</i>	acute	male	symmetrical	<i>oil streak</i>	2-keeled	acute
<i>E. blinguis</i> (Trin.) Hack.	similar	pectinate	<i>oil streak</i>	2-awned	male	symmetrical	<i>oil streak</i>	2-keeled	1-awned
<i>E. ciliaris</i> Kunth	similar	pectinate	<i>oil streak</i>	acute to 2-toothed	male	symmetrical	<i>oil streak</i>	2-keeled	acute
<i>E. citreus</i> (R.Br.) Munro & Benh.	dissimilar	pectinate	<i>oil streak</i>	attenuate 2-lobed	empty	asymmetrical	<i>oil streak</i> on one margin	1-keeled	attenuate 1-lobed
<i>E. elegans</i> Kunth	dissimilar	tufted	<i>oil streak absent</i>	2-awned	male	symmetrical	<i>oil streak absent</i>	1-keeled	1-awned
<i>E. euclaelus</i> Adjanohoun & Clayton	dissimilar	pectinate	<i>oil streak</i>	2-awned	male	symmetrical	<i>oil streak</i>	1-keeled	1-awned
<i>E. hensii</i> K. Schum.	dissimilar	pectinate	<i>oil streak</i>	attenuate 2-lobed	male	symmetrical	<i>oil streak</i>	2-keeled	attenuate 1-lobed
<i>E. hirtifolius</i> Hack.	dissimilar	tufted	<i>oil streak absent</i>	2-awned	male	asymmetrical	<i>oil streak absent</i>	1-keeled	1-awned
<i>E. lividus</i> Hack.	similar	pectinate	<i>oil streak</i>	acute	male	symmetrical	<i>oil streak</i>	2-keeled	acute
<i>E. muticus</i> (Spreng.) Kunth	similar	pectinate	<i>oil streak</i>	attenuate 2-lobed	male	symmetrical	<i>oil streak</i>	2-keeled	attenuate 1-lobed
<i>E. planifolius</i> Renvoize	similar	pectinate	<i>oil streak</i>	acute	male	symmetrical	<i>oil streak</i>	2-keeled	acute
<i>E. platypus</i> (Trin.) Hack.	similar	pectinate	<i>oil streak</i>	acute	male	asymmetrical	<i>oil streak</i>	2-keeled	acute
<i>E. purpureus</i> E.J.Thomps.	dissimilar	pectinate	<i>oil streak</i>	2-lobed	empty	asymmetrical	<i>oil streak</i>	1-keeled	acute 1-lobed
<i>E. royleanus</i> A.Rich.	dissimilar	tufted	<i>oil streak absent</i>	attenuate 2-lobed	male	asymmetrical	<i>oil streak absent</i>	1-keeled	attenuate 1-lobed
<i>E. tripascoides</i> Willd.	dissimilar	pectinate	<i>oil streak</i>	2-lobed	male	symmetrical	<i>oil streak</i>	2-keeled	acute
<i>E. tristis</i> Hack.	similar	pectinate	<i>oil streak</i>	acute	male	symmetrical	<i>oil streak</i>	2-keeled	acute

* Likeness in respect to shape and/or type of indumentum; there is usually some difference in size.

Appendix 3. Some variation in diaspores and types of trichomes on the margin of the lower glume of species from subtribes *Tripsacinae* and *Roettboelliinae*. Species without sessile spikelet imbedded in rachilla.



Fig. A3.1. *Elionurus hirtifolius* (Harris 3098 & Fay, MO) (*Tripsacinae*). Diaspore composed of sessile spikelet, developed pedicellate spikelet and rachilla.



Fig. A3.2. *Elionurus hirtifolius* (Harris 3098 & Fay, MO) (*Tripsacinae*). Trichomes on margin of lower glume – pectinate tuberculate-based tufts of bristles, submargin lacks oil streak.



Fig. A3.3. *Elionurus purpureus* (Thompson, MOR804 BRI) (*Tripsacinae*). Diaspore composed of sessile spikelet, reduced pedicellate spikelet and rachilla.

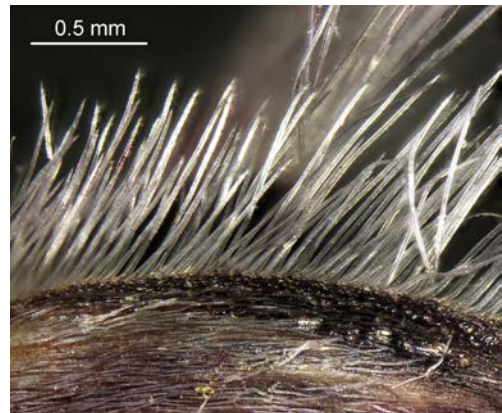


Fig. A3.4. *Elionurus purpureus* (Thompson, MOR804 BRI) (*Tripsacinae*). Trichomes on margin of lower glume – pectinate bristles; submargin with oil streak.



Fig. A3.5. *Eremochloa ciliaris* (Clarkson 7793, BRI) (Rottboelliinae). Diaspore composed of sessile spikelet, pedicellate spikelet absent and rachilla.

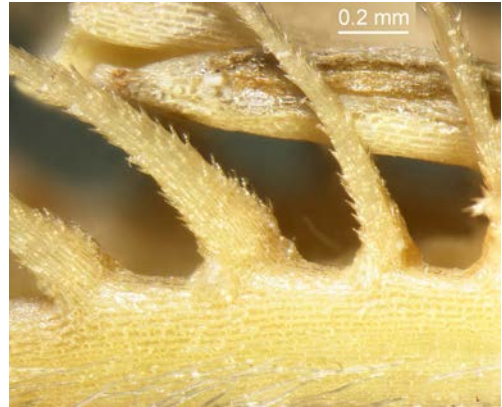


Fig. A3.6. *Eremochloa ciliaris* (Clarkson 7793, BRI) (Rottboelliinae). Trichomes on margin of lower glume – pectinate scabridous setae.

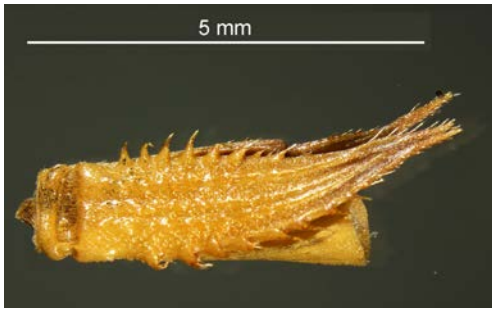


Fig. A3.7. *Jardinea gabonensis* (Alsters 68, MO) (Rottboelliinae). Diaspore composed of sessile spikelet, reduced pedicellate spikelet and rachilla.

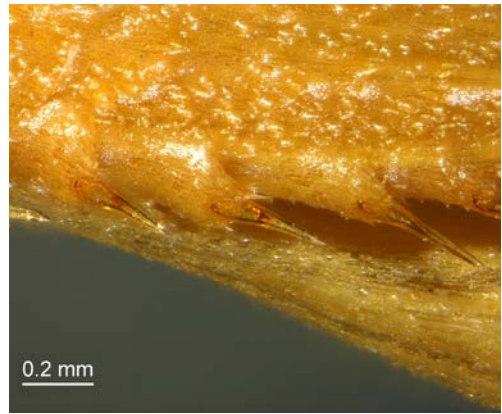


Fig. A3.8. *Jardinea gabonensis* (Alsters 68, MO) (Rottboelliinae). Trichomes on margin of lower glume – pectinate tuberculate-based spicules; tubercles sometimes with additional small bristles.



Fig. A3.9. *Loxodera caespitosa* (Mwasumbi 13796, MO) (Rottboelliinae). Diaspore composed of sessile spikelet, developed pedicellate spikelet and rachilla.

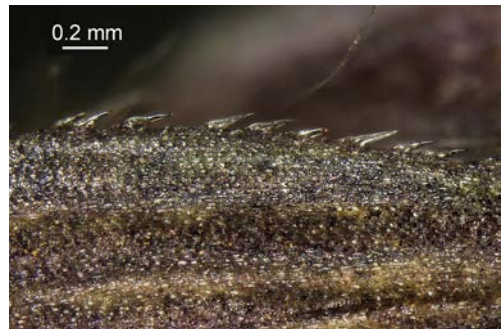


Fig. A3.10. *Loxodera caespitosa* (Mwasumbi 13796, MO) (Rottboelliinae). Trichomes on margin of lower glume – prickly hairs.

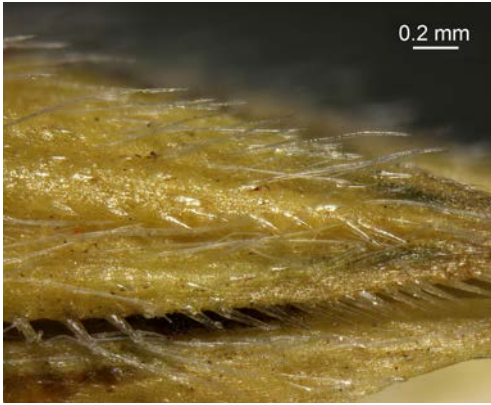


Fig. A3. 11. *Urelytrum agropyroides* (Bidgood 5110, MO) (*Tripsacinae*). Diaspore composed of sessile spikelet, reduced pedicellate spikelet with conspicuous elongated awn (only the base of the awn shown here), and rachilla.



Fig. A3. 12. *Urelytrum agropyroides* (Bidgood 5110, MO) (*Tripsacinae*). RHS: Trichomes on margin of lower glume margin – pectinate spicules.